UNIVERSAL
LIBRARY

OU_170146

UNIVERSAL
LIBRARY

OSMANIA UNIVERSITY LIBRARY
Call No. 500/P26 E Accession No. G 9250
Author Parsons, L. M.
Title Everyday Science Pt. I
This book should be returned on or before the date last marked below. 1925

EVERYDAY SCIENCE

MACMILLAN AND CO., LIMITED
LONDON · BOMBAY · CALCUTTA · MADRAS
MELBOURNE

THE MACMILLAN COMPANY
NEW YORK · BOSTON · CHICAGO
DALLAS · SAN FRANCISCO

THE MACMILLAN COMPANY
OF CANADA, LIMITED
TORONTO

EVERYDAY SCIENCE

A COURSE OF GENERAL SCIENCE RELATED TO HUMAN ACTIVITIES

BY

L. M. PARSONS

D.Sc. (LOND.), D.I.C., F.G.S., F.R. MET. SOC.

SCIENCE MASTER, WESTMINSTER CITY SCHOOL

PART I.

THE SKY, THE EARTH, AND LIFE

MACMILLAN AND CO., LIMITED

ST. MARTIN'S STREET, LONDON

1929

COPYRIGHT

PRINTED IN GREAT BRITAIN

PREFACE

For several years there has been an active movement in educational circles in favour of extending the scope of the science courses usually followed in Secondary Schools. The view held by competent authorities is expressed in three resolutions adopted by the Headmasters' Conference some time ago, namely :

(1) That it is essential to a boy's general education that he should have some knowledge of the natural laws underlying the phenomena of daily life, and some training in their experimental investigation.

(2) That this can best be ensured by giving to all boys adequate courses of generalised science work, which would normally be completed for the ordinary boy at the age of sixteen.

(3) That, after this stage, boys who require it should take up science work of a more specialised type, while the others should for some time continue to do some science work of a more general character.

Though these principles would be accepted as axiomatic by most educationists, it is to be regretted that they have not yet been put into practice in many schools. A Report on Science in School Certificate Examinations just published by the British Association shows that out of about 54,000 candidates who sat for the School Certificate Examination in 1926, 40 per cent. took chemistry as their science subject, 25 per cent. took physics, and 25 per cent. (chiefly girls) botany, while only 2·5 per cent. took general science. As about 3 per cent. only of these candidates propose to proceed to a University or qualify for a subsequent professional examination, and most of the remaining 97 per cent. receive no further education in science, it is evident that the usual courses followed in schools are not adapted to the everyday life and interests of the majority of the pupils, but to the academic requirements of the minority.

No school course in science can be regarded as complete or satisfactory if it neglects the interests of pupils in the natural world of living creatures around them and their own relations to the life of the community. Even to read newspaper reports of natural events and phenomena intelligently requires a general knowledge of things in the heavens above and the earth beneath, of common plants and animals, of life as a whole, including man and his mastery of Nature. It is with the purpose of providing such a survey of the natural world in which we live and our relation to it that this book has been written.

The general plan of the book conforms to the syllabuses of general or everyday science of the Oxford and Cambridge Schools Examination Board, the Oxford Local Examinations and the Civil Service Commissioners. A syllabus of General Science of School Certificate standard has just been included in the Cambridge Local Examinations schedules, and most of the subjects in this syllabus are dealt with descriptively in this book The Cambridge syllabus, however, seems scarcely to have been conceived in the spirit of general everyday science for all, but is rather a combination of introductory courses of physics, chemistry, botany, and other subjects of the usual systematic kind.

An attempt is made in this volume to give a broad general survey of the realm of science suitable for use in schools, whether examinations are the proximate or ultimate aim of the teaching or not. Particular attention has been given to contacts of scientific work and results with everyday life, because it is through these that interest is best created in any subject. For this reason the book may appeal to the general reader who desires information upon common natural occurrences and phenomena brought before him from time to time, or wishes to obtain a general idea of everyday applications of science, as much as to the student preparing for an examination in general elementary science.

The subject matter ranges from a description of the vast objects of celestial space to that of the minute structure of the atom. The Universe, Life, and Man are first described, and then an elementary account of man's dealings with objects in

motion and his relations with matter is given. The subjects dealt with can be studied in schools as a progressive course extending over three years, but in order that the book may be equally suitable to the requirements of those teachers who wish to concentrate on certain sections of the subject matter, three separate Parts of the book are available, namely :

Part I dealing with astronomy, geology, and biology.
Part II dealing with elementary physics.
Part III dealing with elementary chemistry.

The Parts may be studied in any order, but in at least one of them the pupil should carry out experimental work. In each Part there are brief historical notes dealing with the progress of scientific discovery, and also references of a biographical character, as well as a set of typical examination questions, many of them from papers set by the Civil Service Commission, the Oxford and Cambridge Schools Examination Board, and other public examining bodies. Thanks are due to those authorities for permission to use questions from such papers.

Particular care has been taken in the selection and preparation of illustrations for the book, and grateful acknowledgment is gladly made to the friends and industrial firms who have been good enough to provide photographs or other pictures for this purpose. The sources of most of such illustrations will be found indicated in the inscriptions to the figures themselves, but special thanks are due to the Macmillan Company, New York, and to the authors of three books published by that firm, who have been good enough to permit the use of illustrations from their books. The three volumes, to the authors of which I am much indebted for this privilege, are *Practical Chemistry*, by N. H. Black and Prof. J. B. Conant ; *Elements of Chemistry*, by Prof. H. N. Holmes and L. W. Mattern ; and *Practical Physics*, by N. H. Black and Prof. H. N. Davis. Mr. H. E. Hadley has also been good enough to permit me to use a number of illustrations from his excellent book, *Everyday Physics*, and a certain number of figures from other books published by Messrs. Macmillan and Co., Ltd., has been included. I am sure that interest in the text will be increased by the inclusion of so many figures illustrating principles or processes.

In conclusion, I wish to express my sincere thanks to Sir Richard Gregory, who suggested the preparation of this book to me and at every stage has generously given me most valuable advice and guidance. I am also greatly indebted to Mr. A. J. V. Gale, M.A., who together with Sir Richard Gregory has read through the proofs and offered many helpful criticisms.

L. M. PARSONS.

December, 1928.

CONTENTS

PART I. THE SKY, THE EARTH, AND LIFE

CHAPTER		PAGE
I.	The Stars, Nebulae, and the Sun	1
II.	Planets and Planetary Motion	21
III.	The Earth's Crust	43
IV.	The Changing Face of the Earth	65
V.	Plant Life and Products	85
VI.	Soils and their Relation to Plant Life	105
VII.	Insect Life and its Relation to Human Activities	117
VIII.	Some Inhabitants of Sea, River, and Pond	133
IX.	Bird Life	153
X.	The Rabbit and Other Mammals	169
XI.	The Human Body and its Efficiency	187
XII.	Man's Fight against Disease	209
	Questions and Exercises	227
	Index	233

PART I

THE SKY, THE EARTH, AND LIFE

CHAPTER I

THE STARS, NEBULAE, AND THE SUN

THE countless bright objects seen above us in the heavens on a clear night have exercised the thoughts and imagination of mankind during many centuries. With dawning intelligence and an increasing desire to know the " why and wherefore " of things, even primitive man must have marvelled concerning the vast array of far distant points of light. The majesty of the heavenly bodies and the vast regions of space have inspired men's minds with awe and reverence, so that it is no matter for surprise that ancient peoples, such as the Chaldeans 5,000 years ago, worshipped the sun, the moon, and such planets as were then known. The phenomena of comets and of eclipses caused fear and misgiving. Later, in the Middle Ages, a superstitious growth still adhered to the study of the stars, so that the crude alchemy of the chemist had its counterpart in astrology, which dealt with the supposed influence of the heavenly bodies upon the fortunes and destinies of men.

Vanity combined with lack of knowledge caused man to consider that his little world was the centre of the universe, and that all the heavenly bodies, including the sun, revolved around the earth. This, the fundamental idea of the astronomical system of **Ptolemy**, was believed for about 1,400 years, until 1543 when **Copernicus**, a Polish astronomer, showed that the

apparent movements of celestial bodies visible to the naked eye could be best explained by the revolution of the earth and other planets around the sun, with the stellar universe outside this system. Mathematical astronomy took a great step forward with the establishment of the Copernican System, and the century which immediately followed witnessed many other strides in astronomical progress. Although the Italian **Galileo** did not actually invent the telescope, he first used one to such good effect that he proved the revolution of four moons around Jupiter, and showed by observations of sunspots that the sun itself rotates upon an axis.

In 1619, **Kepler,** a German, found that the paths of the planets around the sun are not circles but ellipses, and that the speed at which any planet moves along its orbit is not uniform. Shortly after this our own great mathematician, **Sir Isaac Newton,** showed that it is the attractive force of gravitation which regulates planetary motion and controls the movements of all kinds of matter in space. Newton was not only a mathematician, but also an experimenter, and invented the first reflecting telescope, a class of instrument in which a magnified image is produced by a concave mirror instead of by a lens. Reflecting telescopes of much greater size were made by **Sir William Herschel,** the discoverer of the planet Uranus in 1781, who, earlier in life, was a musician in a Hanoverian military band. With his giant telescope forty feet long, erected at Slough near Windsor in 1789, he discovered thousands of stars and nebulae not known before.

The success of modern astronomy is due not only to the great improvement in telescopes, but also to the use of the camera and the spectroscope. Photographs may be obtained of stars that can never be seen by the eye, since rays that cannot be perceived as light can play steadily upon a photographic plate and produce results if the exposure is sufficiently long. For these time exposures it is necessary to mount the telescope and its attached camera so that they are rotated by clockwork in a direction, and at a rate, to counteract exactly the rotation of the earth.

Real progress in celestial photography dates from the

invention of the dry photographic plate in 1880, and since that time hundreds of millions of stars have been photographed.

THE STARS

On a clear night the heavens appear as a great "inverted bowl" studded with stars. It seems to an observer that he is standing at the centre of a gigantic hollow black hemisphere containing the stars, and this huge spherical space is called the **celestial sphere,** the other half of which is above the remote side of the earth. When visibility is very good, it may be noticed that the greatest concentration of stars is along a broad band called the **Milky Way** or **Galaxy.** This concentration is observed from the other side of the earth also, hence it appears that our stellar universe is shaped somewhat like a huge disc or ring, which may be compared to a grindstone in shape. Our solar system is not far from the centre of this disc, so that we see more stars when looking towards the circumference than when looking up to the flat part.

Many of the stars nearer than those in the vast cluster of the Milky Way are roughly arranged in groups (Fig. 1), and the ancients imagined that the shapes of these groups resembled the outlines of animals or other figures. Thus we have the groups known as Leo (the lion), Cancer (the crab), Capricorn (the goat), Libra (the scales), etc. These groups are called **constellations,** and twelve of them are distributed around the celestial sphere in such a way that the sun appears to pass through them, one after another, during the year. These particular constellations are known as the **Signs of the Zodiac,** and the sun's apparent journey through them is really due to the earth's revolution along its orbit, as explained in the next chapter.

Stars are not all of equal brilliance, the average brightness of the twenty brightest stars being described as the first magnitude, the next in order being those of the second magnitude, and so on. The brightest star in the heavens is Sirius in the constellation of the great dog (Canis Major), and the Pole Star is one of the second magnitude. Stars beyond the sixth magnitude cannot be seen by the unaided eye.

A star of any magnitude appears simply as a point of light, not as a luminous disc of measurable width as in the case of planets. Even the most powerful telescopes fail to resolve a star into anything other than a luminous point, thus suggesting enormous distances between us and the stars, and there is good

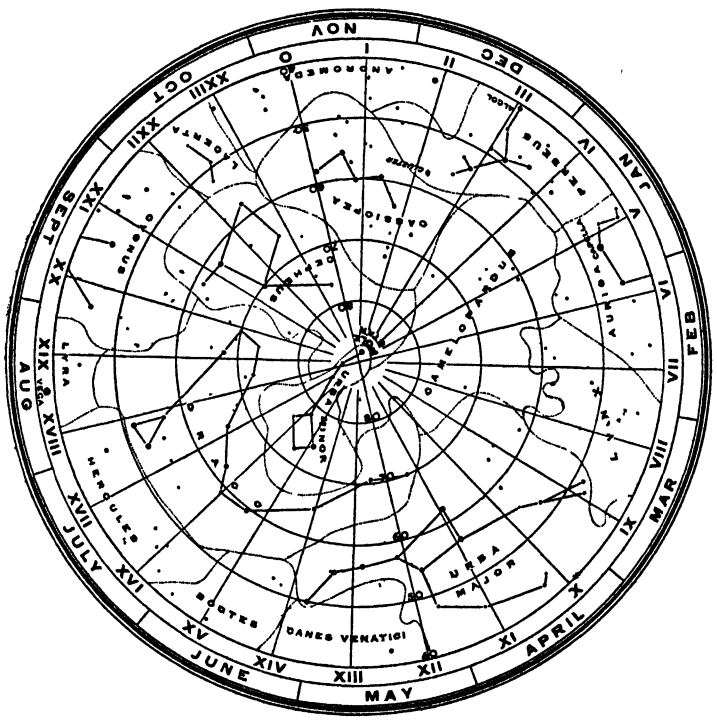


FIG. 1.—STAR GROUPS OR CONSTELLATIONS AROUND THE POLE STAR.

reason for believing that the stars are as far from one another as they are from us.

The distances of the nearer stars can be measured by observations of the apparent shifting of position called **parallax** due to the movement of the earth in its orbit. If the position of a certain star is observed, and noted again six months later, when the earth is at a position on the other side of its orbit,

some 186,000,000 miles away from the position of the first observation, that star is apparently displaced from its first position (Fig. 2). In fact, as the earth moves along its elliptical orbit, the star appears to trace a very minute parallactic ellipse, the apparent size of which depends upon the star's distance. The nearer the star the larger is this ellipse. Calculations based

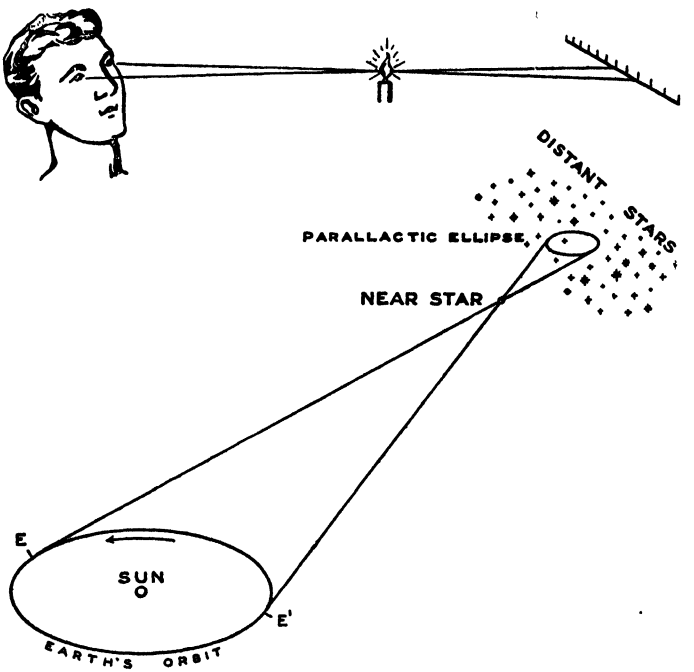


FIG. 2.—PARALLAX,

OR THE APPARENT SHIFTING OF AN OBJECT DUE TO CHANGE IN POSITION OF THE OBSERVER.

upon parallax show that the star nearest to the earth, **Alpha Centauri,** is not less than nineteen billions of miles distant. The parallactic ellipses of even the nearer stars are so small that only experienced astronomers making regular observations with first class telescopes can take such measurements.

The great majority of stars are so far away that their distances cannot be calculated. So vast are the spaces between the

heavenly bodies that mere millions of miles are inadequate; hence other units are employed in astronomy. The distance travelled by light in one year, proceeding at the rate of 186,000 miles per second, is called a **light-year** and is equivalent to six million million miles. The light proceeding from Alpha Centauri takes about four years to reach us, but the greater number of stars are seen by light rays emitted by them scores or even thousands of years ago. Many of the stars we now see may have long since become cold.

At various times star charts and catalogues have been made by competent observers, a very early catalogue being that of Hipparchus made in 125 B.C. If the positions of certain stars as shown on these early catalogues are compared with the positions of the same stars to-day, it is found that they have moved to some extent. The stars have a **proper motion** of their own through space. But it requires centuries for these proper motions to become noticeable, and though in hundreds of thousands of years from now the general pattern of the stars in the sky will be different from that seen to-day, the positions of stars in relation to one another are permanent in our own time, and we regard them as fixed. It is this definite fixed positions of stars and of constellations in our own day that gives such important aid to navigation For practical purposes the stars remain fixed in relation to one another, and the imperceptible proper motion must not be confused with the daily **apparent motions** of the stars. Almost above the earth's north pole is the **Pole Star,** and the stars near it appear to move in circles around it without going below the horizon. Other stars farther towards the horizon rise and set just as the sun does. All of these apparent motions are due to the earth's rotation.

THE STARS IN NAVIGATION

Since the stars appear fixed with regard to one another, they can be used as objects with which to take the bearings of a ship at sea, provided that the correct place of a certain star on the celestial sphere at a particular date and time be known. The work of calculation and preparation of data concerning the

positions of stars at various dates and times is the business of the mathematicians who prepare the "Nautical Almanac." In order that lists and tables of these positions may be given, some generally used scheme of measurement must be employed. On the earth's surface the position of a place is indicated by means of two co-ordinates—**latitude** and **longitude**—and in astronomy the positions of heavenly bodies on the celestial sphere may be

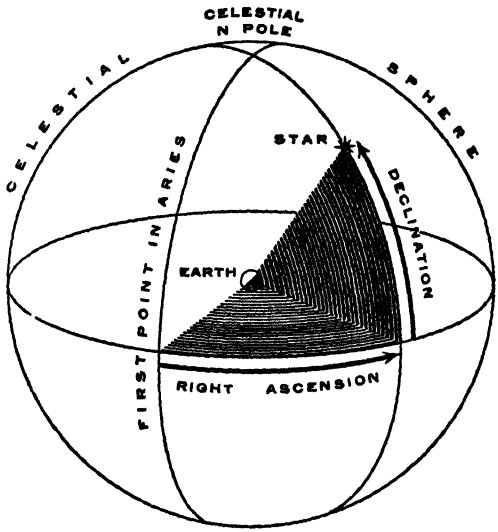


FIG. 3.
THE POSITION OF A CELESTIAL BODY IS DEFINED IN TERMS OF DECLINATION AND RIGHT ASCENSION.

similarly indicated by **celestial latitude** and **celestial longitude.** A more commonly used mode of defining the position of a star is that employing **Declination** corresponding to latitude and **Right Ascension** corresponding to longitude.

The Declination of a star (Fig. 3) is the distance from the celestial equator to the star measured along the hour circle of the star. As in terrestrial longitude we use the Greenwich meridian as the starting position, so in astronomy we use a point (or a great circle through it) on the celestial sphere and called the **First point of Aries** as the starting point. The distance

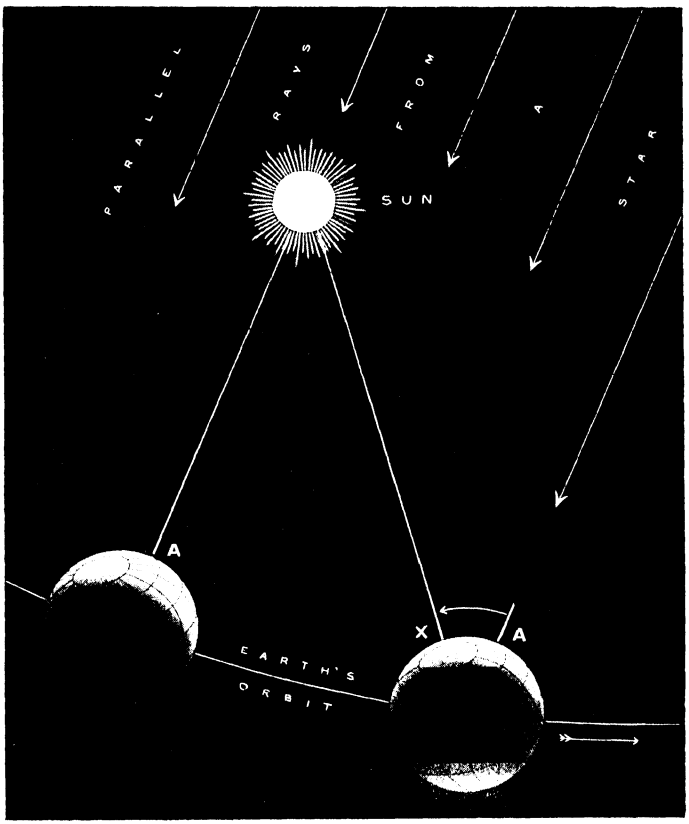
from this point along the equator to the star's hour circle is the Right Ascension of the star. Since the apparent rotation of the star dome is uniform, the Right Ascension is usually expressed as the time which elapses between the crossing of the circle through Aries over the meridian of a place and the crossing of the star's hour circle over the same meridian. The units employed are hours, minutes, and seconds of **sidereal time.** The star chart in (Fig. 1) shows the hours of Right Ascension in Roman figures and also some Declination circles.

In the "Nautical Almanac" the positions of some hundreds of stars are given as seen from any place at any date and time. From such data the navigator can calculate his latitude and longitude. In the northern hemisphere latitude can be determined quite simply without the aid of the "Almanac." Since the Pole Star is practically overhead at the earth's north pole and down on the horizon at the equator, it follows that the angle of elevation of the Pole Star gives the latitude of the place of observation.

SOLAR AND SIDEREAL TIME

Latitude and longitude are not the only measurements in which the use of stars is important. Time is based upon the period taken by the earth to rotate on its axis (Fig. 4). In daily life we use **solar time,** in which the time taken by the earth to rotate once is determined by reference to the sun and is called a day of 24 hours. Since the earth moves forward along its orbit a little each day, any place must rotate through more than 360° to come in line with the sun again, so that the solar 24 hours is really a little longer than the actual time taken by the earth to complete one rotation. Now if the time of rotation is taken with reference to a certain star, **sidereal time** is obtained, and the true period of the earth's rotation is found to be 23 hours, 56 minutes, and 4 seconds, expressed in mean solar units. Sidereal time, though not used by the general public, is useful to the astronomer. Solar time is generally more convenient because the periods of light and darkness at any place are determined by the position of that place relative to the sun and not to the stars.

An important fact concerning solar time must be noted. The earth does not travel along its orbit at a uniform rate, hence the length of the solar day varies slightly. The average,



Drawn by Mr. Scriven Bolton

FIG. 4.—SOLAR AND SIDEREAL TIME.

IN ORDER TO COMPLETE A SOLAR DAY THE PLACE A MUST ROTATE THROUGH MORE THAN 360°.

or **mean, solar day** is taken as the basis of time used in everyday life. Clocks measure mean solar time but sundials, when properly graduated and mounted, measure *true* solar time.

THE CONSTITUTION OF THE STARS

The physical and chemical nature of heavenly bodies is investigated by means of an instrument called a **spectroscope.** Stated quite broadly, this instrument (Fig. 5) is used for the examination or analysis of light emitted by heated objects. The kind of light emitted depends largely upon the chemical nature of the substance and partly upon its physical state, whether it is a glowing vapour or a mass of incandescent solid particles. Most people are familiar with the principle of the spectroscope. When ordinary so-called white light is passed through a triangular piece of cut glass, a band of bright colours is seen ranging

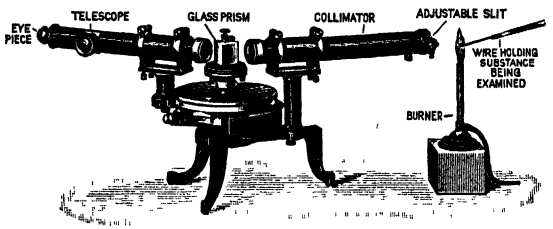


FIG. 5.—A SPECTROSCOPE

from red at one end to violet at the other. The cut glass produces by refraction what might be termed a rainbow effect. Drops of falling rain do exactly the same with sunlight as the cut glass does, and in either case the band of colours is called a **spectrum.**

A spectroscope is an arrangement employed for the examination of the spectra of glowing bodies. In its simplest form the instrument consists of a triangular glass prism placed between two tubes arranged at the required angle. The remote end of one tube bears a slit for admitting light from the object undergoing examination, while the outer end of the other tube contains a magnifying lens or eyepiece by means of which an observer examines a magnified image of the spectrum obtained. The light after passing through the slit enters the prism and is then **dispersed** into colours according to the nature of the substance supplying the light. Sometimes a complete band of colours is seen, as in the case of the spectrum of sunlight, while in some

other cases there are visible only a few bright coloured lines vertically crossing a dark band. *In general, the spectrum of an incandescent mass of solid particles consists of a continuous band of colours, whereas the spectrum of a glowing vapour shows bright lines in a dark ground.*

If the light from a pinch of common salt vaporising in a bunsen flame is allowed to enter the slit, the spectrum seen consists of two thin yellow lines very close together, and these lines for salt always occur in the same positions. Each vaporised substance has its own spectrum consisting of lines of definite colour and occupying definite positions, so that the spectroscope enables us to learn much concerning the chemistry of luminous objects although they may be millions of miles away.

If the spectroscope is directed to a distant star, what do we observe? The spectrum obtained usually consists of a continuous band of colours somewhat similar to that of the solar spectrum, and numerous dark lines are present. The continuous band of colours suggests that the star consists of incandescent particles, but what of the dark lines? Consider again the case of the spectrum of glowing vaporised salt. Two bright yellow lines were obtained. Now if these lines are seen against a background of brighter light also containing the same substance, and due to a hotter mass, they are perceived as dark lines but occupying the same positions exactly as before. Hence the usual stellar spectra suggest that the stars consist of an intensely hot glowing mass surrounded by vapours containing similar substances at a lower temperature. By noting the positions of the dark lines and comparing them with the corresponding bright lines in the spectra of the terrestrial elements, it is possible for an astronomer to say definitely which of these earthly elements exist in the stellar vapours. These dark lines were discovered in the spectrum of sunlight by a German named **Fraunhofer** as far back as 1814, but their significance was not realised until forty years afterwards (Fig. 6). Hydrogen, iron, sodium, magnesium, and calcium are among the chief elements found in the stars.

The temperature of the stars varies considerably. There is reason to believe that stars originally were in the form of very

attenuated gaseous matter Gravitational attraction among these particles caused them to come closer together with the development of heat. At a later stage a cooling process sets in and the temperature falls. It appears that in the earlier part of its life history a star is hotter, larger, and less dense than it is during its later existence The stars are in various

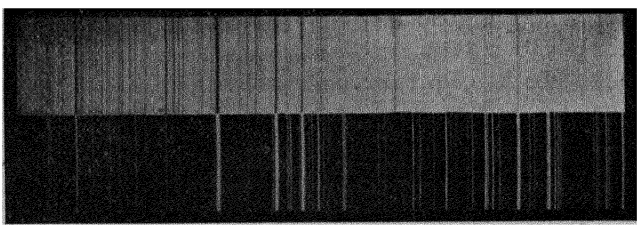


FIG. 6.—SOLAR SPECTRUM.

THE TOP STRIP SHOWS A PART OF THE SOLAR SPECTRUM WITH DARK FRAUNHOFER LINES, AND THE LOWER STRIP AS CORRESPONDING PART OF THE SPECTRUM OF IRON VAPOURISED IN AN ELECTRIC ARC

stages of development, the hotter larger type being known as **giants,** and the smaller cooler kind as **dwarfs.** Some of the giants are hundreds of times as large as our sun

Sometimes a dark star revolves around a bright one so that, when it is passing between us and its bright companion, it obscures some of the light, and causes the brightness to vary periodically. The star **Algol** is a **variable star** of this type.

NEBULAE

Distributed among the stellar spaces, but chiefly in the regions outside of the main star streams of our universe, are enormous patches of cloudy luminous material. These are called **nebulae,** and though hundreds of thousands are known to exist, only two, that in the constellation of Orion, and the great spiral nebula in Andromeda, can be seen by the naked eye (Fig 7). Nebulae resemble the stars in having fixed positions relative to the stars and to other nebulae , and some of them, the so-called " white " nebulae, also resemble stars in the character of their spectra Thus the spiral nebula in

Andromeda exhibits a spectrum consisting of a continuous band of colours with certain dark bands in addition. Nebulous masses of this type are extremely remote and are probably separate universes of stars. On the other hand, the true nebulae

FIG. 7.—THE GREAT SPIRAL NEBULA IN ANDROMEDA.

or " green " kind show spectra of bright lines only and are therefore masses of luminous gas, chiefly hydrogen, helium, and a substance not yet known among terrestrial elements.

In size and shape nebulae are very varied. Many of them extend across vast spaces measuring millions of miles, while in form some are very irregular, such as the nebula in Orion, others are like rings or discs, and some are gigantic spirals. The

spiral nebulae are of particular interest, since they represent other universes in which systems of stars are being evolved. From each of such stars a number of separate planets may be thrown off in course of time. According to this theory, a planetary system commenced as a vast mass of luminous vapour in which a whirling movement was caused by gravitation. As the mass cooled and condensed, the whirling motion increased in speed, so that pieces became detached. A similar condensation and increase of speed occurred in each detached mass so that planets and satellites were formed and retained a rotation about their respective axes. Though this hypothesis is a fascinating explanation of the origin of worlds, it is by no means certain that it is true in all respects, and it may be regarded only as a possible solution to the riddle of the universe so far as the forms of planetary systems are concerned. It is probably beyond the reach of man to solve the problem of the origin of matter itself.

Recent mathematical researches suggest that the universe originally consisted of a uniform gaseous substance of extreme tenuity but extending through such an enormous space that light would take hundreds of millions of years to traverse it. Vast condensations of this material occurred at definite spatial intervals with the formation of something like two million gigantic nebulae separated from one another by intervening spaces each equal to more than a million light-years. Further condensation occurred in projecting portions of these nebulous masses, leading to the production of stars similar to our sun. Stars in passing one another exerted a tide-producing force attracting projecting masses which thus became de ached and formed planets. The planets in their turn were subjected to tidal forces, with the result that moons or satellites have been produced.

In *Nature* of February 26, 1927, Sir J. H. Jeans summarised and illustrated existing knowledge of the evolution of the universe as follows:—We have in succession:

"1. A uniform tenuous gas of density 10^{-31} and of diameter at least hundreds of millions of light-years.

2. Condensations developing in this gas at about a million

light-years apart, and forming separate nebulae with masses of the order of a thousand million suns.

3. Condensations developing in turn in the arms of these nebulae, and forming stars with masses of the order of our sun.

The faintest nebulae which can be observed photographically in the 100-inch telescope of the Mount Wilson Observatory are of about 18th magnitude, and these must be at the amazing distance of about 140,000,000 light-years. Within this distance some two million nebulae must lie. Dr. Hubble finds that these are fairly uniformly spaced at an average distance of about 1,800,000 light-years apart. To construct a model, take 20 tons of walnuts and space them at about 25 yards apart, thus filling a sphere of about a mile radius. This sphere is the range of vision of the 100-inch telescope; each walnut is a nebula containing matter enough for the creation of perhaps a thousand million suns like ours; each atom in each walnut is a solar system with a diameter equal to that of the earth's orbit."

THE SUN

Our existence is influenced more by the sun that by any other body; in fact, life as we know it would be quite impossible without the heat and light brought by the sun's rays. To this majestic lamp in the focus of our planetary system we owe daylight, the warmth which ripens our crops, and the winds which bring us our rain. If it were not for the sun the earth would be a barren frozen waste unfit for habitation. Our domestic fires are possible, and our machinery is driven by the energy of sunshine that shone, millions of years ago, on the forest trees that are now dug up as coal. This, and much more, the sun does for us, though an average distance of 92,700,000 miles separates us from it.

Less than one two-thousandth part of the heat radiated by the sun is received by the earth, so that the total amount sent into space must be enormous. The temperature of the sun's surface is certainly much higher than that of an electric furnace, and this is above 3500° Centigrade, while the temperature near the centre is probably millions of degrees. Several theories have

been advanced to explain the origin of this heat. Radio-active substances give out a great amount of heat as the radium disintegrates, and it is probable that one factor in maintaining the sun's high temperature is of this nature. Another factor may be changes in atomic structure taking place in the sun's material. It is certain that some such generation of new heat must take place to balance the enormous loss by radiation, otherwise the sun could not have given heat and light for hundreds of millions of years during which the earth has supported living creatures. A certain amount of heat is also obtained from the contraction of the sun's material, since the contraction of gases leads to a rise in temperature. It is probable that each of these factors share, though unequally, in maintaining this life-giving stream of radiant heat and light.

As the distance of the sun is known its size can be calculated by observations of the apparent size of its disc. Its diameter is 866,500 miles, and this means that it has a volume more than one and a quarter million times that of the earth. It is, however, composed of material much less dense than that of the earth, so that in spite of its great size it is only 330,000 times as heavy as our planet.

If a piece of well-smoked glass is placed in front of the eye, the sun appears as a uniformly illumined flat disc, but when viewed through a telescope several interesting features can be recognised. The surface known as the **photosphere** is seen to be a shade darker near the edge, and generally to consist of whitish granular masses which have received the name of "rice grains." These are shown by the spectroscope to be luminous clouds composed of metallic vapours. There also exist various dark irregular patches called **sunspots**, and these appear to be distributed along two broad zones, one on either side of the sun's equator (Fig. 8). North or south beyond these zones towards the poles the photosphere is free from spots. The size of sunspots varies considerably, some of them being merely hundreds of miles across while the larger ones may be thousands of miles in width, and millions of square miles in area.

Examination of a sunspot shows that it consists of a dark central area surrounded by a less dark zone, the whole being

fringed by bright whirling clouds or **faculae**. The dark patches (Fig. 9) are areas of spirally descending vapours, cooler than the surrounding photosphere, though still very hot. They appear dark by contrast. Spectroscopic calculations show that the speed of these whirling gases, largely hydrogen, is terrific, anything up to 200 miles per second. The spots all move in

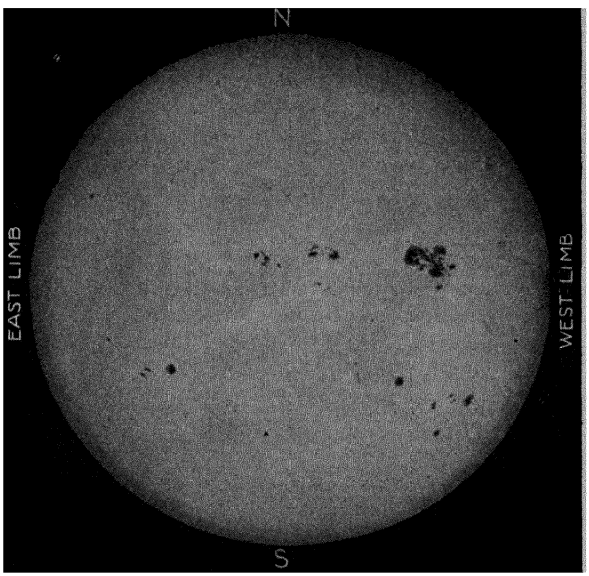


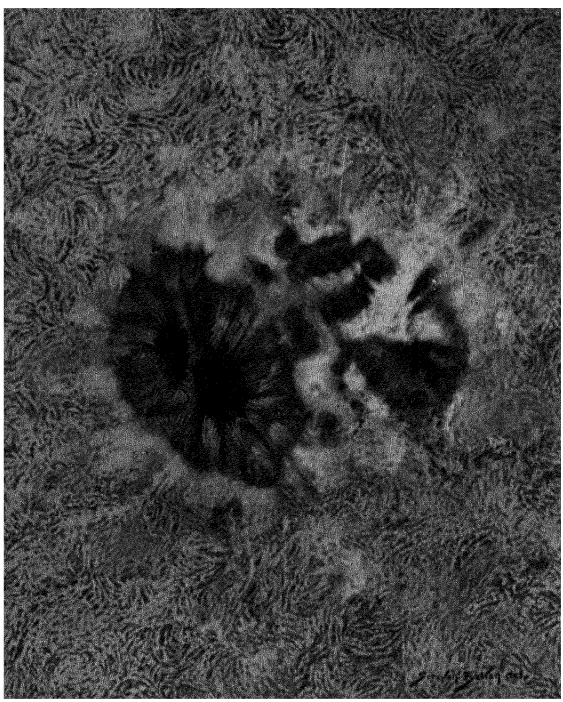
FIG. 8.—THE SUN'S PHOTOSPHERE WITH GROUPS OF SUN SPOTS, ONE ON EITHER SIDE OF THE SOLAR EQUATOR.

one direction from left to right across the face of the sun, disappear round the right edge, and, when they last long enough, re-appear on the left edge some days later.

This proves that the sun rotates on an axis, but a remarkable fact in this connection is that the spots nearer the sun's equator complete the journey in less time than do spots in higher latitudes. From this it follows that the sun is not a rigid solid body, since, if it were, any one spot would give the same rotation period as any other spot. The average period of rotation is

25⅓ days actually, though it appears to be 27¼ days on account of the earth's movement along its orbit.

The terms east and west are used to describe the sun's edges or limbs as we see them, the eastern edge being to the left



Drawn by Mr Scriven Bolton

FIG 9.—STRUCTURE OF A SUNSPOT AND THE SURROUNDING PHOTOSPHERE

and the western edge to the right. Really, the sun rotates in a direction similar to the earth's own rotation

Sunspot activity shows various degrees of intensity. In general, the number of spots increases to a maximum, then decreases to a minimum, and again rises towards a maximum. The period between two successive maxima is about eleven

years, so that the increase and decline occur in a definite cycle. Though there may be no relation between our earthly weather and sunspot activity, there is certainly some definite connection between sunspot maxima and magnetic storms which disturb electro-magnetic instruments on the earth. Also displays of **aurora**, an electrical phenomenon seen in high latitudes, are more common during a sunspot maximum.

What is the chemical composition of the sun? The answer to this question is given by the spectroscope. The solar spectrum, as that of a star, consists of a bright band of colours crossed vertically by very numerous dark "Fraunhofer" lines. Comparison of the positions of these lines show that quite a large number of substances we know on the earth exist also in the sun. Among the more commonly known of these are iron, copper, zinc, lead, silver, aluminium, oxygen, hydrogen, and carbon. The photospheric clouds float in an atmosphere of metallic vapours. Some lines in the solar spectrum cannot be matched by any in the spectra of terrestrial elements. Thus, an unknown substance which has been termed "coronium" occurs in the outermost solar atmosphere, called the **corona**, seen during a total eclipse of the sun.

Many other features of great interest may be observed during a total eclipse. When the intense glare of the photosphere is obscured by the moon, a gaseous zone lower than the corona but rising to 10,000 miles above the photosphere is seen. This is known as the **chromosphere** and is composed mainly of hydrogen which projects upwards in places as deep red **prominences** which may extend for hundreds of thousands of miles beyond the chromosphere (Fig. 10). Some of these prominences resemble huge tongues of flame, and the spectacle is grand in the extreme. Although the eye in the ordinary way can see these features only during a total eclipse, spectroscopic means have now been found by which the prominences can be studied at any time.

Another recent development of spectroscopic investigation is the study of elements in the sun one at a time by means of an apparatus called a **spectroheliograph**. In principle this is a selective spectroscope which enables an astronomer to photograph those solar clouds which are composed of one element

only, say hydrogen, or calcium—to obtain, as it were, a picture of the sun painted with a single pigment It is impossible to give here any adequate description of the immense strides made in astronomical science by means of the spectroscope and its modifications

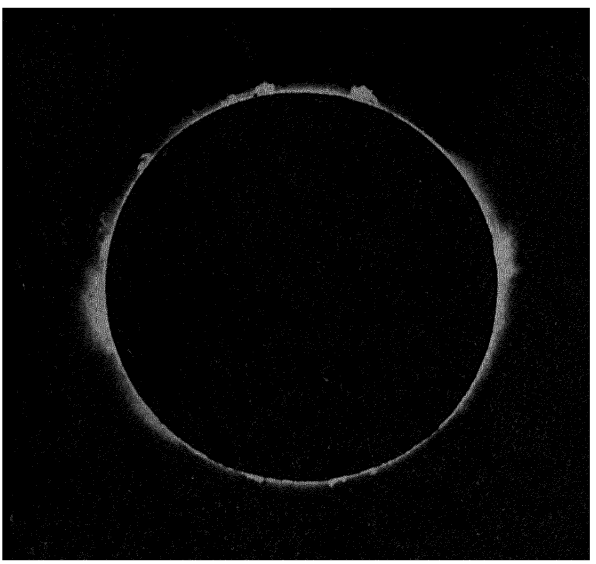


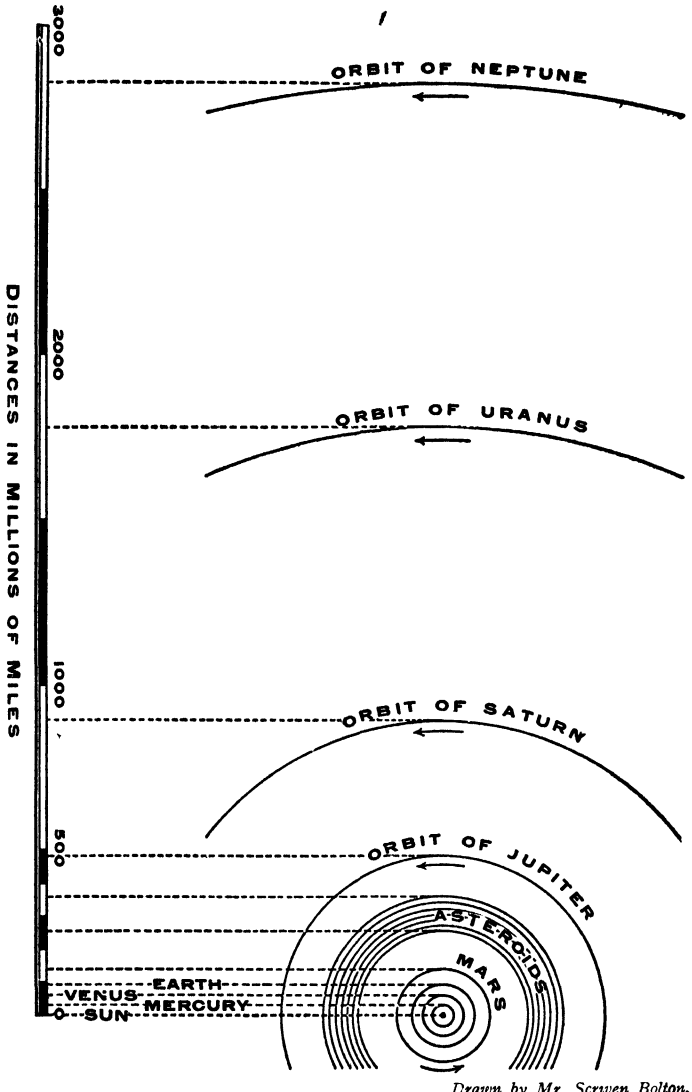
FIG. 10.—TOTAL ECLIPSE OF THE SUN
AS PHOTOGRAPHED AT GIGGLESWICK, YORKSHIRE, ON JUNE 29, 1927
(By kind permission of the Astronomer Royal)

As in the case of the stars, the sun has a proper motion through space. Accompanied by its attendant system of planets it is moving towards the constellation Hercules Its apparent motions, daily through the sky, and yearly through the signs of the Zodiac, will be considered later.

CHAPTER II

PLANETS AND PLANETARY MOTION

As the sun moves through space it is accompanied by several planets, or 'wanderers,' each of which revolves along its own orbit (Fig. 11). Proceeding outwards away from the sun the planets are: **Mercury, Venus,** the **Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.** There is also a large number of planetary fragments revolving along paths situated between the orbits of Mars and Jupiter, and the name **asteroids** or **minor planets** has been given to this group of smaller bodies. All of the major planets from Mercury to Saturn inclusive were known to the Ancients, and there is no record as to when or by whom they were first discovered. Sir William Herschel, in 1781, while exploring the heavens with a telescope of his own construction, attained the hitherto unknown achievement of discovering a new planet. This was given the name **Uranus.** Many years afterwards careful mathematical observations of its movements in its orbit led to the conclusion that some still more remote heavenly body was exercising a disturbing gravitational influence upon it. This more distanct object proved to be the planet **Neptune,** the discovery of which in 1846 ranks as one of the finest triumphs of mathematical science. A young Englishman named **Adams** and the French mathematician, **Leverrier,** independently worked at the problem, Adams being the first to arrive at the true position of the new planet. The Englishman, however, was hampered by lack of sufficiently powerful telescopic aid, and though he passed on his information to others, his work was not taken seriously. Leverrier also lacked the necessary instrumental aid, but communicated his result to the Berlin astronomer Galle who, possessing an up-to-date star chart, quickly found the



Drawn by Mr Scrwen Bolton.

FIG. 11.

THE RELATIVE DISTANCES OF THE PLANETS FROM THE SUN

new planet by means of his powerful telescope, almost exactly in the position calculated for it.

With the exception of Neptune, the distances of the planets from the sun are according to a simple mathematical relation known as **Bode's law.** If 4 be added to the numbers 0, 3, 6, 12, 24, 48, 96, and 192 we obtain the series 4, 7, 10, 16, 28, 52, 100, and 196. These figures represent approximately the relative distances of the planets Mercury to Uranus respectively, including the asteroids, from the sun. In fact, the minor planets, some 1,600 of which are now known, were discovered by attention being directed to the fact that no planet had been found to occupy the position represented by the number 28 in the series. The first—and the largest—of the asteroids, discovered on January 1, 1800, has been named Ceres, and its diameter is about 480 miles, but the brightest is Vesta, which has a diameter of about 240 miles. Some of these bodies are a little larger but all are very small compared with the major planets.

It will be observed that if the numbers in the series given above be divided by ten, the figure representing the earth's distance from the sun is then unity, and it is an easy matter to calculate roughly the distance of any other planet by multiplying the earth's mean distance from the sun, 92,700,000 miles, by the number corresponding to the planet in question. Thus 5·2 is the number representing Jupiter's position, and 92,700,000 × 5·2 gives 482,040,000 miles as the approximate distance of Jupiter from the sun.

Neptune is 2792 millions of miles distant from the sun and takes nearly 165 years to complete one revolution along its orbit, while Mercury, the nearest member of the system, is 35,900,000 miles distant and performs its revolution in 88 days.

Unlike a star, which appears always as a point of light, a *planet exhibits a definite more or less circular disc*, and when the distance is known, observations of the apparent size of its disc supplies the necessary information for the calculation of the planet's size. Proceeding outwards from the sun, the first three planets—Mercury, Venus, and the Earth are of increasing size, but then comes Mars, which is considerably smaller than the Earth. The size then increases enormously, reaching greatest

proportions in Jupiter, the volume of which is equal to 1230 Earths, and then decreases again, both Uranus and Neptune being considerably smaller.

In his book *The Vault of Heaven*, Sir Richard Gregory gives a description of the solar system which enables one to form a clear idea of both the distances and sizes of the planets. He says: "The Earth is approximately eight thousand miles in diameter. Let us represent this by one foot and construct an imaginary Solar System on the scale of one foot to eight thousand miles. The dome of St. Paul's Cathedral, more than one hundred feet in diameter, is a fitting representation of a hemisphere of the Sun. Mercury would be proportionally represented by a baby's head at Chancery Lane; Venus, by a globe rather less than one foot in diameter revolving in a path at the distance of Charing Cross from the Cathedral dome; the earth by a one-foot globe at Buckingham Palace; and the moon a cricket ball circling round her at a distance of thirty feet. Mars, a man's head, travelling in a circle having for its radius the distance from St. Paul's to South Kensington Museum, the minor planets, or asteroids, small shot, revolving at the distance of Hammersmith; the radius of Jupiter's orbit would be just beyond Richmond, the planet itself being a globe eleven feet in diameter; Saturn a nine-foot globe would be at Staines, near Windsor, and would move round St. Paul's at this distance; Uranus would be a four-foot globe at Reading; and Neptune, a globe four and a half feet in diameter, would have for the radius of his orbit, the distance from London to Oxford."

On this scale the nearest star would be at a distance of 500,000 miles. Another example may help to emphasize these enormous celestial distances. If an inch be taken to represent the distance of the earth from the sun, then on this scale the nearest star would be about $3\frac{1}{4}$ miles away.

Mathematical calculations involved in the determination of the distances, orbits, sizes, and masses of planets are of too complicated a character to be described here, but the chief results of such calculations are summarised in the table which follows:

Name.	Average diameter in miles.	Average distance from sun in millions of miles.	Period of revolution in days.	Period of rotation.	Number of known satellites.
Mercury	2992	35·9	88	88 sidereal days	—
Venus -	7660	67	224·7	Not known definitely	—
Earth -	7914	92·7	365·3	23 hr. 56 min.	1
Mars -	4200	141	687	24 hr. 37 min.	2
Asteroids	243 (Vesta)	259	1600 (average)	—	—
Jupiter -	85,000	482	4,332	9 hr. 55 min.	9
Saturn -	71,000	884	10,759	10 hr. 14 min.	10
Uranus -	31,700	1,780	30,687	unknown	4
Neptune	34,500	2,780	60,127	unknown	1

If any of the other planets are capable of supporting life as we know it, they are Venus and Mars, which are like the earth in several ways. For example, the Martian day is only a little longer than ours, seasonal variations are probably very similar, and there is a definite atmosphere. The period of a planet's rotation on its axis is measured by observations of surface markings, which are very clear in the case of Mars. Venus, much nearer the sun, has a dense atmosphere and is so bright that no special permanent markings have been found with which to obtain the time of its rotation. Mercury, still nearer the sun, apparently has no atmosphere, and observations of certain lines believed to be cracks have given its rotation period as 88 days, the same time as that required for its revolution. Uranus and Neptune being very remote, and their surfaces indistinct, their rotation periods have not been determined.

The physical conditions of the various planets differ considerably. The first four, Mercury to Mars inclusive, have a fairly high density, about five times that of water, and appear to be solid globes, but the density of the outer members of the system is much less, being least in the case of Saturn, which is considerably lighter than a globe of water of the same size. It is probable that these larger less dense planets are composed mainly of vapours surrounding a semi-liquid interior. Though all of

the planets are relatively cool and are seen by reflected sunlight, the more remote members may contain much more internal heat than those nearer the sun.

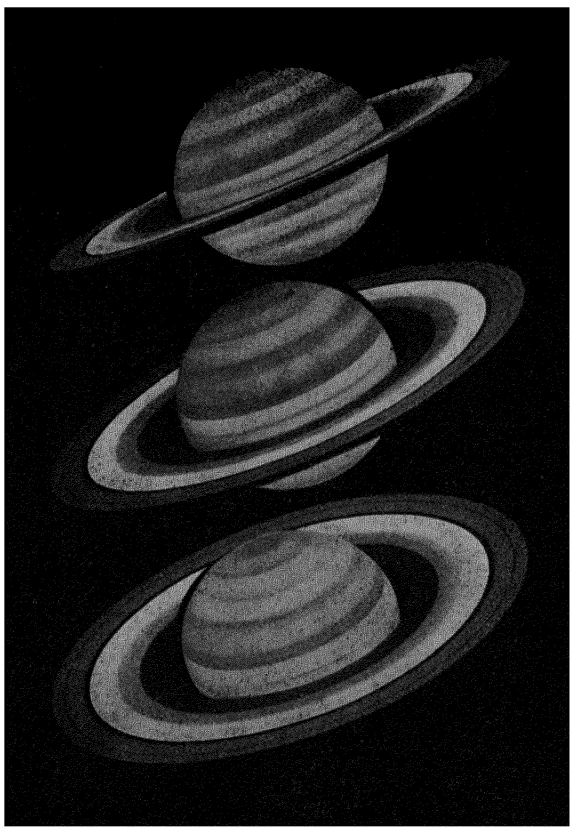
MOTIONS OF THE PLANETS

All of the planetary orbits lie nearly in the same plane, and the planets themselves all revolve in the same direction around the sun. The orbits are **ellipses,** or oval figures, though most of them are nearly circles. That of Mercury, however, is more eccentric or elongated, so that this planet's distance from the sun varies by so much as fourteen millions of miles during a complete revolution. Since the movements of the planets are controlled by gravitation and the orbits are elliptical, it follows that the velocity with which a planet moves along its orbit varies, being greatest when the planet is nearest to the sun, or in **perihelion.** These facts were discovered by Kepler, the German astronomer, who also showed that the square of the revolution period is proportional to the cube of the planet's distance from the sun. These relations between planetary orbits, velocity, and distance are generally known as **Kepler's Laws.**

The orbits of the inferior planets, Mercury and Venus, lie inside that of the earth, so that one of these two planets occasionally comes between us and the sun, and is then seen as a dark spot on the sun's surface In the case of Venus, these **transits** are of interest as they have afforded one means of determining the sun's distance from the earth. Another result of the inferior position of these orbits is that Mercury and Venus both exhibit **phases** similar to those of the moon. At certain positions these planets are visible as complete discs, at other positions as half discs, and when they are nearly between us and the sun they appear as crescents. The superior planets outside of the earth's orbit are always seen as complete discs.

Besides the planets, other celestial bodies, including satellites or moons attached to planets, **comets,** and **meteoric swarms,** move along definite paths or orbits In the case of Jupiter and Saturn, which have 9 and 10 satellites respectively, it is interesting to note that one satellite of each exhibits *retrograde* motion;

that is, revolves around its planet in a direction contrary to that of all the other satellites. The four moons of Uranus, also the one known moon of Neptune, are all retrograde compared with the usual direction of the majority of planetary satellites.



Drawn by Mr. Scriven Bolton.

FIG. 12.—THREE POSITIONS OF THE PLANET SATURN ILLUSTRATING VARIATION IN THE APPEARANCE OF THE RINGS.

Though not a satellite in the ordinary sense, the three rings of Saturn (Fig. 12), consist of innumerable solid particles revolving in streams around the planet. The aspect of the

rings, as seen from the earth, alters from time to time. When Galileo first observed Saturn, he did not recognise its rings, but thought the planet had two moons close to it. Later, the rings were edgewise to the earth and Galileo could not see them at all, so he was worried because what he thought were moons had disappeared. It was not until some fifty years afterwards that the ring system of Saturn was understood. Our own satellite,

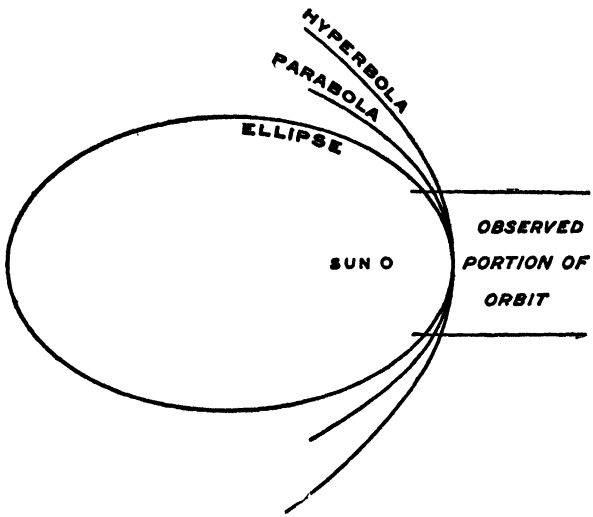


FIG. 13 —DIFFERENT SHAPES OF ORBITS.

the moon, exerts a considerable influence upon human affairs and will be considered later in connection with the earth.

Comets consist of very attenuated luminous matter extending over great volumes of space, some of the larger ones attaining the enormous length of more than 50 million miles. A comet's material is more concentrated in the part known as the head, while the matter forming the tail is so widely diffused that stars and other objects are clearly visible through it. The total mass or amount of matter is small though the volume is so great, hence the density is very low. These celestial visitors rush in from outer space, pass around the sun and then recede, the whole

journey being along a definite orbit. Those which return at regular intervals, such as **Halley's Comet,** which visits us every 76⅓ years, move along orbits which are still elliptical though very eccentric or elongated (Fig. 13). There are many, however, which move along orbits that are **parabolas,** and these comets, once they have passed the sun, never return.

Shooting stars are pieces of matter, usually quite small, which are attracted from outer space into the earth's atmosphere, when they become white hot through friction with the air. **Meteors** or **fireballs** are similar in character to shooting stars but brighter. Usually these objects vaporise in the air, but occasionally one reaches the ground, when it is found to be composed mainly of nickel and iron. Great numbers of these fragments travel in swarms, and when the earth's atmosphere encounters such a swarm a large shower of ' stars ' apparently radiating from a point is visible. Every year, about the middle of November, the earth encounters a swarm which is evidently proceeding along an orbit which crosses that of the earth during that month.

THE EARTH

Our planet is not properly spherical since rotation on its axis has caused the equatorial portions to bulge outwards at the expense of the polar regions, which have been very slightly flattened. The equatorial diameter is about 7927 miles, while the polar diameter is 27 miles less. Though the earth is frequently described as an oblate spheroid, this is scarcely correct, since pendulum experiments connected with the force of gravity at various places on the surface show that the earth is an irregular ball having a form peculiar to itself. It is more correctly described as a **geoid.** The surface irregularities, mountain ranges and ocean hollows, are very small compared with the diameter of the earth. The highest peaks in the Himalaya are about five miles above, and the deepest parts of the Pacific Ocean are the same distance below standard sea-level, which is defined as the average height of the tide at Liverpool.

The oceans and seas constitute a relatively thin water covering or **hydrosphere** occupying about three-quarters of the earth's surface. The continental masses forming the remainder are so

arranged that they form an almost continuous ring of land near the north pole and taper to pointed extremities in the southern hemisphere, an arrangement which has suggested the theory that the earth is somewhat like a tetrahedron with curved faces. Land and sea areas are in nearly all cases diametrically opposite one another, as can be easily observed by reference to a geographical globe. The results of the distribution of land and sea areas are described fully in text-books of geography, but the movements of the planet must now be considered

THE EARTH'S ROTATION AND THE DETERMINATION OF TIME

The rising and setting of the sun and of those stars which go below the horizon are due to the rotation of the earth on its axis once in 24 hours. The true period of rotation is determined by observation on stars as explained in the previous chapter, where the importance of mean solar time is also emphasised. The periods of daylight and darkness at any place are determined by the relation of that place to the sun's rays. As a place is carried by the earth's rotation from darkness into the light, the sun appears to rise above the horizon. During some hours which follow, the sun appears to move southwards and rise higher in the heavens until it reaches its highest position for that particular day, when it is noon, natural time (*i.e.* not conventional summer time), for that place. The shadow cast by a vertical stick in the ground is then shorter than at any other time of that day, and extends in a north and south direction. The shadow indicates the noon line or **meridian** of the place, and the sun is said to cross or transit the meridian at noon. How high the sun rises above the horizon on any day, and how short the shadow is, depend upon the latitude of the place and upon the season. The sun is always vertical at noon above some place within the tropics, but is never elevated more than 62° at London. For reasons which are discussed later in connection with the seasons, the sun's noon elevation at London varies from 15° in winter to 62° in summer.

The sun having 'crossed the meridian' of a place then appears to move towards the west and descend until it 'sets' or goes

below the horizon. The place is then carried into the darkness, and experiences night. Owing to refraction, or bending of light by the earth's atmosphere, dawn occurs a little before the sun actually makes its appearance above the horizon, and twilight lasts for some time after it has set. These refraction effects are more pronounced in higher latitudes where the sun's rays, being more oblique, pass through a greater thickness of air. Within the tropics, daylight and darkness come quickly.

The sun's apparent daily motion through the heavens being due to the earth's rotation, it is obvious that when it is noon at one place it will be before noon at any other place farther to the west, and afternoon at more easterly places which have been carried farther round towards the darkness and night. Distance west or east of a given line is expressed by **longitude**, and the given standard of reference is the north and south line or meridian through Greenwich. If this line is extended to meet the earth's poles, we have a large semi-circle and all places on this line have the same time. When it is noon at Greenwich it is also natural noon at many other places, three other towns approximately on the Greenwich meridian being Grimsby, Newhaven, and Havre. But most places are not on the Greenwich meridian and have a different natural or **local time.**

Since there are 360° in one complete rotation, it follows that *every* 15° *of longitude means a difference of one hour.* Thus Truro in Cornwall is about 5° west of Greenwich, so that if it is noon at Greenwich the local time at Truro is 11.40 a.m. Another twenty minutes must elapse before the sun crosses the meridian of Truro. What time will it be at Moscow, 37½° east longitude, if it is noon at Greenwich? Since 15° is equivalent to one hour, 37½° means 2½ hours. Moscow being east of Greenwich has had its noon and is moving towards night, hence the time there is 2.30 in the afternoon.

If every place adopted its own local time, the co-operation necessary for transport, trade, etc., would be extremely difficult. It would be almost impossible to arrange a railway time-table. Some system of common time over large areas must be employed, consequently in Great Britain and Western Europe Greenwich time is used. Irish time, which is about 25 minutes behind that

of Greenwich, is determined by the longitude of Dublin. In the countries of Central Europe, also in Scandinavia and Italy, Central European time, which is one hour in advance of Greenwich time, is employed. The United States, extending through more than 70° of longitude, has adopted five time belts, the time of any belt being one hour different from that of the adjacent belt.

So far, we have considered only the time at fixed places on the earth's surface, but what of time in relation to a travelling object, a ship for example? When sailing eastwards a ship goes to meet the sun, so that dawn occurs a little earlier than it would do if the ship were at rest. The period of time between two successive risings of the sun appears a little less than the earth's rotation period; the days are shorter and by the time the ship has reached the far side of the earth an extra day has been gained. On the other hand, should the ship be sailing westwards the days are slightly longer since sunset is delayed, and a day is lost by the time the ship reaches the other side of the earth. The calendar must be adjusted and this is done when a ship crosses longitude 180°, for this reason called the **date line.** If the ship is sailing eastwards a day must be taken off, but if the course is westwards a day must be added. It is easy to understand this adjustment by remembering that the earth makes a complete turn on its axis from west to east in a day. If, in addition, a journey is made around the world from west to east, then a day or one extra rotation has been added. If the journey is from east to west a day is lost.

As we have seen, when the longitude is known, local time can be found. Conversely, if local time is known the longitude of a place can be ascertained provided correct Greenwich time is also obtainable. On ships, accurate chronometers give Greenwich time, and local noon can be found by noting the time of the sun's highest position in the heavens. The difference between the local time and that of Greenwich gives the longitude, according to the relation 1 hour of time means 15° of longitude.

The consequences of terrestrial rotation are not confined to matters of time. Air being a fluid, the directions of the permanent winds are influenced by rotation. The heated air above the equator rises and the cooler air of higher latitudes flows in to take its place. If the earth were stationary, these inflowing winds

would blow directly from the north and from the south, but rotation causes them to flow from the north-east and south-east respectively. These particular winds are known as the **Trade Winds.** Similarly, other winds blowing in the latitudes of the British Isles flow from the south-west and not directly from the south as they would do if the earth did not rotate. This means that Great Britain receives rain-bearing winds from the Atlantic instead of drier winds from France, a matter of considerable

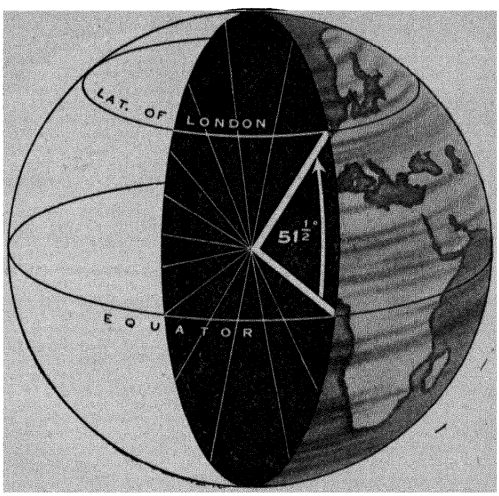
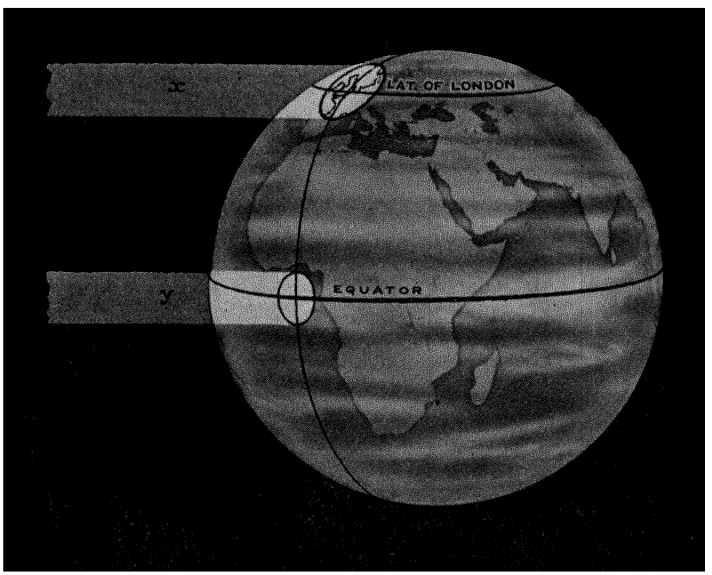


FIG. 14.
THE ANGLE OF 51½° AT THE CENTRE OF THE EARTH MEASURES THE LATITUDE OF LONDON.

importance in connection with climatic conditions. A less apparent result of rotation is the *tangential velocity* acquired by objects on the earth's surface. The widest part of the earth, the equatorial region, rotates at a speed about 1000 miles per hour, and objects on it there travel at the same rate. Fortunately gravitation is greater than this tangential velocity, otherwise objects would fly into space. Theoretically, the velocity at the poles is zero, and in temperate latitudes as in the British Isles the speed of rotation is about 500 miles per hour.

Distance north or south of the equator is called **latitude,** the

equator itself being the line of reference or position from which latitude is measured. If a person commences at London (Fig. 14) to travel southwards along the Greenwich meridian and continues until he reaches the equator, he will have journeyed through an arc of a circle which is opposite an angle at the centre of the earth This angle, which in the case of London is $51\frac{1}{2}°$, measures the latitude of the place. Distances on the



Drawn by Mr Scriven Bolton

FIG. 15.

THE CONNECTION BETWEEN LATITUDE AND QUANTITY OF HEAT RECEIVED PER SQUARE MILE THOUGH THE BEAMS *x* AND *y* ARE EQUAL, THEY SPREAD OVER DIFFERENT AREAS ON THE EARTH

surface are proportional to the angles at the centre, and as the earth is not properly spherical the average surface distance equivalent to one degree of latitude is 69 miles. Given the latitude of a place it is quite easy to calculate its distance from the equator Thus, in the case of London the distance is $51\frac{1}{2} \times 69$, or $3553\frac{1}{2}$ miles. The latitude of a place is found by observing the elevation of the Pole star as explained in the

previous chapter. Observations on other stars will serve, but in that case reference must be made to the "Nautical Almanac" for correct positions, etc. Just as longitude determines the local time, so latitude is a vital factor of the climate at any place.

Owing to the curvature of the earth's surface the sun's rays strike the ground at different angles, vertically at places within the tropics, and very obliquely at places near the polar regions. Where the rays strike vertically (Fig. 15), there will be much more heat received per square mile than at places where the rays meet the ground at a much smaller angle. Two equal beams of sunlight, x and y, produce very different temperature results because in one case x the same quantity of heat is spread over a bigger ground area than in the other case y. *The higher the latitude the less heat is received per square mile.* But the amount of heat received at most places differs at different times during the year, because the angle of reception varies with the seasons. This variation is more pronounced in high latitudes than within the tropics where the sun's rays are always nearly vertical.

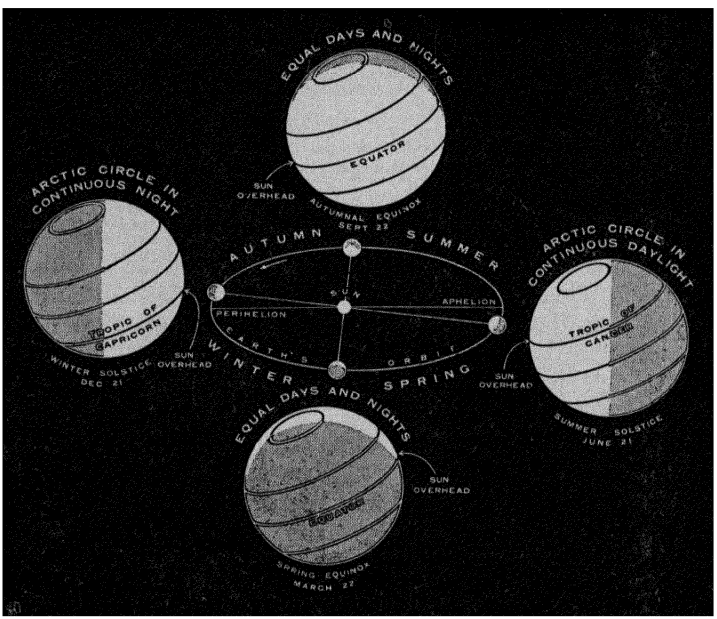
THE EARTH'S ORBIT AND THE SEASONS

The earth performs one complete journey along its orbit around the sun in 365¼ days. The calendar is adjusted by adding an extra day once in four years, thus producing a 'leap year' with the extra day in February. The earth's orbit being an ellipse and the sun situated in one focus, the earth is nearer to it sometimes than at other times, the average distance being 92,700,000 miles. It so happens that the earth is nearest the sun, or in **perihelion,** in December and about 3,000,000 miles further away at **aphelion** during June, hence the higher temperature of summer in the northern hemisphere is not the result of smaller distance from the sun. Within the tropics the temperature is much the same all the year round, but in higher latitudes there are distinct seasonal variations (Fig. 16).

These seasons are the result of three essential factors: (1) *the revolution of the earth around the sun*; (2) *the earth's axis being inclined* 66½° *to the plane of its orbit,* and (3) *the axis retains this position as the earth moves along its orbit.*

Though the axis does alter its position slowly, it requires thousands of years for such alteration to produce appreciable changes in seasonal variations. In our own time, the northern extremity of the axis continues to point approximately towards the Pole Star

Now consider the two positions of the earth in its orbit on June 21, and December 21, respectively Since the sun is so



Drawn by Mr Scriven Bolton

FIG 16

THE CAUSE OF SEASONAL VARIATION IN LATITUDES BEYOND THE TROPICS NAMES OF SOLSTICES AND EQUINOXES REFER TO CONDITIONS IN THE NORTHERN HEMISPHERE

far distant, the rays which strike the earth are parallel, hence those which fall on the equator do so at an angle different from that of rays which fall on higher latitudes, as we have seen. In June the rays fall perpendicularly along the Tropic of Cancer and other rays illumine the north pole, so that the region within the Arctic Circle remains in the light throughout the twenty-four hours. This is the period of the **midnight sun** seen in the far

north. At this time, in the latitudes of Great Britain, the sun remains above the horizon longer and passes through a greater arc than at any other time of the year. But though it is summer for us, it is winter for similar latitudes in the southern hemisphere, where the sun's rays fail to reach the south pole, which thus remains in darkness for some months. Six months later conditions are reversed, the south pole receiving the sun's rays, while the north pole remains in darkness. The sun is then directly overhead of the Tropic of Capricorn; it is summer in the southern hemisphere and winter in the northern. After December 21, the sun appears to move northwards away from the Tropic of Capricorn and slowly approaches the northern tropic.

Thus the two tropics are the turning positions of the sun. The change is not abrupt, the sun apparently remaining above each tropic for a day or two, hence June 21, is called the **summer solstice** and December 21, the **winter solstice.** The summer solstice is not the hottest time of the year for Britain, though it is astronomically mid-summer. In our latitudes the hottest period occurs in July or even August, after the ground, etc., have been thoroughly warmed by the summer sunshine.

What about the intermediate positions of the earth on March 21 and September 21? At these dates the sun is directly overhead at the equator, and neither polar region has any advantage over the other. In March it is spring in the northern hemisphere, which is then advancing towards its summer, and, of course, it is autumn in the southern hemisphere, which is moving towards its winter season. On these dates the sun is above the horizon twelve hours and below it twelve hours. The daylight and darkness periods are equal except for dawn and twilight effects. The sun rises at 6 a.m. and sets at 6 p.m. natural time. Since these diurnal periods of night and day are roughly equal, these dates are called the **equinoxes,** March 21 being the **vernal equinox,** and September 21 the **autumnal equinox.** Owing to dawn and twilight effects, the periods of light and darkness are really *equal* some days before March 21, and a little after September 21.

Apart from these important seasonal variations, the apparent yearly movement of the sun through the heavens is another result of the earth's journey along its orbit. We are already at

so great a distance from the sun that the vastly greater distances from the sun to the stars cannot be perceived. It appears to us that the sun is moving through the constellations or star groups (Fig. 17). As the earth moves forward on its orbit, the sun appears to move in the course of a year through the principal groups of stars called the twelve **Signs of the Zodiac.** On June 21, the sun appears to be in the sign of Cancer, the Crab,

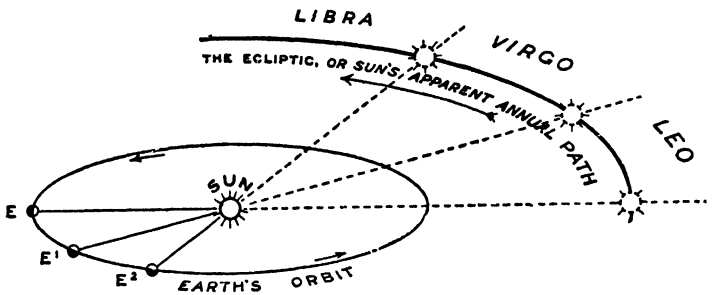


FIG 17.
THE SUN'S APPARENT MOTION THROUGH THE SIGNS OF THE ZODIAC

hence the name given to the northern tropic above which the sun is vertical at that date. Similarly, the sun appears to be in the sign or group called Capricorn, the Goat, on December 21 (hence the name of the southern tropic), in the group Aries at the vernal equinox, and in Libra at the autumnal equinox.

THE MOON

The earth's satellite is very much nearer us than any other heavenly body, its average distance being 238,850 miles. Its orbit is slightly inclined to that of the earth and is rather eccentric, so that when the moon is in **perigee,** or its nearest position, it is some 31,000 miles nearer than when it is in **apogee** or its most remote position. The time taken by the moon in performing one revolution is 27⅓ days as determined by reference to a star, but if taken with reference to the sun, owing to the movements of the earth the time which elapses between two successive 'new' moons is 29½ days, and this period is called a **lunar month.** In ordinary daily life, however, we use the more

convenient **calendar months** containing a number of complete days.

The moon rotates on its axis once in $27\frac{1}{3}$ days, the same time in which it revolves around the earth, and the result of this is that *only one side of the moon is ever seen by us.* Place some mark on a tennis ball, hold the ball and carry it around a chair always keeping the mark on it facing the chair, and you will realise that the ball has rotated on its axis once while it has also revolved around the chair once. As a matter of fact, we see a little more than half of the moon, as we obtain views a little farther towards the moon's poles on account of its orbit being sometimes above, and sometimes below the plane of the earth's own orbit. The moon's rate of travel along its orbit varies, and this enables us to see just a little bit farther round the edges. These slight variations of the lunar surface presented to our view are called **librations.**

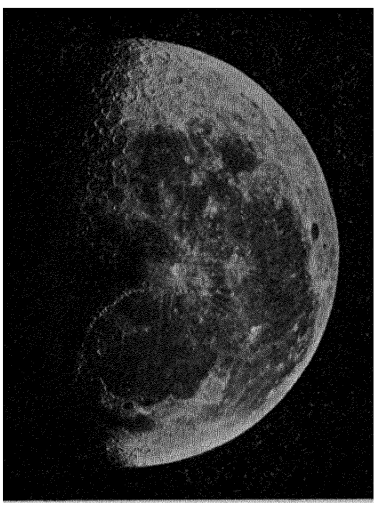
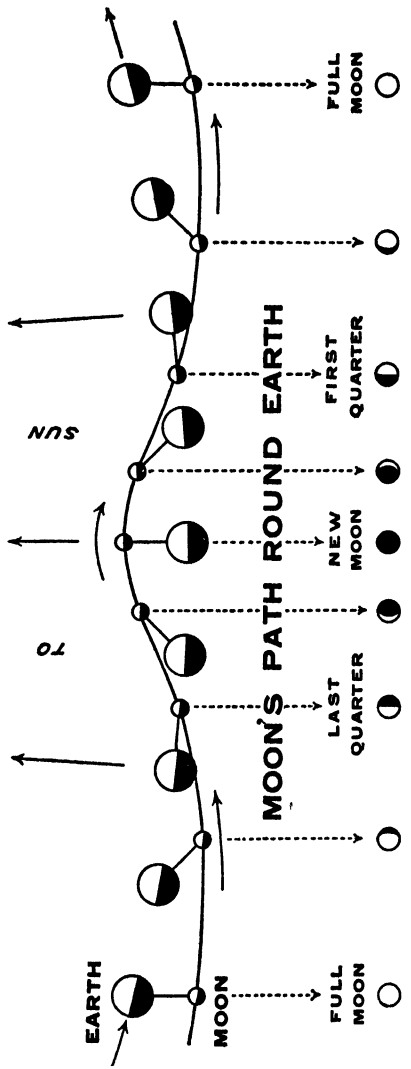


FIG. 18.—THE MOON
ABOUT EIGHT DAYS AFTER THE PERIOD OF NEW MOON.

The part of the moon's surface which we can see is extremely beautiful when viewed through a telescope (Fig. 18), showing great numbers of rounded craters presumably of earlier volcanic origin, ranges of mountains, large cracks or fissures, white streaks the nature of which is doubtful, and great grey plains which have been miscalled 'seas.' It is now known that *there is neither water nor an atmosphere on the moon*, hence life as we know it here cannot exist there. Knowing the distance of the moon, measurements of its apparent diameter have supplied information concerning its real diameter, which is 2163 miles; and this means that in volume, the earth is equal to 49 moons. The density of the



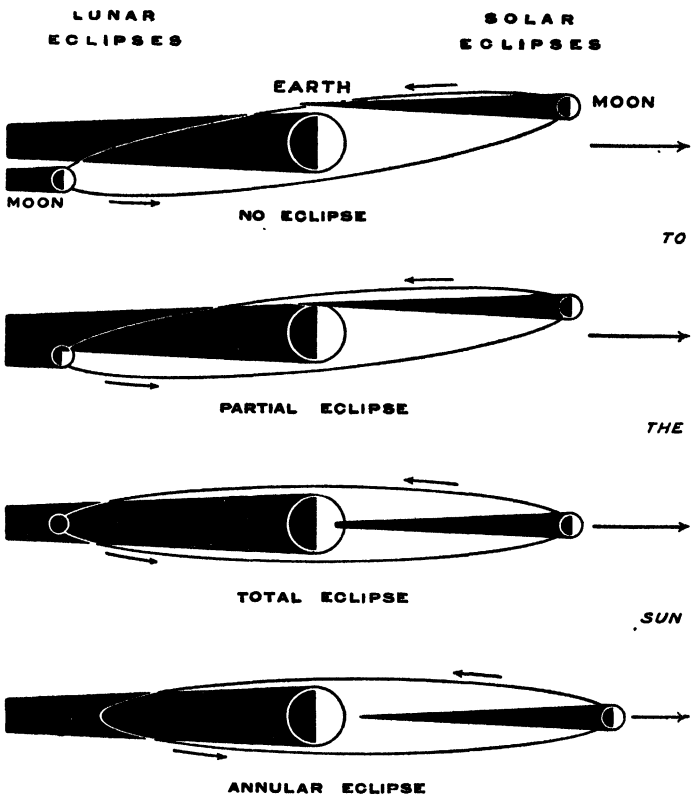
Drawn by Mr. Scrwen Bolton.

FIG 19.—THE MOTION AND PHASES OF THE MOON.

substances composing the moon is as a whole much less than that of the terrestrial rocks; it is on account of the smaller

size that objects on the moon weigh only $\frac{1}{6}$ of their weight upon the earth.

The moon exhibits **phases**, that is, its appearance is different at different parts of the lunar month (Fig. 19). It 'shines' by



Drawn by Mr. Scrwen Bolton.

FIG. 20.—ECLIPSES OF THE SUN AND MOON.

light from the sun reflected by its surface, and as it journeys around the earth, it is clear from the diagram that we see different amounts of the illumined surface. It waxes as it proceeds from the position of *new* moon to that of *full* moon, then it decreases, or wanes. At the former position the dark

side of our satellite is facing us and we do not see it, but at full moon the whole of the illumined surface is visible At positions between these extremes we see curved surfaces varying from thin crescents near the new moon to gibbous shapes towards full moon. At first and third quarter the illumined surface appears as a semi-circular area.

The orbit of the moon being inclined to that of the earth there are two points called **nodes** where these orbits intersect. On some occasions when the moon is at, or near, one of these nodes, the sun, moon and earth are all in the same straight line, so that an eclipse occurs. Since the moon must be in the plane of the earth's orbit for an eclipse to take place, that plane is also called the **plane of the ecliptic.** Should the moon come between the earth and the sun, the latter is eclipsed, the moon appearing as a dark object obscuring the sun (Fig. 20). Over a small portion of the earth's surface the moon is seen to blot out the sun completely, so that for people in that restricted area the eclipse is total, and features described in Chapter I may be observed But over most of the earth the eclipse is partial, only a portion of the sun's face being covered by the moon. When the earth comes between the sun and the moon, the latter moves into the earth's shadow and is eclipsed, the eclipse being total if the whole of the moon passes into the region of the earth's shadow. If the orbits of the earth and of the moon were both in the same plane, an eclipse of the sun and of the moon would occur in each lunar month.

Although the moon is relatively small, it is so close to the earth that it exerts a strong gravitational pull which causes the oceanic waters to be heaped up at positions under the moon, and on the opposite side of the earth. This rise of water is called a **high tide** and as the earth rotates it brings various places in turn under the moon, so that these places experience high tide in succession. A more detailed explanation of tides is given in Section II, Chapter XIII.

CHAPTER III

THE EARTH'S CRUST

THE relatively thin outer portion of the earth, the part upon which we live and into which we probe for minerals, is called the earth's **crust.** Though in the regions of latitude of Great Britain most of the earth's surface is covered with soil and vegetation, we may obtain glimpses of the crust in quarries, railway cuttings, river courses, and in the cliffs and beaches near the sea. In these places various kinds of rocks are visible. Any natural mass of substance large enough to form an appreciable part of the earth's crust is called a **rock,** whether it is hard like granite or soft like clay; for example, the mud in a river estuary is geologically as much a rock as the limestone cliffs which tower above the sea.

In some cases rocks consist of an aggregate of relatively small grains of different substances, and each of these substances is called a rock-forming **mineral.** Thus in the rock called **granite** we can distinguish glassy grains of **quartz,** pink crystals of **felspar,** and dark glistening flakes of **mica.** Quartz, felspar, and mica are the rock-forming minerals which together compose granite. Sometimes a single mineral species may occur in such large masses as to form a rock by itself. Quartz often forms as much as 95 per cent. of another rock called **sandstone,** and limestone usually consists almost wholly of a mineral known as **calcite.** Similarly **salt** is both a rock and a mineral. The term 'mineral' is often used in an economic sense to mean any kind of rock or mineral substance that is mined for commercial purposes. In most cases these commercial 'minerals' are more correctly termed rocks, since they occur in extensive masses. Slate, limestone, coal, and sand are examples.

Geology, the study of rocks and minerals, is of great importance to miners, civil engineers, surveyors, farmers, builders, and many others. *Man's relations with the earth's crust is probably the greatest factor of human existence.* Our food is dependent upon soils derived from decaying rocks ; fuels, metallic ores, building materials, and many other necessities must be mined ; estuaries must be cleared of river transported mud ; coasts must be protected against drifting shingle, and tunnels have to be drilled through great mountain ranges. The enormous influence of rocks and minerals upon daily life will be realised when it is understood that *the occupations of people, the density of population, the scenery, the means of transport, and to some extent the climate of any region depend chiefly upon the kind of rocks present in that particular area, and the way in which they are arranged.*

Rocks are of many different kinds, but in a broad general way it is possible to recognise three great groups according to the ways in which rocks have been produced. The **sedimentary** group includes all those rocks which have been formed by the accumulation of sediments generally deposited under the water of the sea or of lakes, but occasionally heaped up by wind, or other agency on the land. Most rocks in the world belong to this group ; certainly 85 per cent of those in Great Britain are ancient sediments. The **igneous** group is composed of those rocks which have solidified from fusion due to heat, whether the solidification took place quickly at the earth's surface as in the case of **volcanic** rocks, or slowly and under great pressure at some place far below the surface of the ground, as in **plutonic** rocks. The third great division is the **metamorphic** group, which includes rocks that are produced by later alteration of either sedimentary or igneous rocks, the agents of such alteration being heat and pressure.

SEDIMENTARY ROCKS

The surface of the earth is slowly but constantly changing, particularly the relative arrangement of land and sea areas. The shallow seas around the British Islands, for example, have at times been land areas, and where land is now, in former times there was sea. Land conditions and marine deposition alternate

in cycles. Several seas have at different periods covered the site now occupied by Great Britain. Agents of destruction, chiefly wind, rain, and frost, are always breaking up the land into fine particles or sediments which are carried by rivers and then discharged into the seas around the coasts, or into lakes. The lighter particles, mud and clay, are carried farther out to sea than the heavier fragments of sand and gravel, which settle down nearer the shore. These sediments are slowly built up layer upon layer one above another, and eventually, as the sea recedes they will become dry, and form new land. The various layers are called **strata,** or beds of rock.

Nearly all sedimentary rocks exhibit this stratification, and it is obvious that the oldest strata are those which underlie the

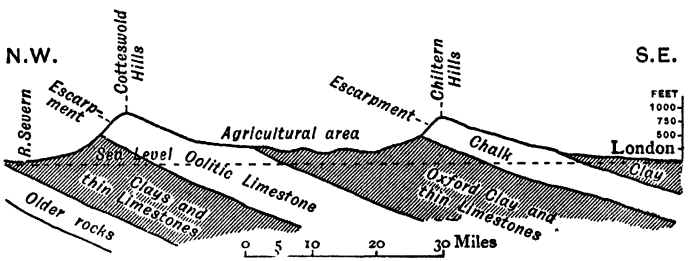


FIG. 21.—GEOLOGICAL SECTION OF THE COUNTRY BETWEEN THE SEVERN VALLEY AND LONDON.

others. *The relative ages of strata are thus determined by their order of superposition.* If the country from the Severn to London were cut open vertically by a huge knife, we should see a section exhibiting strata of ancient sediments gently dipping towards the east, so that the oldest appear at the surface in the Severn Valley and the youngest occur near London (Fig. 21). Since most seas contain living creatures, the sediments contain various animal remains, such as shells, corals, sea urchins, teeth of fish and other *hard* parts. Similarly, sediments accumulated in lakes and estuaries often contain plant remains. Such remains of former animals and plants now found, more or less mineralised, in sedimentary rocks are called **fossils.**

Now let us consider the chief types of sedimentary rocks, and their influence on daily life.

CONGLOMERATE

Many parts of the coast exhibit large tracks of beach composed of pebbles of various sizes rounded by mutual friction caused by the waves and tides In the far distant future, this shingle may become cemented to a compact mass by sand or other substances deposited between the pebbles, and a rock called **conglomerate** will be formed A conglomerate (Fig 22) is a sure indication of the former existence of a beach, though the site may now be

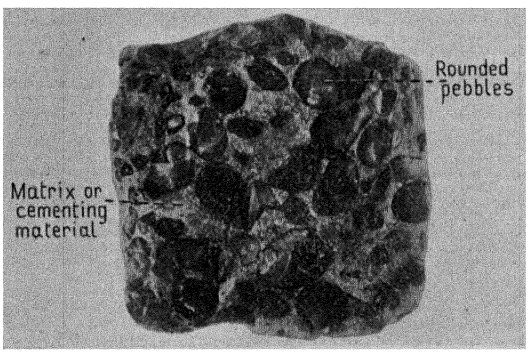


FIG 22 —A PIECE OF CONGLOMERATE.
(Photo by G S Sweeting of specimen in the Geological Collection of the Imperial College of Science)

hundreds of miles inland These pebble beds are fairly hard, resist weather well, and often form low ranges of hills Nottingham Castle stands upon a conglomerate forming a distinct ridge which extends across that part of the town As a rule these old beaches do not contain useful minerals, though some of them make good building material, such as that used in the construction of the main railway station at Bristol.

SANDSTONES

Just as modern shingle is succeeded seawards by wide stretches of sand, so conglomerates are usually associated with extensive layers of **sandstone.** Sand grains eventually become consolidated in much the same way as do pebble beds. Rain water

trickling through the mass of sand long after it has become land carries such substances as silica and oxide of iron into the spaces between the grains, and this welds the whole mass into a very compact firm rock. Sand itself consists of broken fragments of various minerals derived from the wear and tear of other rocks. Usually most of these fragments consist of the mineral called **quartz**, though many other minerals are often present in varying amounts. If these fragments are quite small, a fine grained sandstone is the result, but if they are relatively coarse a grit is produced and these are very useful as grindstones for sharpening steel, etc.

The older sandstones of the world are often thousands of feet thick, forming massive hills and generally fine scenery. The climate is usually bracing, but the absence of useful minerals apart from building stone causes these areas to be somewhat thinly populated. The chief occupations consist of sheep-rearing and catering for tourists, who visit the district to enjoy the scenery and the bracing air. Unlike limestone districts, sandstone areas have remarkably pure river water, and natural caverns are very uncommon. The Old Red Sandstone of Caithness in north-east Scotland is a massive formation of this kind, and such old sandstones must be distinguished from much more recent and less compact sandy rocks which build less impressive scenery, though they yield sand for glass making and other purposes. Younger, more friable sandstones of this kind occur in the south-east of England, and as these are porous they are valuable as a source of water which collects in them. Some sandstones containing few fossils appear to have been deposited on land by the agency of wind. They are old deserts.

CLAY

Since **clays** consist of minute rock particles which have been carried farther out to sea, the presence of such rocks indicate moderately deep water conditions at the time of deposit. Nearly all clays are of marine origin, though a few, such as the Wealden Clays forming the vales of Kent and Sussex, were formed in lakes or estuaries. The fossils, marine or freshwater species of shells, etc., found in a clay yield the evidence concerning its mode of

origin. Though it occurs as a definite bed sandwiched in between other strata, a clay does not usually exhibit stratification within itself; it appears as a compact mass.

The utility of clays depends largely upon the fact that they occur in these compact and plastic masses. As this class of rock is soft, and only feebly resists the work of wind and rain, a typical clay district consists of either flat or gently undulating country, such as that in large portions of Oxfordshire, where a blue marine deposit known as Oxford Clay is found. A district of this type is almost entirely an agricultural one, and the population, though not great, is fairly evenly distributed in small market towns. Here and there clay is dug in brickyards and a certain amount of earthenware is made locally. Communication from one place to another is an easy matter compared with that in a hard sandstone area where roads and railways must use the river valleys.

Another typical clay region is found in Cheshire, but here great sheets of rock salt are interbedded with the clay. These valuable deposits of salt are really the dried-up floors of ancient salt lakes. Similarly, deposits of a pink or white mineral called **gypsum** are found in clays of the same age and kind. In its purer forms this substance is called **alabaster,** and being very soft, is easily worked into ornaments and bowls for electric lights. The cruder forms of gypsum are used for the manufacture of Plaster of Paris. Clays yielding salt and gypsum do not often contain fossils, as conditions in salt lakes are not very suitable for living creatures.

THE COAL MEASURES

A most important group of rocks called the **coal measures** consists of freshwater clays alternating with thin sandstones and coal seams. As the sandstones are only a few feet thick at a time, the resulting landscape is gently undulating. The Midland coalfields may be taken as typical examples. An earthy form of iron ore called **clay ironstone** occurs as lumps or nodules in the clays, and this together with the coal leads to such areas being the most densely populated though least attractive districts. Ironworks exist side by side with pit shafts, and clay pits are

numerous. Communications are easy, and there is usually a large network of railways.

Impressions of fern leaves, etc., may sometimes be seen in a piece of coal indicating that this mineral is really fossilised plant remains. Each seam of coal represents so much vegetable matter, reed-like trees and gigantic ferns, which was buried by silt discharged into lakes, millions of years ago. Forests sank beneath the water and were buried by sediments which formed soils for new forests to arise, and these in their turns were submerged and covered. Freshwater species of shells found in the coal measures prove the lacustrine origin of these rocks. In other cases it appears that leaves, twigs, roots, etc., were drifted down rivers into the mud of estuaries and there covered. Vegetation thus buried gradually decomposes, losing various gaseous substances and the residue becomes the hard stony material we call coal.

Some rocks are composed of matter very similar to that in a clay, but this matter is arranged in very thin layers or laminae, several of them in a bed an inch thick. This kind of rock is called a **shale,** and in some of the Scottish examples vegetable remains in the shale have decomposed with the formation of oil which is obtained by distillation.

LIMESTONES

In deeper water, still more remote from land, the shells and other hard parts of marine animals accumulate on the sea floor as these creatures die. In the course of time huge shell banks and other heaps of organic remains become consolidated to a firm pale grey rock known as **limestone,** since the organic remains are composed of carbonate of lime or calcite. Most limestones are of a marine origin though a few have been formed in lakes as shown by the nature of their fossil contents—freshwater snails and pond mussels. A piece of marine limestone that has been exposed to the action of the weather for a long time generally shows the various structures of the remains composing the rock. Rod-like bodies termed encrinites are frequently present in great numbers, so may be corals and shells (Fig. 23). Some of the structures are so minute that they can be seen only by the aid

of a microscope. At the present day a cream-coloured mud dredged up from the floor of the Atlantic ocean is composed mainly of similar very minute shells. This **Globigerina ooze,** as it is called, after the species of shell known as *Globigerina*, is in many ways similar to the chalk that forms hills in the south-east of England and elsewhere

Though chalk is soft, most limestones are very hard, and when of great thickness they form rugged mountain scenery with deep valleys called **dales.** Percolating rain dissolves the rock in

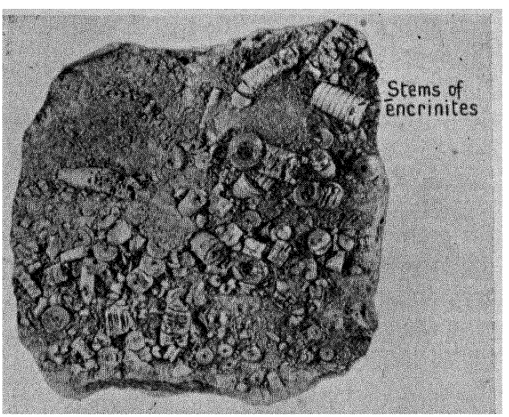


FIG 23.—A PIECE OF WEATHERED LIMESTONE
Photo by G S Sweeting of specimen in the Geological Collection of the Imperial College of Science

places, so that the hills frequently contain many natural caverns often having pillar-like **stalactites,** while many streams disappear underground and come to the surface as springs in other parts of the district. Water in limestone areas is very hard and must be softened before it can be used for steam engines and some domestic purposes.

These massive limestone districts are usually bleak and thinly populated, but contain important tourist centres such as Matlock and Buxton in the Peak district. A certain amount of agriculture is carried on, chiefly the rearing of sheep, which can exist on the short grass clothing the hill slopes The limestone

is quarried in places for the production of lime used in agriculture and other industries, while limestone itself is transported for use as a flux in the smelting of iron ore, etc. The thick 'Carboniferous Limestone' is responsible for the scenery of the Pennine Range (Fig. 26), the Peak District (Fig. 24), the Avon Gorge at Bristol, the Mendip Hills, and many parts of Wales.

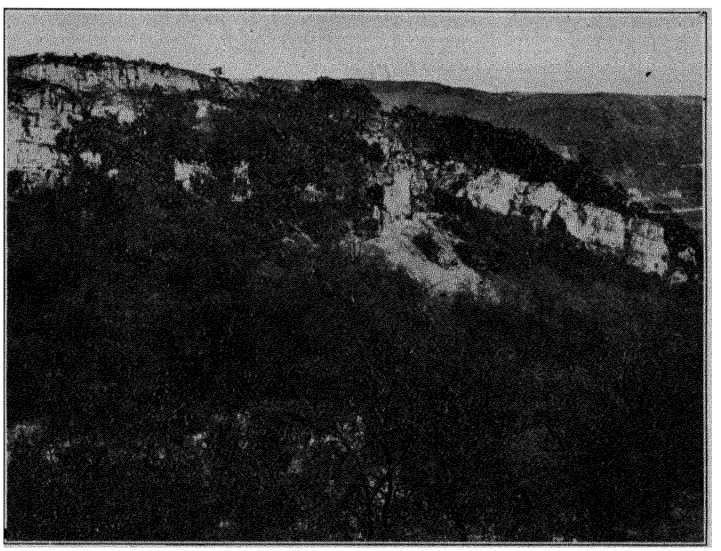


FIG. 24.—TYPICAL LIMESTONE SCENERY,
MATLOCK DALE, DERBYSHIRE.
(By courtesy of the Director, Geological Survey.)

Communications in these districts are difficult and railways must take advantage of the river valleys. A geological map, that is, one which shows the kinds of rock present, is given in Fig. 25 of the country around Derby, and it is possible from this to form a mental picture of the scenery and of the occupations of the people living in different parts of the region.

CRUSTAL ARCHITECTURE

Though the kind of rock present in an area is of prime importance, the arrangement of rocks is a factor in both the

evolution of scenery and the development of human activities. In Great Britain the most usual arrangement of sedimentary rocks

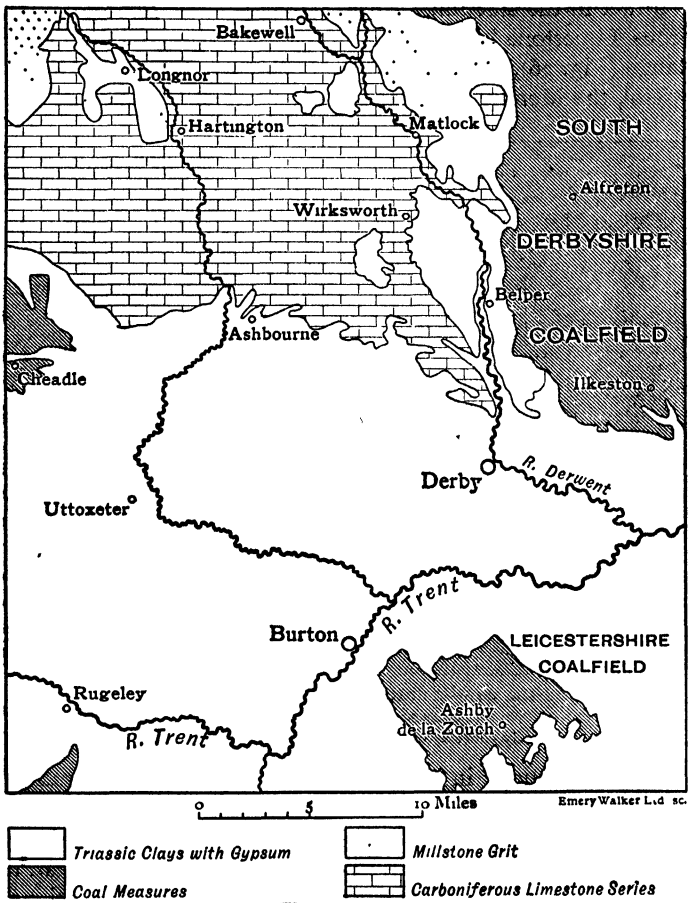


FIG. 25.—GEOLOGICAL MAP OF THE DISTRICT AROUND DERBY.

consists of very gently inclined strata such as those extending from the Severn to London. This piece of country has already been illustrated by a geological section or drawing which shows how the strata would appear if the ground were cut open verti-

cally (Fig. 21). Geologists in walking over the country collect sufficient evidence from quarries, railway cuttings, etc., to enable them to obtain a correct interpretation of rock arrangements. Let us examine, without too much detail, the section from the Severn to London.

The oldest of these particular strata consist of relatively soft thin limestone and clays forming the Severn Valley. Proceeding eastwards a traveller soon comes to the steep face of the Cotteswold Hills, a fine range due to a harder yellow limestone called **oolite,** because it is formed largely of minute egg-like grains of limestone. A piece of oolitic limestone resembles in appearance the hard roe of a fish. This rock, which is more massive than the other oolites, forms a high ridge extending many miles across the country towards the north-east, and such a ridge due to this arrangement is called an **escarpment.** Nearer London another less massive escarpment of chalk forms the Chiltern Hills, which like the Cotteswolds form a sheep-rearing district.

The agricultural country between the two escarpments is composed mainly of the Oxford Clay and thin limestones not massive enough to form prominent ranges of hills. These rocks including the clays are for convenience classified as 'oolites,' though oolitic structure is found only in the limestones. Around London the clay known as **London Clay** together with some sandy beds and gravels form a flat area which would be simply an agricultural district if it were not for London, a city of enormous growth due to its magnificent position. Farther to the west of the Severn, rocks still older than the oolites come to the surface in Herefordshire and Wales, and it is interesting to note that, since the Coal Measures are older than the oolites, most of the great manufacturing districts of England are situated to the west of the oolite escarpment.

In England, strata are usually gently inclined, and though they may appear horizontal in a quarry, they are found to dip slightly when traced over many miles of country. If traced far enough they may sometimes be found to change their direction of dip owing to the existence of a folded arrangement.

As the earth cooled, the rocks of the crust, endeavouring to fit themselves to a contracting mass, were subjected to strains and

stresses which caused some to be thrown up into folds in various places and at different times. In this way most of the great mountain ranges of the world, such as the Alps and the Himalayas, have been formed. Geologically, these great ranges are young compared with our own Pennines.

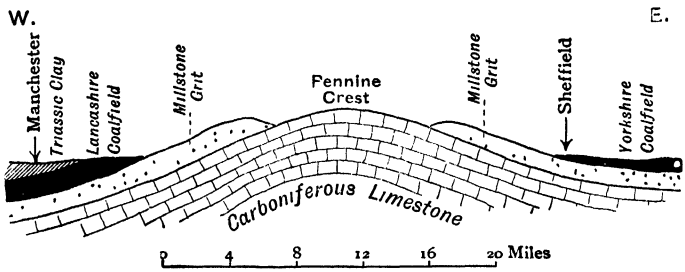


FIG 26.—THE PENNINE ANTICLINE.

If we study the country between Manchester and Sheffield (Fig. 26), we find that the strata rise and fall in a simple fold called an **anticline** because the beds of rock dip away from the crest of the Pennines both towards the west and towards the east. The chief effects of this arrangement are obvious The hard limestone has been carried upwards, intensifying the height and

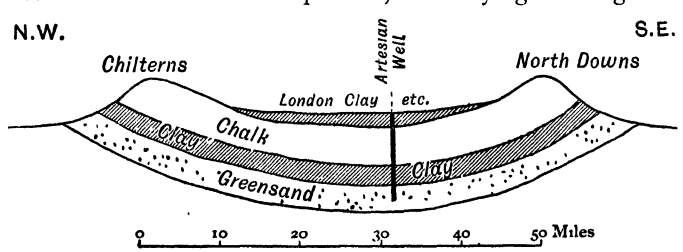


FIG. 27.—THE SYNCLINAL FOLD OF THE LONDON BASIN.

bleakness of these highlands. The Coal Measures have been divided into two widely separated coalfields, that of South Lancashire on one side, and that of Yorkshire on the other. The Pennine fold forms a sufficient barrier to most of the rain coming from the west, so that the climate of Lancashire is very different from that of Yorkshire.

Anticlines are often associated with folds of the opposite kind

called **synclines.** In this arrangement the beds of rock dip from both sides downwards towards the central part of the fold. The London Basin is a fold of this type, and a section from the Chilterns in the north to the North Downs in the south of the area is given in Fig. 27, so that the repetition of the hills can be understood. Two chalk escarpments have been formed, and the country between them is composed of London Clay and various gravels. Both the chalk and the greensand below it are excellent holders of water so that borings in the lower parts of

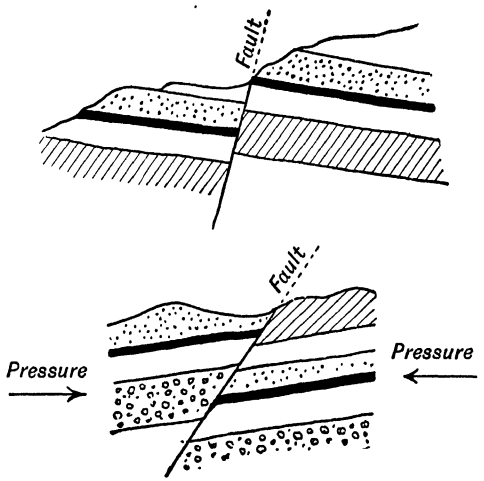


FIG. 28.—GEOLOGICAL SECTIONS ILLUSTRATING FAULTS.
THE UPPER FIGURE REPRESENTS A NORMAL FAULT, THE LOWER FIGURE A REVERSED FAULT.

the London Basin cause water to rise to the surface. Such **artesian wells** operate because water in the rocks up in the hills is at a higher level than that in the boring.

In mountain systems such as the Jura and the Alps, anticlines and synclines follow each other in succession, and though it is not always the case, the synclines are usually valleys while the anticlines are the crest of the mountains.

Movements of the earth's crust are also responsible for fractures called **faults** which may or may not be associated with folding. The great majority of faults are due to gravity, a part of the

ground having fallen down relative to the remaining parts as shown in the upper figure of Fig. 28. These are called **normal** faults, and should a large piece of country collapse between roughly parallel faults of this kind a **rift valley** is produced. The central lowland area of Scotland is such a rift valley where Coal Measures have been let down between hard crystalline highlands to the north and slate uplands to the south. The Valley of the Jordan in Palestine is another example.

The converse of a rift valley is a **horst,** a mass of rocks left standing up when the country around it has collapsed. Some of the mountains of Central Europe are of this type. If pressure from the sides causes a mass of rocks to be pushed up above others, as shown in the lower section in Fig. 28, the fault is said to be **reversed,** and is sometimes termed an **overthrust.** The structure of the Scottish Highlands is complicated by a great number of gigantic overthrusts sometimes involving miles of country. Faults on a large scale modify scenery, and on a smaller scale have important influence on mining operations. Solutions and heated vapours have, in former times, carried mineral substances, such as lead ore, into cracks and cavities caused by faults, which thus become important mineral veins. A coal seam ceases suddenly against a fault, and by studying the direction of slope of the fault, a miner can tell whether he must go up or down to recover that particular seam.

THE GEOLOGICAL RECORD

The vast mass of sedimentary rocks in the world forms a great natural ' book ' containing the record of life on our planet since the fossilized remains of animals and plants found in these rocks show us quite clearly the kinds of creatures which inhabited the earth at various periods. The complete book from those early pages known as the **Pre-Cambrian rocks** to the present time contains a great collection of old sediments, which, if taken together and in their correct order, forms a volume many scores of miles in thickness. All these pages do not occur in one country, however. Even in the British Isles, where rocks of most geological ages are represented, there are some important gaps. Generally, if a set of strata of a certain age are missing

in one country they may be found in another. This means that while one area was a land surface undergoing slow destruction by the weather, another area was covered by sea where sediments were being deposited. Some rocks were deposited under conditions very unsuited to living creatures and therefore contain few or no fossils, and in other cases strata which were originally fossiliferous have been removed by denudation or altered by heat and pressure with consequent destruction of organic structures which may have been present. These causes produce a few gaps in the history of former living things, so that *the geological record is said to be imperfect.*

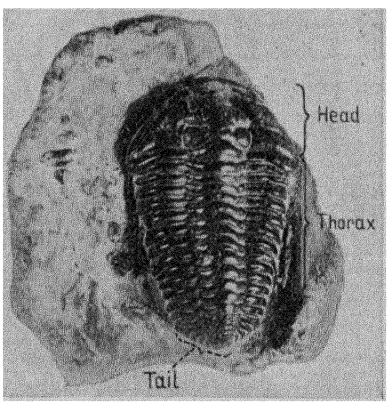


FIG. 29.—A TRILOBITE.
Photo. by G. S. Sweeting of specimen in the Geological Collection of the Imperial College of Science.

This imperfection is relatively slight, however, and the study of fossils, or **palaeontology,** enables us to form a fairly accurate conception of the development of life upon the earth. The general development or evolution of living creatures has proceeded from the simple to the complex. In the earlier fossiliferous rocks termed **Palaeozoic,** we find only fossils of simple animals including shells, corals, sponges, trilobites, and early types of fish and reptiles. The trilobites so called because their bodies were tri-lobed, were something like the modern wood lice and are occasionally found in the rolled up condition (Fig. 29). Rocks containing trilobites occur chiefly in Wales. The Coal Measures containing a rich fossil flora are also of Palaeozoic age.

The country between the Severn and the Chilterns is composed of Middle Period or **Mesozoic sediments.** Fossils found in these are more advanced than those occurring in the Palaeozoic formations. Besides shells, sea urchins, corals, and ammonites, the first birds and mammals made their appearance. But this

period was essentially the age of reptiles, some of them being of huge size and known as Dinosaurs, while others, the Pterodactyls, were able to fly. The ammonites (Fig 30) were a group of molluscs related to cuttle fish and inhabited coiled shells, though these are found uncoiled in the later stages of the history of the group, and it died out in the chalk period The remaining younger sediments were laid down in the **Tertiary** or **Cainozoic Period.** During tertiary times the animals and plants slowly

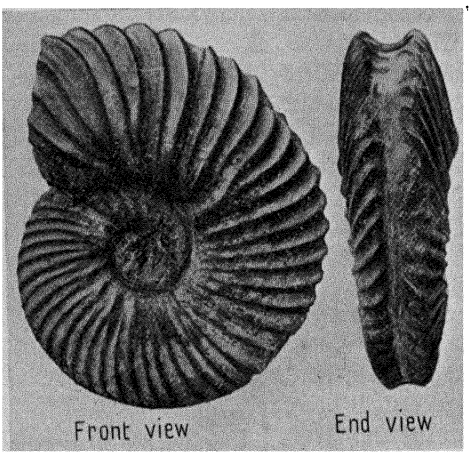


FIG 30 —AN AMMONITE.
(Photo by Dr L. F. Spath)

became more and more like those living to-day, and towards the end of this period man himself was an inhabitant of the earth

The whole time represented by all of the fossilferous strata taken together is probably about 600 million years

Apart from questions of organic evolution, fossils supply information concerning earlier geographical conditions. As we have seen, the former existence of seas, lakes, and desert areas are indicated by fossils or their absence The presence of arctic shells or of tropical plants yield definite information concerning the climate existing at the time when rocks containing such fossils were deposited Certain strata often contain very

characteristic fossils which are therefore of use in determining the age of rocks when the order of superposition may not be seen easily. By means of these **zone fossils,** as they are termed, rocks in one country may be correlated with those in another. Zone fossils are of particular value to the prospector since they indicate the presence of certain strata that may contain useful minerals.

IGNEOUS AND METAMORPHIC ROCKS

The solid materials ejected from a volcano fall upon the ground or upon sediments being deposited near the coast. Volcanoes are usually situated near the sea, and in bygone times vast sheets of **lava** have been poured over the sea floor and afterwards covered with more sediment. In this way old lava streams and beds of fragments or ' ash ' have become *interbedded* with ordinary sedimentary strata, and with them may form escarpments, anticlines, etc. Sometimes old volcanic craters and channels are visible, as in Derbyshire, but frequently the actual vents are either concealed under later rocks or have been destroyed by **weathering.** In these cases sheets of interbedded lava remain as evidence of former vulcanism. Old lavas of great thickness are thus found as beds of rock between other strata in Wales, the Lake District, the Midlands, and in Scotland. In the formation of rugged mountain districts supporting a thin population, volcanic rocks resemble the harder limestones and sandstones. The scenery is often magnificent, and results in a ' tourist industry.'

Snowdon is a mass of lava and volcanic ash some 3000 feet thick poured from great vents hundreds of millions of years ago. By far the most ancient volcanic rocks found in Britain, and indeed in the world, are those found in Charnwood Forest in Leicestershire, and at the Wrekin in Shropshire. These take us back into the mists of antiquity to a period so remote that few if any living creatures had then made an appearance on the earth. In north-eastern Ireland occurs a plateau composed of lavas of very different age and type. These **basalts** were discharged from huge fissures miles in length, and there were several different eruptions at different times, though all of them occurred within

the Tertiary Period Basaltic plateaux of a similar type are found in the Idaho region of North America. A pronounced feature of this class of rock is the formation of columns as the mass cools The Giant's Causeway in Northern Ireland is a fine example

Volcanic rocks vary considerably in appearance, some being light pink or green, while others are grey or black They are usually fine grained, and some show great numbers of pores and cavities due to the escape of steam as the material cooled If we

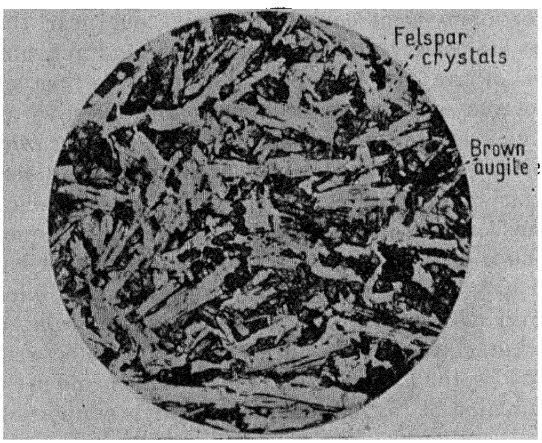


FIG 31 —A THIN SECTION OF BASALT AS SEEN UNDER A MICROSCOPE

(Photomicro by G S Sweeting of specimen in the Geological Collection of the Imperial College of Science)

examine a thin slice of black lava or basalt with a microscope (Fig 31), we find that it is composed of white elongated crystals of felspar and brown crystals of a mineral called **augite.** The crystals of felspar and augite are well formed due to the absence of any other rocks pressing upon them as the molten mass cooled Such well-formed crystals are said to be **idiomorphic,** and are characteristic of most volcanic rocks Both the felspar and the augite are present in two distinct sizes, one set of each mineral being much larger than the other crystals, the latter forming what

is called the **ground mass.** The larger crystals were already formed when the lava was ejected, and the smaller crystals of the ground mass were formed as the rock solidified. *This differentiation into two distinct generations of crystals is another characteristic of volcanic rocks.*

Many useful substances are obtained from volcanic material. Basalt makes an excellent road 'metal' and is extensively quarried for that purpose. Owing to the chemical instability of the felspar, some basalts decay under the influence of the weather and form brown or red clays called **bauxite** which are very valuable sources of the metal aluminium. Pumice is a light coloured very porous lava used as an abrasive, and a dark volcanic natural glass called **obsidian** is used for knife handles, etc.

The **Plutonic rocks,** named after Pluto, the god of the underworld of the Ancients, are crystalline masses, such as granite, which solidify some distance below the surface of the earth. They become visible at the surface because rocks above them are removed by prolonged 'weathering.' One of the best examples in Britain is Dartmoor in South Devon. This picturesque and thinly populated moorland is composed of granite which has been thrust into ordinary strata, slates and grits, of middle Palaeozoic age. Since plutonic rocks are thrust as irregular masses into other rocks they are said to be **intrusive.** Intrusions have occurred at various geological periods, consequently intrusive rocks are of different ages. Smaller offshoots of the granite or other plutonic rock frequently extend along the bedding planes of the invaded strata and are called **sills.** Offshoots thrust into cracks and fissures more or less at right angles to the stratification are known as **dykes.**

The conditions under which a plutonic mass solidifies are quite different from those influencing the consolidation of a lava flow at the surface. A piece of granite, which may be regarded as typical, exhibits crystals of quartz, mica, and felspar large enough to be seen by the unaided eye, and in some cases, such as Shap granite from Westmorland (Fig. 32), crystals of red felspar more than an inch in length are present. This particular rock is much used for the fronts of shops and banks.

Though the crystals in plutonic rocks are larger than those in a lava, they are very imperfectly shaped owing to the pressure of superincumbent rocks at the time of solidification They are not idiomorphic. In dykes and sills the minerals are usually shaped better as these smaller masses cool more quickly and frequently under less pressure. The microstructure of a dyke rock is somewhat similar to that of a lava Plutonic rocks are useful mainly as building stones

The **felspar** in a granite is a different species from that in a basalt, but it similarly decays forming a white clay called **kaolin**

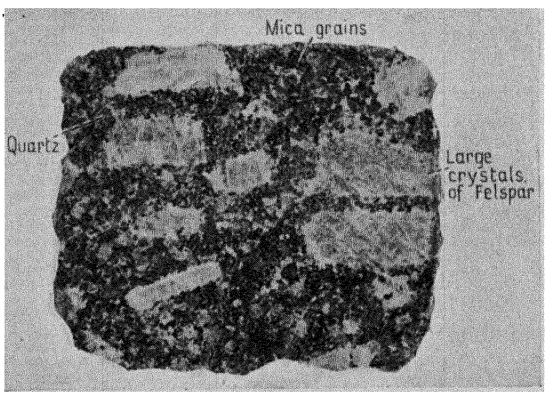


FIG 32 —A PIECE OF SHAP GRANITE
(Photo by G S Sweeting of specimen in the Geological Collection of the Imperial College of Science)

which is the best material for the manufacture of good china ware Kaolin is found extensively in South Cornwall and in consequence an important local industry is the manufacture of china.

Metamorphic rocks are produced by alteration of *any* class of rock, though there is a relation between the original material and the metamorphic product. Thus granites are converted to a crystalline rock called **gneiss,** clays and shales become **schists** and **slates,** sandstones become **quartzites,** and limestones are converted to **marble** with the destruction of any fossil structures which

may have been present. In a general way, two modes of alteration may be recognised. A heated intrusive mass such as granite bakes the surrounding rocks and produces *thermal* metamorphism. In the other process, huge masses of rock are pushed bodily over others and the resulting heat and pressure produce *regional* or *dynamic* metamorphism. In either case the results are similar ; granites become gneiss, clays are altered to slates, and so on.

The chief result of metamorphic changes is the production of new structures, one of the more valuable being the **cleavage** of slate which enables it to be split into remarkably smooth thin slabs. This quality together with the absence of porosity makes this rock a most useful material for roofing, cisterns, etc. Slates occur in the older Palaeozoic rocks, the best being worked at Penrhyn and Blaenau Festiniog in North Wales. Another new structure found in gneiss and schist is a stringy or banded arrangement of the minerals called **foliation.** Thus a piece of schist is composed of strings or folia of mica alternating with folia of quartz grains. If felspar is also present, the rock is a gneiss. Both schists and gneisses form bleak mountain country such as that in the Highlands of Scotland and of Donegal.

CHAPTER IV

THE CHANGING FACE OF THE EARTH

RESTLESSNESS is a characteristic feature of Nature. In both the organic world of living things and in the inorganic portion of the universe, one thing which really appears everlasting is the Law of Change. The earth's crust affords a magnificent and varied example of this rule. Though the great hollow of the Pacific Ocean may have been subjected to relatively slight alterations, the continental masses have been considerably modified, ancient lands having foundered beneath the sea. The lost continent of Atlantis in the North Atlantic is not altogether a myth, and the string of islands known as the Antilles or West Indies in the Caribbean Sea now represent the sunken land mass which may be termed *Antillia*.

As we have seen in the previous chapter, the British Islands have been engulfed by the sea many times, and at another period, not so long ago geologically, they were united with Western Europe, when the site of the North Sea was a land area. New land is slowly being constructed while old land surfaces are being gradually but surely destroyed by wind, rain, ice, and other agents of destruction.

MOVEMENTS OF THE EARTH'S CRUST

Enormous quantities of rock particles are taken by rivers to the sea where they accumulate on the submerged platform called the **continental shelf.** Although most rocks in themselves appear rigid, the earth's crust as a whole is by no means rigid. In time the countless thousands of tons of rock material collected upon the continental shelf weigh it down (Fig. 33).

The sea floor sinks and the adjacent land rises correspondingly. This game of see-saw played by the weighted sea floor and the neighbouring land is termed **isostasy** or **isostatic balance,** and explains why the higher land is not worn down to a low level at the rate it would be if it were merely a question of the removal of rock matter

The borders of the continents are the most unstable regions of the earth, and this instability produces large fractures with resulting **earthquakes** and causes volcanic phenomena. The lands bordering the Pacific Ocean on both the Asiatic and the

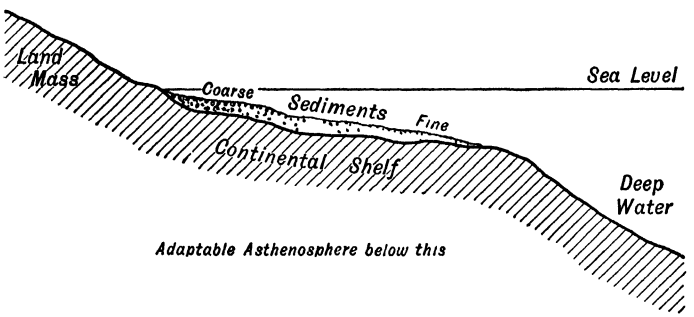


FIG 33 —ISOSTATIC BALANCE,
AND THE FORMATION OF SEDIMENTS UPON THE CONTINENTAL SHELF.

American sides are regions most susceptible to disastrous earth tremors, as evidenced by recent seismic occurrences in Japan, and calamities in California and Chile. Another line of crustal weakness extends through the region of geologically young folded mountains from the Alps to the Himalaya. The most unstable portion of Europe is in southern Italy where the Apennines swing round toward the Atlas Mountains of North Africa.

Though a sinking continental shelf may account for most earthquakes, other possible causes include the tidal forces which attract the solid ground as well as the oceanic waters, the collapse of caverns, the slipping of large land masses, and volcanic disturbances, though it should be clearly understood that most great earthquakes occur unaccompanied by any vulcanism. Any of these causes may produce a kind of wave-motion which, commencing at the **focus** or place where the cause

operates, proceeds rapidly in all directions through the surrounding rocks. Just as a ripple travels through water, so a complex type of wave motion traverses rocks. There are some important differences however. Whereas water waves may rise and fall several feet, particles of rock usually vibrate through only a fraction of an inch, and though wave motion in water travels slowly, that in rocks proceed at rates measured in thousands of feet per second. If a severe earthquake occurs in New Zealand, delicate instruments called **seismographs** record it in England about twenty minutes later. The earthquake wave travels right through the earth, a distance of nearly 8000 miles, in that time.

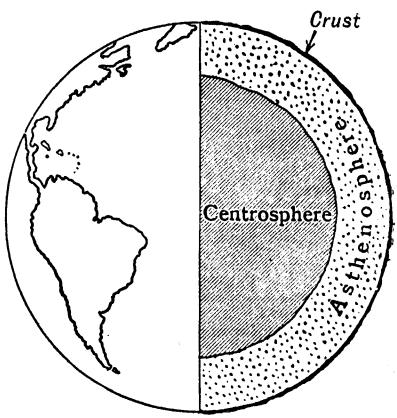


FIG. 34.—SECTION THROUGH THE EARTH.

Wave motions travel comparatively slowly through liquids, and modern researches on the speed of earthquake waves have led to the conclusion that *the earth is solid throughout*, and that the great central portion is composed of some substance, possibly iron, as rigid as steel. An earthquake originates three different kinds of waves and at least one of these could not pass through the earth if the centre or core were liquid.

It is now known that between the great iron **centrosphere** and the thin unstable crust is a shell some hundreds of miles in thickness composed of a solid though movable material which adapts itself to crustal movements. This shell of adaptable substance has been called the **asthenosphere,** a term which signifies weakness, since the material is more or less plastic and not rigid (Fig. 34). The continental shelf sinks and the land near it rises because of this adaptability of the asthenosphere.

In relation to human life and property earthquakes are wholly an evil, but those which occurred in past ages have left us a

legacy of fissures and faults along which sometimes valuable metallic ores have been retained for our use. In other cases, as that of Central Scotland, gigantic disturbances have let down and thereby preserved coal bearing rocks or other strata of economic value.

VOLCANIC ACTION

If the earth is solid throughout, how is it that molten rock is ejected from volcanic vents? Below the surface of the ground the temperature of the rocks rises rapidly. Observations made in mines and deep borings show that there is an average rise of

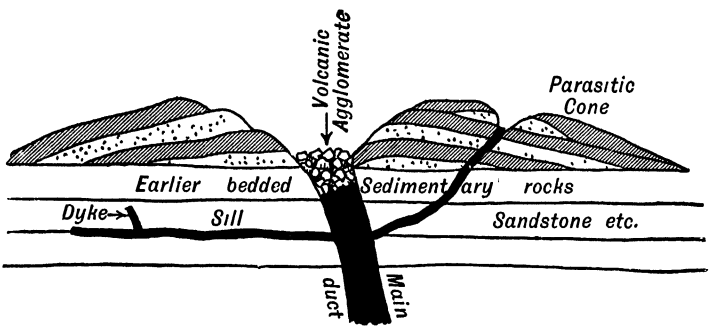


FIG. 35.—SECTION THROUGH A VOLCANO

temperature of 1° F. for every 60 feet of descent At a depth of a few miles the temperature must be high enough to melt the rock material in *normal* circumstances, but owing to the pressure of the rocks above, the material cannot melt unless the pressure is relieved by fracture or other cause When such relief of pressure occurs, the superheated rocks become molten and are forced upwards along fissures or channels to the surface (Fig. 35).

Volcanoes are distributed usually in lines but occasionally in groups along the weak unstable portions of the earth's crust, and, as we have seen, these regions are mainly the borders of the continents, particularly the land fringing the Pacific Ocean. The motive power which is mainly responsible for volcanic action is **steam** formed from water percolating through rocks and coming in contact with the heated mass below.

There are two distinct types of vulcanism. In a normal volcano, matter is ejected from one or more rounded vents or craters, while in **fissure eruptions** great quantities of molten rock flow more or less quietly from long cracks or fissures in the ground. The huge sheets of basalt in Northern Ireland have been produced in this way, and fairly modern eruptions of the fissure type have occurred in Iceland, where the earlier landscape has been blotted out as if molten sealing wax had been poured over the country.

In the usual eruption of a normal volcano there are generally three successive phases. At first the materials ejected are gaseous, by far the greater portion being steam which ascends several miles into the air, becomes cooled and condenses with the production of rain. The second phase, known as the 'ash stage,' is characterised by the bursting of huge lava bubbles within the crater. The explosive force hurls fragments of all sizes into the air. The larger fragments fall back around the vent and help to build up the usual volcanic cone, while the finer dust particles mingle with descending rain and form a mobile volcanic mud. It was volcanic mud of this type which overwhelmed the town of Herculaneum near the foot of Vesuvius in the classic eruption of the year A.D. 79, while at the same time the more distant Pompeii was covered with hot 'ashes.' The third and final phase consists of molten lava which rises above the lip of the crater and flows quietly down the mountain slopes. If the material is of the more viscous type, its progress is slow, but in the case of the more mobile fluid lavas, such as basalt, the rate of travel may be equal to that of an express train.

It follows from this that the more viscous lavas build steep cones, whereas the basaltic kind build relatively low dome-like structures when such material is ejected from normal craters and not from fissures. Though a normal eruption exhibits the three successive phases, it sometimes happens that the lava stage may not occur, the force having spent itself too soon. This was the case in the great eruption of Vesuvius mentioned above, though disastrous flows of lava have been ejected from that volcano in more recent times. Certain abnormal eruptions are characterised by great explosive violence during the ash stage resulting

in disastrous clouds of minute incandescent dust which sweep down the mountain side devastating all in front of them. The destruction of St. Pierre in the West Indies in the year 1908 was due to such a dust avalanche. The island of Krakatoa in the Sunda Strait blew up in the year 1883, scattering fragments and dust which produced darkness for a distance of 150 miles. Windows were broken at Batavia, a town a hundred miles away.

Some volcanoes may remain quiet for centuries and then break out again. Old volcanoes which have never been known to erupt are said to be extinct. In former times, particularly during the Palaeozoic period, Great Britain has been the scene of great volcanic outbursts. In Derbyshire and other places actual vents can be seen filled with lumps of lava which fell back into the old craters. Along the coast of Fifeshire occur numerous ancient volcanoes the inner structures of which have been exposed by the destructive action of the sea, and more can be learned from these old dissected vents than from a visit to a modern volcano, the internal workings of which are hidden from view.

Though much destruction and loss of life has been caused by great eruptions, man benefits in many ways from volcanic activity. The magnificent scenery produced by ancient lavas and the uses of pumice, obsidian, and road metal have already been noted. Many volcanic rocks, particularly basalts, form very rich soils, and some basalts decay forming a clay which is the world's chief source of aluminium. The interaction of sulphurous and other vapours in the neighbourhood of some craters and vents yields extensive incrustations of sulphur. Vapours issuing from the ground in regions such as Tuscany, where vulcanism is in its dying stage, yield boracic acid and natural high pressure steam which is actually being used to generate electricity at the volcanic power station of Larderello. (Fig. 36). It should be noted that natural inflamable gas and oil wells are not volcanic, since steam is not the motive power. In this case decomposing vegetable or animal matter is regarded as the origin.

Like the natural vapour springs known as **fumaroles** and **soffioni** of Tuscany, water volcanoes or **geysers** occurring in

the Yellowstone Park District of North America and in New Zealand are symptoms of the approaching extinction of vulcan-

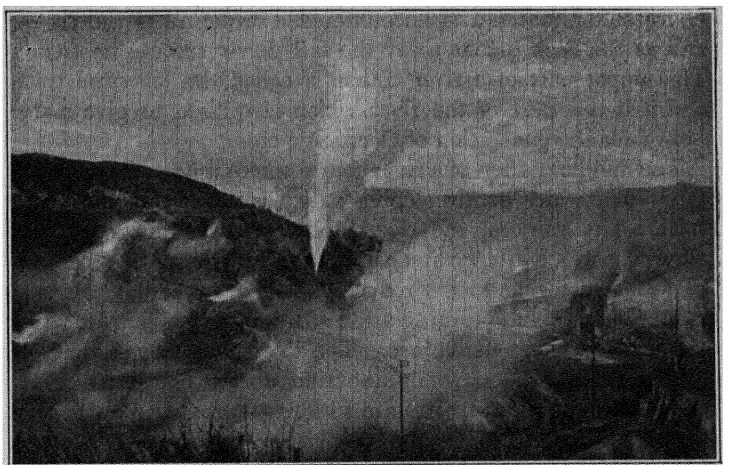


FIG. 36.—GENERAL VIEW OF THE STEAM FIELD OF LARDERELLO.

icity in a region. Eventually even these cease, and a district formerly a theatre of mighty convulsions becomes stable; its volcanic history is complete.

CHANGES PRODUCED BY RIVERS

Though the face of the earth has been much changed by earthquakes and volcanoes along definite lines, most countries in nearly all latitudes are subjected to persistent modification by wind, sunshine, frost, rain, ice, and the sea, which function sometimes as destructive agents, at other times in a constructive capacity. The most widespread of these agents is **rain**, which, collecting as streams that unite to form rivers, wears away rocks, transports the particles, and finally deposits them in another place. In a typical river course three distinct portions are recognisable. In the hill country where the river commences its journey the slope is steep, the velocity of the water is consequently great and its work is mainly of a destructive character. Stones often of

considerable size are swept forward with much consequent wear and tear, including the formation of rounded **pot holes** excavated by stones whirled round in eddies. When a hard bed of rock above softer material is encountered a waterfall is the result, and as the rock breaks away the fall slowly recedes upstream. This upper part of a river course is called the **torrential tract,** and it is this part of the river which is utilised to give water power for the generation of electricity, etc.

The middle portion of a river course where it flows more slowly through a wider gently sloping valley is known as the **valley tract.** The work of the river is here partly destructive and partly constructive since much of the coarser transported material is deposited owing to the reduced velocity. Another result of reduced speed is the turning aside of the waters by harder rocks encountered along the course. The river in taking the path of least resistance often winds about in curves called **meanders.** Sometimes the meanderings are so tortuous that two turns may meet and coalesce with the result that the detached curved remnant forms an **ox bow lake.** At each turn of the river the velocity is greater on the outer or convex side so that the ground on this side is worn away farther while sediments are deposited on the other concave side. The gently sloping valley tract usually provides good pastures, and in the absence of valuable minerals constitutes an agricultural area.

In the lower part of the river course or **plain tract** the speed is reduced to a minimum, the sediments settle down and construct a flat alluvial region. In the case of large rivers such as the Nile, the water divides into distributaries which flow past great patches of deposited **alluvium,** as such fine transported rock material is called, and in this way a **delta** is produced. *These large alluvial tracts form the most fertile soil in the world.* Prolonged silting in this way produces enormous fertile plains such as that of Lombardy in Northern Italy. In England the rivers around the Wash have produced a fairly large alluvial plain, the Fen District, which on account of the soil and a moderate rainfall is the finest wheat growing area in the country.

By depositing its own silt, a great river like the Hoang Ho in

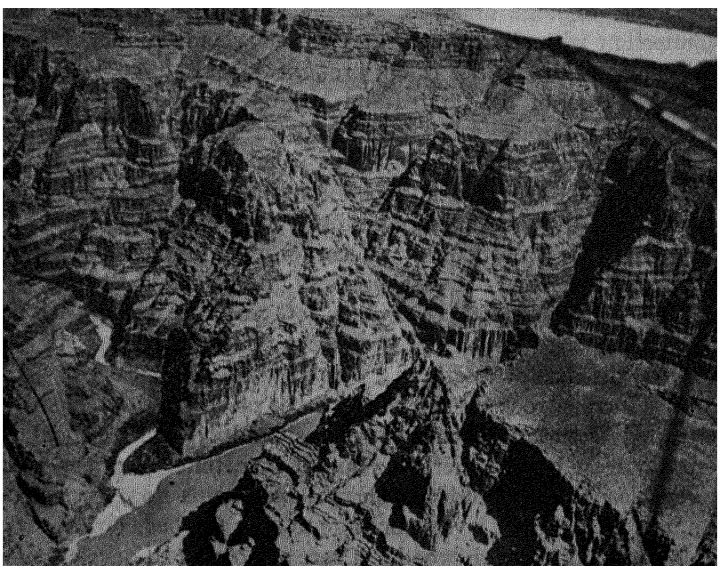
China builds up a natural embankment or **levée** on which the water continues to flow. At times, as in Mississippi floods, the pressure breaks down this embankment with disastrous results to both human life and property. The necessity for the clearance of alluvium from estuaries by dredging affords another example of the fact that deposits of this nature, so valuable in agriculture, may be a nuisance in other ways. The decline of ports such as Boston in Lincolnshire is due to silting combined with the increased tonnage of ships. One of the chief difficulties in connection with the Severn tidal power scheme is that due to the enormous quantities of silt brought down by that river. In the plain tract of the Po in Italy, Adria and other ancient ports have been completely separated from the Adriatic Sea by silt transported from the Alps.

The transport of silt and pebbles is work of a mechanical nature, but rivers frequently perform work of a chemical kind as well. This is particularly the case where the water flows over limestones, which are in part dissolved and thus taken to the sea in solution. A striking example of Nature's providence is afforded by the existence of huge beds of *soluble* nitrates in the *rainless* districts of Northern Chile.

Any form of rock destruction whether mechanical or chemical is called **erosion** or **denudation**. A special type of mechanical erosion may be considered here. It sometimes happens that rivers derived from snow on distant mountains flow through a rainless area. Such rivers continue to cut their beds downwards as a saw cuts through wood. There is no rain to develop side streams and the result is a deep valley called a **canyon** such as the magnificent example carved by the Colorado River in North America (Fig. 37).

One of the greatest benefits which river action has conferred on mankind consists of the means of communication through hilly or mountainous countries. The head waters at the upper end of a river are constantly cutting the valley backwards, so that eventually one valley may cut back into another on the opposite side of the mountains. In this way a **pass** is produced, and a line of communication from one side of the mountains to the other is made possible. The importance of river valleys in

relation to railway routes and roads will be understood better by a brief consideration of the evolution of a drainage area such as the small but classic river system draining the Weald, in south-east England (Fig 38) At the end of Mesozoic times a long oval chalk-covered land emerged from the Cretaceous Sea. The longer axis of this mass extended roughly from west to east, so that the rain which fell drained chiefly towards the north and



(*Photo Topical Press*)

FIG 37 —GRAND CANYON, COLORADO, AS SEEN FROM THE AIR.

to the south. Such modern Wealden rivers as the Wey, Mole, and Medway flowing towards the Thames, and the Sussex Ouse, Arun, and Adur proceeding to the south coast, are descendants of early streams which first determined the main direction of Wealden drainage. Rivers of this type, the direct consequence of land uplift, are called **consequent streams.**

As the work of these early streams progressed, the central portion of the chalk dome was slowly removed with the exposure

of the Greensand, Weald Clay, and Hastings Sandstone beneath, the last-named now forming the hilly central area of the Weald, while the clay forms the Vales of Kent and Sussex. The chalk has been left as an oval ring of hills around the area, but the process being gradual, the rivers have steadily cut gaps through the chalk. These gaps are used by the Southern Railway in linking London to important towns on the south coast. Near each gap an important town is situated by reason of the lines of communication, examples being Maidstone (15), Dorking (2), Guildford (1), Lewes (12), and Newhaven (13).

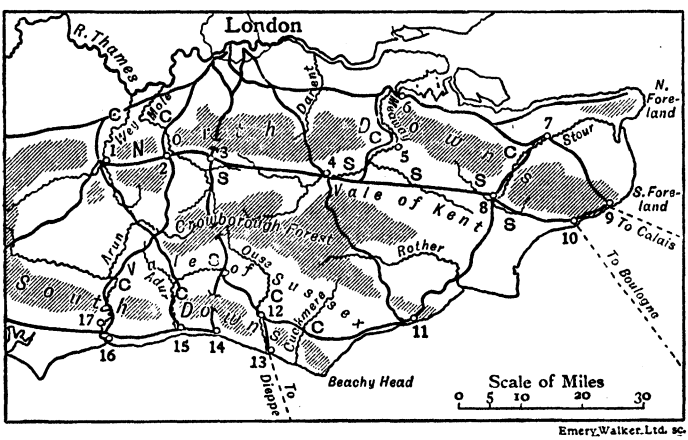


FIG. 38.—THE RIVER SYSTEM OF THE WEALD.
CONSEQUENT STREAMS, C, SUBSEQUENT STREAMS, S.
Numbers refer to towns.

As the process of Wealden denudation continued, later tributary streams flowing roughly east and west developed in the Weald Clay, and these are known as **subsequent streams.** Since these later rivers flow in valleys parallel with the chalk and greensand ridges, they are often described as **longitudinal,** in contradistinction to the earlier rivers which flow in **transverse** valleys more or less at right angles to the chief ranges of hills. In the process of denudation a river may be so modified that eventually part of it may be longitudinal, and other parts trans-

verse. This is the case of the Medway, which remains transverse where it flows through its gap in the chalk.

The relative values of both types of valley can be estimated by reference to the trans-Alpine railway routes (Fig. 39). The St. Gothard route which connects Lucerne with Bellinzona penetrates the centre of the Alps by means of two transverse valleys, that of the upper Reuss on the northern side and that of the Ticino on the southern side of the Alps. Similarly the Mount Cenis route connecting south-east France with north-west Italy,

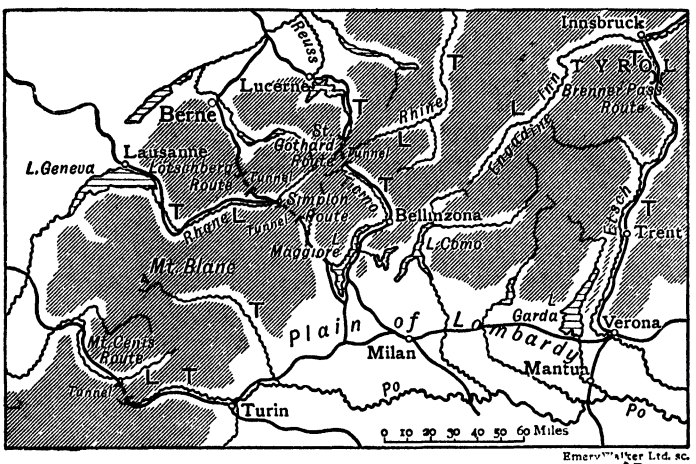


FIG 39.—ALPINE RIVERS AND RAILWAY ROUTES
LONGITUDINAL VALLEYS, L, TRANSVERSE VALLEYS, T.

and the Brenner Pass route linking the Tyrol with the Plain of Lombardy, make use of valleys mainly transverse in character. The Simplon route, however, uses the Rhone Valley, which is partly transverse though mainly longitudinal. Where mountain ranges have to be crossed, it is obvious that *the transverse valleys determine the main lines of communication.*

In time, even a high mountainous region like the Alps may be worn down by rivers so that a fairly level **peneplain** is produced. Should such a denuded country be uplifted by earth movement. the rivers gain a new lease of life and the system is said to be **rejuvenated.**

Frost, wind, and sunshine are important auxiliary factors operating in changing the landscape. Water in becoming ice expands and exerts considerable pressure on the sides of cracks and crevices in rocks, thus loosening fragments of various sizes. Wind transports loose fragments from one place to another, and this is particularly the case with the finer particles of sand, which are often carried from a shore line to a considerable distance inland unless impeded by vegetation. Heaps of sand, or **dunes,** often 60 feet high, are constantly being shifted by the wind, and in some cases ancient cities as those in the Desert of Gobi in Asia have been completely buried.

An interesting **aeolian** or wind-borne deposit, found chiefly in northern China though to a lesser extent in eastern Europe, is called **loess,** and is composed of fine particles of clay which have been blown into valleys forming deposits sometimes thousands of feet thick.

Sand and other fragments blown by the wind scratch and wear away other rocks in the course of time. The wind thus causes destruction as well as transport. The effect of the sun's heat is to provide material capable of being transported by wind. The sand of the desert is due to alternating expansion of rocks by heat during the day, and contraction on cooling at night. In some cases the surface layer of bare rock peels off under the influence of heat, a process known as **exfoliation.**

ICE AS AN AGENT IN MODIFYING SURFACE FEATURES

Where the temperature of the air is sufficiently low, snow falls instead of rain. Near the earth's poles snow and ice collect at sea level, but on the equator only the higher parts of mountains above 16,000 feet are capable of retaining snow all the year round. The **snow line,** or altitude at which snow remains throughout the year, varies with latitude, being above 8500 feet in the Alps, the latitude of which averages 46° N. No mountains in Great Britain are sufficiently high to reach the snow line, although the altitude of the snow line would be considerably lower than that in the Alps.

The lower portions of snow in a mountain snowfield are pressed into a compact mass of ice, portions of which slowly descend the valleys as **glaciers.** Pressure lowers the temperature at which ice melts, so that as the ice presses against the floor and sides of the valley it melts, turns a corner, and then re-freezes to a firm mass again In this way a glacier adapts itself to the shape of its valley. But the valley does not have things all its

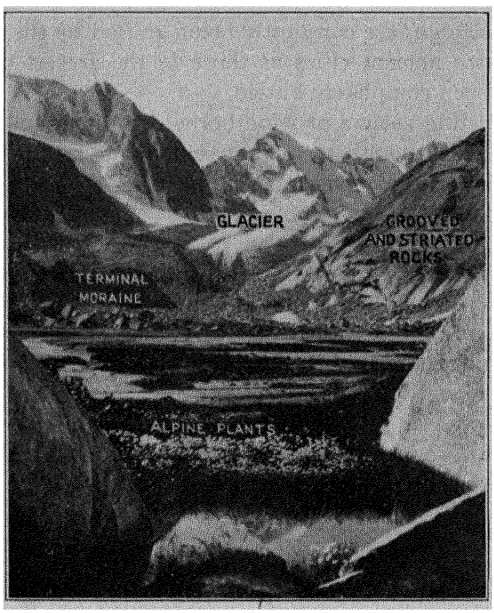


FIG 40.—AN ALPINE GLACIER
WITH MORAINES, GROOVED ROCKS, AND ALPINE FLORA
(By courtesy of the Swiss Federal Railways)

own way Lumps of rock of various sizes are torn from the floor, become embedded in the ice and act as erosive tools which scratch and grind the bed and sides of the valley. Scratches and striae and rounded rocks remain in a valley as evidences of former glaciation long after glaciers have disappeared, owing to a change in climate These rocks are called **roches moutonnées** because, as explained by De Saussure, who first applied this term

to them, they "unite to produce the effect of a good thick fleece, or of those wigs that are also styled moutonne." Large numbers of fragments and boulders also fall from the valley sides on to the moving glacier and form heaps of rubbish called **moraines** which are carried by it down the valley to the place where the ice melts. Here all this moraine matter carried either on or in the ice is deposited in a heap forming a **terminal moraine.**

Old moraine material deposited by glaciers of a bygone age form extensive deposits called **boulder clays** which contain **erratics** or lumps of rock often carried long distances from their original sources. Thus, boulders of Norwegian rocks have been formerly carried across the site of the North Sea and deposited in the east of England. Sometimes large erratics are quietly dropped by melting ice upon some ledge or other peculiar position when they are known as **perched blocks.**

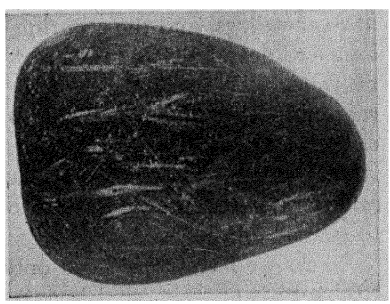


FIG. 41.—A BOULDER ROUNDED AND STRIATED BY GLACIAL ACTION.

(Photo. by G. S. Sweeting of specimen in the Geological Collection of the Imperial College of Science.)

There is no lack of evidence concerning the former glaciation of the British Isles and many other countries, including places now tropical like India and Australia. Boulder clays, erratics, etc., tell a true tale, and even the directions along which the ice moved can usually be deciphered by the study of striae, roches moutonnées, and erratics. Collected evidence shows that so far as Great Britain and northern Europe are concerned *there have been several ice ages with intervening warm periods.* When the ice mantle assumed its greatest proportions it did not quite reach the present position of the Thames. Southern England, then joined to the continent of Europe, was a land where primitive man pitted his wits against cave bears, hyenas, and the mammoth.

Deposits of boulder clay on the hill slopes of northern Britain have in many cases produced a better agricultural soil than

otherwise might have been the case, but the chief result of glaciation is the production of fine scenery, or at any rate, the improvement of mountain scenery which already exists. Deep U-shaped valleys have been carved by the downward erosion of great weights of ice, while high above the main valleys, water descends as falls from smaller 'hanging valleys' due to little tributary glaciers that did not dig very deeply. The Staubbach near Lauterbrunnen in the Bernese Oberland is typical of such falls (Fig. 42).

The higher part of the Alpine region is the scene of the most flourishing 'tourist industry' in the world. The dry powder-like snow annually draws thousands of visitors for winter sports while the beautiful lakes offer an equally attractive summer season. Formerly, the Alpine glaciers descended much lower in their valleys, and the scouring action of ice and stones carved long and deep hollows called **rock basins** which are now occupied by water. In the north-west of England smaller narrow lakes radiating from Scafell are due mainly to glaciation. In some cases a deposit of boulder clay across a valley has dammed a stream and thus produced a lake. Many of the Scottish lakes and the small mountain tarns of North Wales owe their existence to similar processes.

So far we have considered only glaciation of the **Alpine** type, but there is another kind known as the Greenland or **Polar ice cap** type. In this, a thick mantle of ice many thousands of feet thick covers enormous areas, and the border of this icy mantle forms high glistening cliffs. Boulders torn from the ground under the ice cap form a ground moraine which, owing to the irregular surface of the ground, may work upwards through the ice in places forming heaps called **nunataks.** Where the border of the frozen mantle reaches the sea, huge masses of ice break off and float away as **icebergs.** These drift to lower latitudes where they finally melt, and it is of great importance that shipping should, when possible, keep to the south of the limit of ice floating in the North Atlantic. Collision with an iceberg was responsible for the sinking of the *Titanic* in the summer of 1912, one of the greatest disasters that has ever happened at sea. An International Ice Observation and Ice Patrol in the North Atlantic is

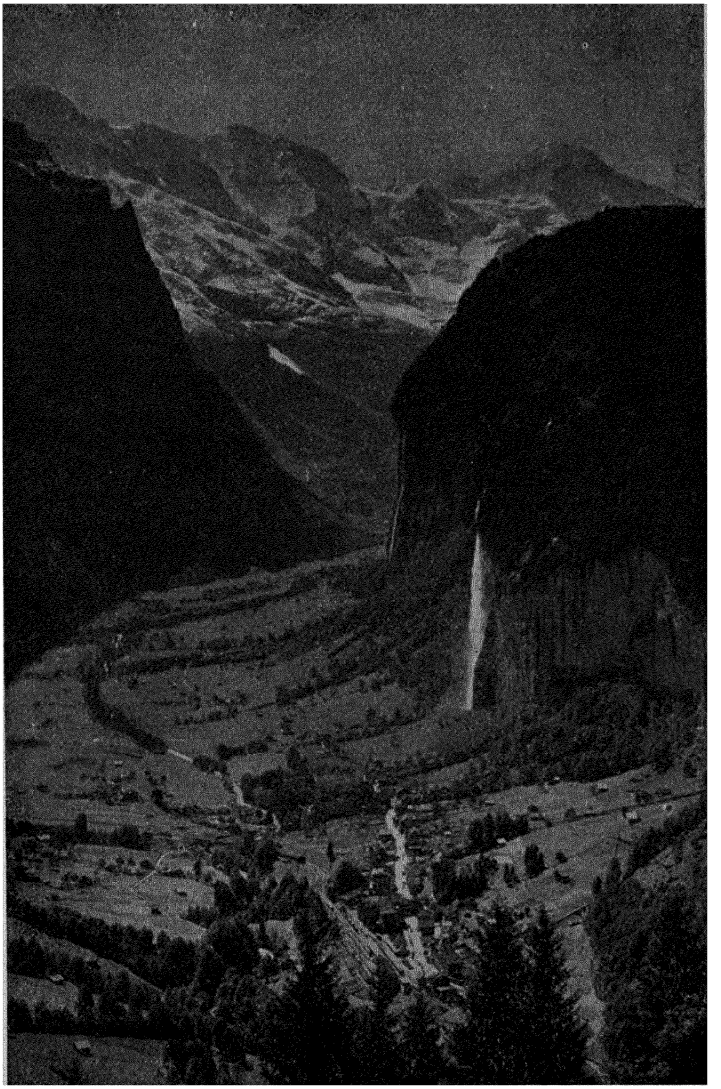


FIG. 42.—THE VALLEY OF LAUTERBRUNNEN, BERNESE OBERLAND.
A FINE EXAMPLE OF A DEEP U-SHAPED GLACIAL VALLEY. THE STAUBBACH WATERFALL IS SEEN ON THE RIGHT.
(By courtesy of the Swiss Federal Railways.)

now maintained which warns shipping of the positions of icebergs. The cooling of the air by bergs off Newfoundland causes extensive fogs, another source of danger to ships passing between Canada and Great Britain. The great Antarctic ice cap is even larger than that around the north pole though of a very similar type.

DESTRUCTIVE AND CONSTRUCTIVE WORK OF THE SEA

The action of the sea, though usually of a destructive character, is in some cases constructive. The large shingle deposit of Dungeness, and many square miles of new land near Rye in Sussex, formed since the Roman occupation, are examples of such constructive work. In many cases drifting sand and shingle is a nuisance, necessitating the construction of **groynes** which to some extent control the transport of pebbles by the sea. The larger features of coastlines : headlands, cliffs, level stretches of sand, estuaries and indentations of various shapes, etc., are determined by three main factors—*the destructive force of the sea, the kind of rocks, and the arrangement of these rocks.*

The destructive force of the sea depends partly upon tides and currents, though chiefly upon the pounding force of waves which use lumps of shingle as battering rams with which to make further inroads into the land. On the other hand, a foreshore of large blocks may sometimes afford a measure of protection to the land behind it. A fairly level strip of foreshore formed in this way is known as a **plain of marine erosion.** The kind of rock facing the sea is, perhaps, the main factor. In general, hard rocks such as granite, limestone, sandstone, and basalt will form cliffs presenting a fairly uniform front to the sea. The coast-line of North Devon between Minehead and Barnstaple, where hard old slates and grits extend along an almost unbroken front for 25 miles, is an excellent example of this. Soft rocks, like clay or shale, are worn away more quickly. If soft rocks extend over long distances and the destructive power of the sea is uniform, a fairly straight but low type of coast will result, but where soft rocks alternate with harder ones, an indented coast is

produced, the softer material being the bays, the harder rocks forming the headlands. Many parts of the coasts of Wales and of western England afford good examples of this differentiation. The part of Pembrokeshire near St. David's Head (Fig. 43)

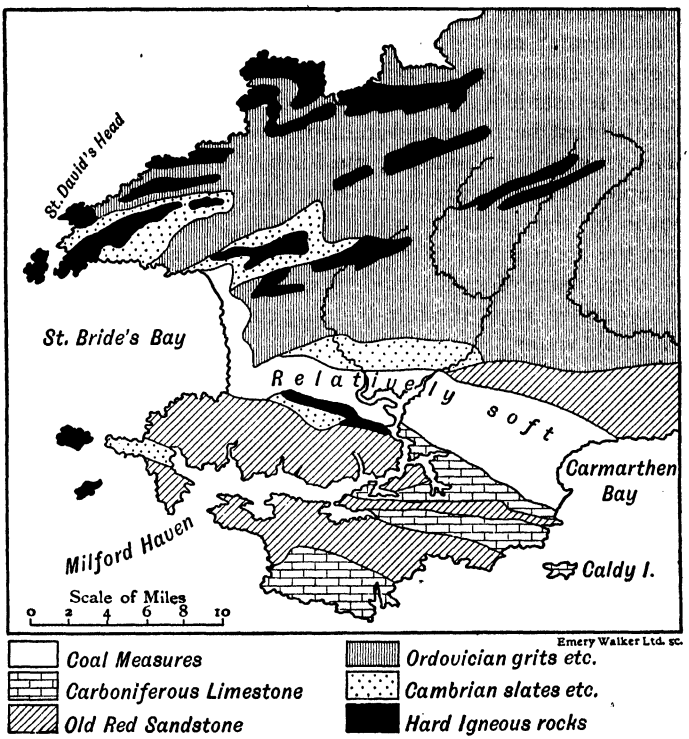


FIG. 43.—GEOLOGICAL MAP OF PEMBROKESHIRE.

shows promontories composed of hard igneous rocks alternating with sedimentary sandstones, etc., which, though hard, are soft in comparison with the igneous material.

The influence of rock arrangement is well illustrated by the south-west coast of Ireland, where the sea works against a series of anticlinal and synclinal folds, the result being several long narrow gulfs or creeks coinciding with the synclines. A fiord coast like that of western Scotland or of Norway is due to a

different cause. Here the great number of inlets or fiords are really old land valleys which have been drowned by the sea owing to the land having subsided. Of course, marine erosion still proceeds, but the main configuration of such coasts is due to slow sinking of the land in relation to sea level. The edges of continental masses slowly rise in some places and sink in others, as shown by old raised beaches on one hand, and submerged forests like that in Cheshire on the other. Many of the world's finest harbours and industrial waterways are formed by this slow secular subsidence, the Firth of Clyde being a famous example. Parts of the ocean floor also rise or sink slowly as shown by the great naturalist Charles Darwin, who inferred from the great depth of coral structures in coral islands, that the lower parts of such islands must once have been nearer the ocean surface, since the reef-building coral animals can live only in shallow water.

CHAPTER V

PLANT LIFE AND PRODUCTS

No man can say exactly what life is, or how and when it originated. Living creatures—both plants and animals—differ from non-living or inorganic matter in being able to assimilate foodstuffs and so build up and repair their tissues, in their power of secreting or excreting substances, in being able to reproduce their kind, and in their ability to adapt themselves more or less to their environment or surroundings. But we are still unable to define Life.

There is, however, a fundamental jelly-like substance called **protoplasm** containing the elements carbon, oxygen, hydrogen, nitrogen, and sulphur, and all living things are composed of this substance which Huxley described as 'the Physical basis of Life.' The chemical elements composing protoplasm occur in many forms of non-living matter, and it may be that living organisms of an extremely simple kind developed from inorganic substances under unknown conditions which existed on the earth many hundreds of millions of years ago.

The geological record is silent concerning the first creatures which must have inhabited the earth, the chief reason for this silence being the fact that the simplest types of organisms, then as now, were probably without hard parts capable of being fossilised. In the far north-west of Scotland occur ancient sediments, the so-called 'Fucoid beds,' containing markings closely resembling the form of seaweeds, though these may be only of mineral origin. The earliest fossilised animal remains consist of sponge spicules, impressions of jelly fish, early types of shells, and others which must have had a long line of simpler ancestors preceding them, but the remains of these have not

been found. In view of the extremely simple structure of the lowliest organisms living to-day, this unfortunate gap in the geological record is exactly what we should expect to find. But after this gap, the record of the rocks more than makes amends by the enormous amount of evidence it supplies in support of the theory that the various species or kinds of living things have slowly evolved from earlier and simpler ancestors.

The facts of evolution were first investigated adequately by the great naturalists **Charles Darwin** and **Russell Wallace.** Darwin's book *The Origin of Species*, published in 1859, after more than twenty years of careful observation and experiment, produced as great a revolution in scientific thought as did Newton's work on gravitation. Stated very briefly, the theory of evolution explains the different species of animals and plants as being due to variations in all living creatures of any particular group, and the struggle for existence by which some creatures adapt themselves to their surroundings better than others have done. Those which alter in such ways as to fit them better for the struggle for life survive, whereas those groups which do not adapt themselves adequately, eventually die out or become extinct. Constant adaptation and improvement in both the plant and animal worlds have led to the formation of innumerable **species**, and ' the survival of the fittest.'

Though environment, or an organism's surroundings, is an important factor in its development, there is another equally important factor known as **heredity**, in virtue of which certain characteristics and tendencies are passed on from one generation to the next. The extent to which heredity may influence later generations has been investigated by many different naturalists, but particularly by **Mendel**, a former Abbot of Brünn, in Austria, whose discovery of certain principles of inheritance is of deep significance in the study of biology. An adequate discussion of both ' Darwinism ' and ' Mendelism ' is, of course, beyond the scope of this book, and we must now pass to a general consideration of plant life.

SIMPLE PLANT AND ANIMAL FORMS

Living at the present time are an enormous number of very simple minute organisms, both plants and animals, and others which resemble plants in certain ways and animals in other ways. At the bottom of the scale of living creatures the vegetable and animal worlds overlap, and it is reasonable to suppose that both kinds of the creatures which form two such well-defined groups to-day, originated from simple common organisms, though they soon diverged along two widely different lines. If we consider one of the simplest of minute plants and compare it with one of

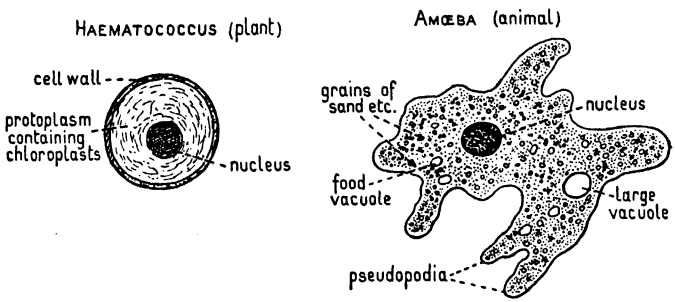


FIG. 44.—UNICELLULAR ORGANISMS.

the simplest of animals, we shall be able to obtain some ideas concerning the similarities and differences of the two classes of organisms.

The green slimy substance which collects in water butts consists of great numbers of microscopic spherical plants called *Haematococcus pluvialis* (Fig. 44). Each unit or cell is a complete plant in itself, and is composed of protoplasm, though different structures are seen at different parts of this protoplasmic substance. On the outside is a containing wall consisting of material called **cellulose** * derived from the protoplasm, and it is this cellulose that builds a more or less firm casing which pre-

* Cellulose of older woody plants becomes impregnated with a substance called lignin, so that the physical properties are not quite the same as those of young cellulose.

serves the shape of plants whether they are microscopic and *unicellular* (*i.e.* one cell only), as Haematococcus, or large, and composed of millions of cells as an oak tree. Near the centre is a darker portion of protoplasm called the **nucleus** which controls the life and reproduction of the plant. Between the nucleus and the containing wall is a mass of protoplasm, containing granules or **chloroplasts,** coloured green by a substance termed **chlorophyll,** probably the most wonderful substance in the world. *Chlorophyll enables plants to obtain energy or power from sunlight for the construction of organic foodstuffs and hence to build up fresh protoplasm from non-living inorganic substances got from the air and from the soil.* The great majority of animals have no chlorophyll and therefore cannot live on inorganic substances; they must obtain their supplies of protoplasm from other animals or from plants. Without plants, animal life would be impossible, hence *the main use of vegetation is the production of food for animals.*

In plant cells generally, there are usually some apparently empty spaces termed **vacuoles** and these contain a watery fluid commonly known as **cell sap.** Simple unicellular plants like Haematococcus and Bacteria multiply or reproduce by a process of division. In Haematococcus the nucleus divides into two, four, or more parts, each part taking so much protoplasm, and becoming a separate organism liberated by the breaking down of the old cell wall. The new individuals composed of naked protoplasm are in this particular species pear-shaped and provided with two thread-like **cilia,** the motion of which causes the little creatures (in this form called **zoospores**) to swim about, but after a short time they build new cell walls, withdraw the cilia, and become ordinary staid Haematococcii similar to the parent organism. Reproduction by this means of division is said to be **asexual** since there are not two different sexes concerned with the process as there are in the higher plants and animals.

Now consider one of the simplest of animals, a microscopic creature, called **Amoeba,** found in the soil and in ponds (Fig. 44). Like the Haematococcus this organism is composed of one cell possessing a nucleus, the division of which leads to reproduction. Cavities or vacuoles are present, one large vacuole being con-

nected with the control of water in the organism, the others usually being spaces formed during the process of food capture. This creature differs from the simple plant in several ways. There is no definite cell wall composed of cellulose and there is no chlorophyll, hence its food must consist of *protoplasm* obtained from other organisms. These other organisms must be caught, and in order to do this the Amoeba, having no rigid wall, constantly changes its shape, sending out **pseudopodia** or projections of protoplasm which wrap around the food, and the whole organism 'flows' along. Such food as is not absorbed is excreted or thrown out of the cell; it *reaches* the surface of the organism and is left behind as the organism moves about. The organism is capable of considerable movement and is said to be *motile*, whereas in a plant the protoplasm moves within the cell but the cell as a whole is usually *non-motile*. These facts are equally true for large plants and animals. A plant is rooted to one place and has its food brought to it by water and air, while nearly all animals move about in search of food and consequently live a very active life in most cases.

Some of the friends, and unfortunately many of the greatest enemies, of mankind are microscopic unicellular plants called **Bacteria**, which multiply at an enormous rate, many millions being produced from a single organism in a few hours. Friendly or useful bacteria are made use of in the manufacture of vinegar, in preparing for use the fibres of flax, hemp and jute, in causing cheese to mature, while others in the soil assist in the preparation of nitrogenous compounds for plant food; the hostile varieties include the 'germs' which produce deadly diseases such as consumption, cholera, diphtheria, typhoid, and many others with which man is always at war, as well as bacteria producing undesirable fermentation in foodstuffs such as that which causes milk to become sour.

FUNGI AND THALLOPHYTA

Another useful unicellular plant of considerable interest is **yeast**, employed in baking and brewing. A yeast cell is rounded, has a definite cellulose wall, and usually several vacuoles are

present. But it differs from the plants we have considered in having nuclear matter though no proper nucleus, and in the absence of chlorophyll. This means, of course, that there is no green colouring matter, and as the organism is thus incapable of building up protoplasm from inorganic matter, it must live on already prepared foodstuffs, such as sugary liquids. It multiplies by giving off little bud-like growths, which break away from the parent organism and become complete yeast cells. Such a mode of reproduction is called **budding.** But when yeast is kept warm (87° F.), the cells multiply in a different manner. In these circumstances each cell divides into four equal parts, each part building a cellulose wall and containing a share of the protoplasm, forming bodies called **spores,** which retain their vitality for a long time, and may be caused to develop or 'germinate' later on. The ability of yeast to produce **fermentation,** a process in which sugar is converted to alcohol, is the reason for its use in the manufacture of beer. Beer is an artificial product, and the yeast used for it is cultivated, but in vineyards, yeast cells exist naturally in the soil. Substances like that in yeast which produce fermentation are called **enzymes.**

In the multicellular plants, either simple or more advanced types, great numbers of cells combine to form structures called **tissues,** and these tissues also combine to construct **organs** such as roots, leaves, and flowers. There is an exceedingly great variety of multicellular plants, some much more advanced in structure and function than others. Among the lower types of such plants are the **Fungi,** which include edible mushrooms (Fig. 45), and poisonous toadstools. These resemble yeast (a unicellular fungus) in having no chlorophyll, hence they are not green, and either live as *parasites* on other plants, obtaining the foodstuffs which these other plants manufacture for themselves, or subsist upon dead organic matter (*saprophytes*). Thus, the common mushroom grows upon decaying vegetable matter in open fields, and is cultivated on prepared 'beds' in cellars.

These plants multiply by means of minute dust-like spores obtained from the mature blackened **gills** on the underside of the **pileus** or upper umbrella-like part of the mushroom. In fact, the so-called mushroom is simply a spore-producing

structure, the main portion of the plant consisting of a mass of whitish threads extending through the underlying soil. Mushrooms are cultivated from **spawn** which is composed of these whitish threads made into a compact mass with manure. When parts of a plant, such as these threads, develop into a complete plant, the process is known as **vegetative reproduction,** a process often artificially employed in gardening when cuttings are taken and planted in the soil, or when buds are grafted on to a well-established plant. Another interesting case is afforded by the

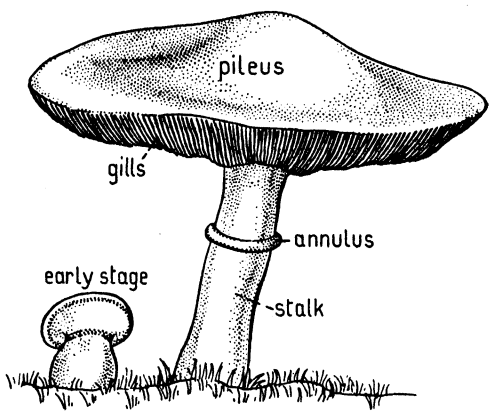


FIG. 45.—THE COMMON MUSHROOM.

strawberry, which sends out horizontal runners or shoots along the ground, the new plants developing from the nodes or outgrowths on the runner while the rest of it decays. Most of the plants which arise from bulbs are other examples.

Since fungi contain no chlorophyll and therefore sunlight plays no part in their existence, they can grow well in the dark, and some of the moulds and mildews which collect on food, leather, and other objects in damp places belong to this group of plants. A very interesting case which may be regarded as a partnership between a green organism manufacturing food and a spore-producing fungus is afforded by the various lowly plants termed **Lichens.** These are found as greyish incrustations on stones and other objects. The fungus part of the arrangement is

recognised by the brownish flat or cup-like spore-producing structures.

Among other primitive plants are the seaweeds belonging to the group called **Algae,** one of the best known being *Ulva,* the weed growing on piers and breakwaters. In this, the plant body is ribbon-like, though there is no differentiation into plant parts or organs as found in the higher divisions. Such a plant body, merely a flat expansion, is called a **thallus.** Seaweeds contain chlorophyll, though sometimes the green colour is more or less masked by brown colouring material as in *Fucus,* the common branched weed of the seashore The ash of burnt seaweed, called **kelp,** is a valuable source of iodine. Other Thallophyta include mosses and liverworts, which are pronounced moisture-loving plants, found on damp earth in early spring, in corners near brooks or in crannies of wet hedge banks.

Of the flowerless plants or **Cryptogams** the more advanced in structure and function are the ferns which, to some extent, resemble the flowering plants in possessing definite roots, stems, and leaves The club-mosses of moorland, the horsetails of swampy places, and certain other plants are related organisms. The structures exhibited by ferns and the life-history of their spores are very complicated and a description is not possible here. Enormous strides in development separate the simple Thallophyta from the ferns, and it is interesting to note that the great Carboniferous forests of long ago which have left us such a rich legacy of coal were composed mainly of gigantic ferns and huge members of the horsetail family.

FLOWERING PLANTS

In most of the vegetable types we have considered, reproduction usually takes place by means of spores—unicellular bodies which become detached from the parent and then develop as separate plants. In the higher plants which we are about to consider, the **Phanerogams,** reproduction takes place by means of **seeds,** which are multicellular and complex bodies in which a young plant or embryo must be formed before the seed is set free from the parent. In most flowers there are male organs of

reproduction and female organs, and since a female cell or **ovum** is fertilised by union with a male cell or **pollen** grain, this mode of reproduction is described as **sexual reproduction.** Usually, both the male and female organs are present in the same flower, when it is described as **hermaphrodite,** examples being most of the familiar flowers seen in the herbaceous borders in our gardens. In some plants, as in the vegetable marrow and the hazel-nut

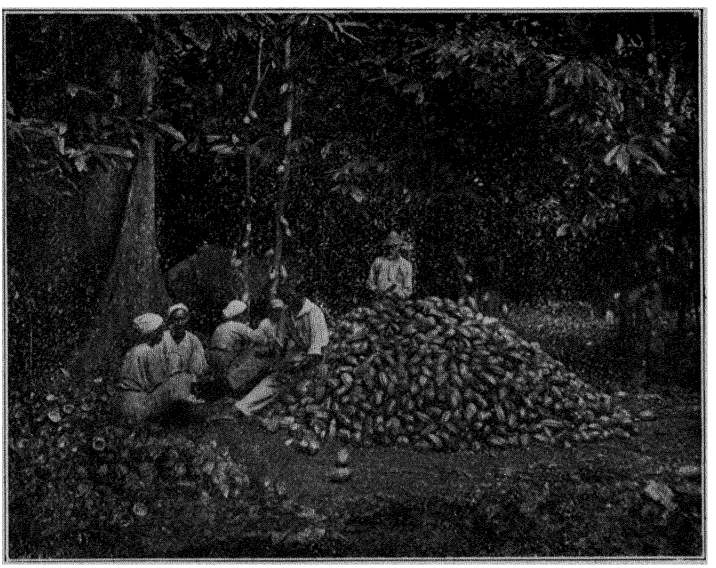


FIG. 46.—REMOVING COCOA BEANS FROM THE PODS.
(By courtesy of Messrs. Cadbury Bros. Ltd.)

and oak trees, there are two distinct flowers on the same plant, but in relatively few other cases there is a definite male plant and a separate female plant as in willow, and poplars. Yet another type of reproduction is exhibited by many flowering plants : roses, daisies, and others which can develop from true ova without fertilisation by a male cell. Such a process is termed **parthenogenesis.** But in all cases, no matter which mode of reproduction is employed, every living thing originally comes from a primitive simple cell.

THE ORGANS OF A PLANT AND THEIR FUNCTIONS

Although the number of different flowering plants is exceedingly great, typical examples are all built more or less according to a general plan, each consisting of four parts or organs—root, stem, leaves, and flower. Each of these parts performs definite functions contributing to the general life of the plant, which may be illustrated best by reference to one well-known example, say the Wallflower. If possible, obtain one of these, wash the soil from its roots, and examine the plant carefully.

The **root** consists of numerous yellow or pale brown branching structures which taper to pointed extremities. This branching and twisted arrangement enables this part of the plant to come into contact with as much soil as possible, so that a good supply of material for food manufacture in the higher part of the plant may be obtained. The root itself has no chlorophyll. Attached to the roots, particularly the more slender parts, are many fine thread-like **root-hairs** through the cellulose walls of which soil water passes to the inside of the plant by a process called **osmosis** in which liquids pass through a separating membrane, in this case the cellulose wall. The weak solutions which pass into the root-hairs have to be forced upwards through the stem into the leaves of the plant. Several factors contribute to this forcing process. The water of the soil continues to pass into the roots and hence produces what is termed **osmotic pressure,** and the root itself exerts a **root pressure,** while **capillarity** or the ability of very narrow tubes to suck up liquids also assists in causing water to pass right through the plant. Finally, water not utilised by the plant is discharged as water vapour into the atmosphere by way of the leaves. This passage of water through the plant is called **transpiration,** and all of the means by which it is accomplished are not yet fully understood. Roots also serve as a means of anchorage for the plant.

The **stem,** which in this case is branched, consists of numerous more or less upright rod-like structures which are angular in cross section. Each portion of the stem contains numerous slight outgrowths called **nodes,** which are the positions at which leaves and branches arise from buds, the comparatively smooth

parts between the nodes being known as **internodes**. The stems are green, particularly when young, and contain chlorophyll, so that a certain amount of food formation occurs, and this is assisted by numerous pores or **stomata** which permit the gases of the atmosphere to enter. But the chief functions of stems are the construction of a suitable scaffolding upon which the leaves may be extended to meet the sunlight and air, and the conveyance of the plant fluid or sap to the leaves.

The **leaves** of a plant constitute the chief food factory of the organism. Generally the more leaves there are the better, and the wallflower is no exception to this, there being dozens of leaves on a single plant. Each leaf is flattened, elongated, rather narrow, and has a gently curved non-indented outline (compare the indented leaf of a buttercup). The flattened part, called the blade, is attached by a little stem or **petiole** to the main stem. Extending down the middle of the leaf is a primary **vein** from which other veins extend on each side, and these secondary veins bear still smaller ones. This system of veins is connected with the water supply which passes upwards from the stem and roots, so that the water and dissolved salts from the soil which it contains are brought to the food-producing factories.

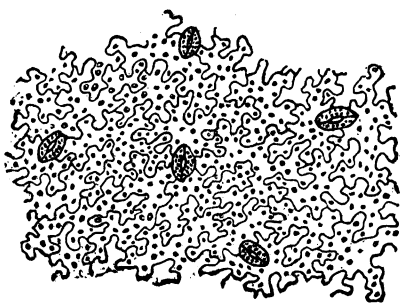


FIG. 47.—PART OF A LEAF SHOWING STOMATA HIGHLY MAGNIFIED.

How is this food manufactured by leaves? Though a leaf is covered by a thin membrane or cuticle, this is pierced by numerous oval openings or stomata which admit carbon dioxide from the air (Fig. 47). Under the influence of sunlight the chlorophyll causes the carbon of this gas to combine with water to form sugar and starch, which are known as **carbohydrates**. Unused oxygen is returned to the air, so that during the daytime green plants are improving the condition of the air for animals which require oxygen but not carbon dioxide. It must not be

imagined, however, that plants do not require oxygen. They breathe or respire air for the sake of oxygen as animals do, though no special organ is set aside for this purpose. It may be said that respiration takes place all over the plant's body.

The formation of sugar and starch by the influence of sunlight is called **photo-synthesis**, and it is this process that makes life, as we know it, possible. These carbohydrates contain carbon and water, while the solution passed up from the soil supplies not only water but also nitrogenous matter, so that by further synthesis, or ' building up,' new protoplasm is obtained, and the plant grows. Leaves, so vital to the living plant, are also valuable economic products for man; for example, cabbage and related vegetables are chiefly leaves, while tea and tobacco are also leaf products.

Water is required as a food and as a carrier of other foods in the process called transpiration. Since water passes out as vapour through the stomata of leaves, many plants run the risk of losing too much water, hence some means of checking this loss must be employed. The stomata themselves are of adjustable size, being regulated by two surrounding **guard cells**, but this is in many cases insufficient. In cold weather of the winter months, transpiration is checked by the shedding of leaves in the case of **deciduous** trees, while in those **evergreens** which inhabit cold countries various adaptations of the leaves themselves produce the required result. Pines and firs have tough needle-like leaves with their stomata sunk in depressions, so that they are not too exposed to the air. In desert plants, moisture must be carefully conserved and this is accomplished by spiny and hairy leaves on a fleshy stem having a waxy surface, as in Cacti, and sometimes water is stored in these stems. A few plants may get too much water and in such cases broad surfaces lead to much evaporation, or water may drip from points.

THE FLOWER

The large number of little flowers together form what is termed an **inflorescence**. Examine one of the florets (Fig. 48) of the wallflower and it will be observed that the lower part of it, where

it joins the **pedicel,** or last part of the stem, is composed of four little curved blade-like structures or **sepals** which together form a cup, the **calyx,** in which the other parts of the flower rest. The largest part of the flower, the coloured **corolla,** comes next, and this is composed of four petals surrounding a hollow which contains the organs of reproduction. Both male and female organs are present, so that the plant is hermaphrodite. The male organ or **androecium** is composed of six pillar-like structures called **stamens**—two shorter ones towards the sides and four taller ones nearer the middle. Each stamen consists of a filament supporting a sack-like body, or **anther,** containing the male cells or pollen grains. The female organ or **gynoecium** placed in the centre is an elongated vessel, the **ovary,** containing numerous **ovules.** There are two sides or **carpels** which unite to form this vessel and at its summit are two pointed structures, each of which is called a **stigma.** The ordinary domestic pea-pod is a larger but similar vessel containing ovules (peas), the two sides of the pod which later separate being the carpels.

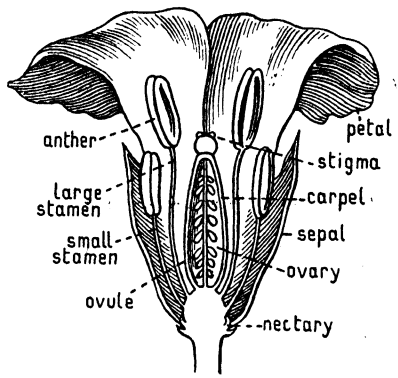


FIG. 48.—LONGITUDINAL SECTION SHOWING STRUCTURES OF A FLORET OF THE WALL FLOWER.

In the process of fertilisation the anthers burst or **dehisce,** causing the yellow dust-like pollen to fall upon the stigma of the female organ, whereupon the pollen grains may germinate. A slender pollen tube grows out from a pollen grain, pierces the tissues of the female organ and grows right down to the ovules within the ovary. But the flower does not rely altogether upon the pollen *falling* upon the stigma. At the base of each of the two lateral stamens is a kind of gland or **nectary** which secretes a sweet honey-like substance for the purpose of attracting insects, which incidentally pick up some of the pollen grains and transfer

them to the stigma. The beautiful colours of flowers also assist in the attraction of insects. Cases in which pollen is carried from one flower to another by insects or by the wind are examples of **cross pollination,** which is, of course, essential for the fertilisation of flowers that are not hermaphrodite. Generally, the pollen will fertilise only another flower of the same kind, but occasionally a member of a different family may be fertilised, the resulting plant being known as a **hybrid.**

The various parts of the wallflower should be compared with those of other flowering plants in order that variations in the shape of the leaves, in the number of sepals, petals, and other features may be noted. Simple plants such as the dandelion, buttercup, primrose, etc., make good material.

THE DISPERSAL OF SEEDS AND FRUITS

The ova being fertilised, the carpels and their contents constitute the **fruit**—the part of the flower that remains after the sepals and petals have dropped. Usually the ova are surrounded by matter, the **endosperm,** which later will act as a supply of food for the young embryo during the early stages of its development before it has roots and leaves available for the production of its own foodstuffs. The fertilised ovum with its surrounding food supply is known as a **seed** (in a fruit there is usually a large number of seeds) and this little body remains dormant or inactive during the winter months. When spring comes the seed awakes, water enters through a minute aperture, the **micropyle,** the covering swells, a tiny root or **radicle** appears, then the

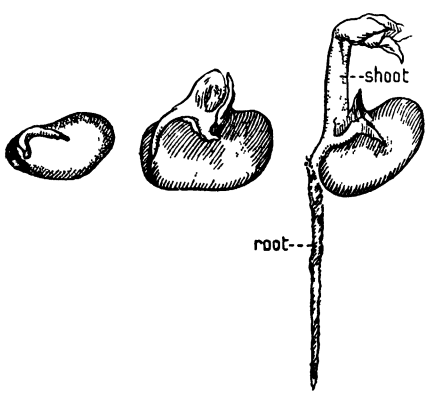


FIG. 49.—THREE STAGES IN THE GERMINATION OF A BEAN.

plumule or first stem emerges and grows upwards (Fig. 49). This early process of development is called **germination,** and for seeds to germinate successfully sufficient oxygen for respiration must be available, while there must also be moisture, and the temperature must generally be considerably above freezing point.

In order that the young plants may develop freely, the seeds must be taken from the parent plant and placed in soil preferably elsewhere to avoid overcrowding, *i.e.* they must be dispersed. Many seeds, such as those of the dandelion, develop hairy fibres, so that they may be carried by the wind. This device for **wind dispersal** has supplied us with a most valuable material in the dirty white fibres around the seeds of the cotton plant (*Gossypium*), which is related to the Golden Hollyhock and wild Mallow. These fibres vary in length from ½ in. to 2½ in., while the seeds are about the size of small peas and contained in pods or **bolls,** about 75 of which yield a pound of raw cotton. After the fibres have been removed by a suction process, the seeds are crushed for the extraction of oil, and the residual pulp, which still contains some oil, is then pressed and made into oil-cake, a valuable cattle food. Though originally a perennial, the plant is now cultivated as an annual in warm countries, chiefly the United States, Egypt, and India. In some other plants, burdock for example, structures like hooks cause the fruit to adhere to a passing animal, while the water lily has light and buoyant seeds which float away from the parent plant. But most plants disperse their seeds themselves by some method in which they are discharged from the carpels when the latter burst or dehisce, sometimes, as in the sweet pea, curling or twisting of the carpels causing the seeds to be thrown in all directions.

PURPOSES AND USES OF FOOD STORAGE IN PLANTS

The process of food storage in the seeds or other parts of plants is of great importance in connection with our own diet, since man often steps in and appropriates the food which is meant for the young embryonic plants. Cereals, such as *wheat*, from which we obtain **flour** for our daily bread, consist of fruits surrounded by food consisting of a mealy substance, largely starch (Fig. 50).

The grasses which feed our sheep and cattle are related plants, which are often consumed before they can mature. Many seeds store **fats** or **oils**, such as those found in olives, brazil nuts, flax (linseed), coconut, and the castor-oil plant, and often valuable nitrogenous foodstuffs called **proteins** are stored, particularly in *peas* and *beans*.

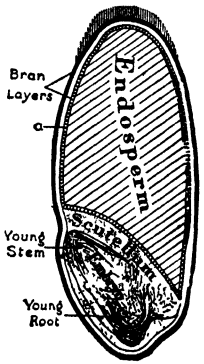


FIG 50 — LONGITUDINAL SECTION THROUGH A GRAIN OF WHEAT.

The number of vegetable foods which man and his domesticated animals obtain from various fruits, leaves, and roots is too great to be discussed adequately here, but one or two others which constitute the basis of great industries must be mentioned briefly. In the **cocoa** and **chocolate** industries the natural product is the fruit of a tropical tree, the correct name of which is *cacao*. The tree is often 20 feet in height and the fruits consist of brightly coloured lemon-shaped pods often as much as ten inches in length, too large to be borne by slender stems, hence the flowers grow directly upon the trunk and thicker branches (Fig 51).

Coffee is obtained from the seeds of the sub-tropical plant *Coffea arabica* and other related shrubs, which require a warm and moist climate but not so much heat as the cacao plant. Tea is made from the leaves of hardy shrubs related to *Camellia*, and, like coffee, must be regarded as a stimulant rather than a food.

Food storage is effected not only by seeds but also by other parts of plants, for example, by certain leaves as in an **onion**, which consists of a short stem having little adventitious roots below and two sorts of leaves above (Fig. 52). The outer white scale leaves are stored with food and surround the inner foliage leaves, which become green as they reach the light. An onion is a typical bulb and should be compared with others such as those of the tulip, hyacinth, and daffodil. A **potato** is a swollen underground stem or **tuber** rich in starch, and grown from older 'seed' potatoes having 'eyes' or buds which develop into new plants. Sometimes it is the root which becomes distended with

food, as in carrots, turnips, parsnips, and beetroots, the last named being extensively cultivated in temperate countries for the sake of the stored **sugar,** which is extracted by slicing the root and then immersing it in hot water. The remains of the beet after the extraction of the sugar is useful as a food for cattle.

Plants such as the beet are termed **biennials,** since their normal course of life extends over two years. During the first year they develop a great number of leaves which manufacture large

FIG. 51.—FLOWERS AND SEED PODS ON THE CACAO TREE.
(By courtesy of Messrs. Cadbury Bros. Ltd.)

quantities of food for storage, and if left undisturbed they flower and produce seeds in the second year.

The life cycles of plants vary considerably, and there are many which grow from seeds, become mature, and flower all in the same year and are therefore called **annuals**; others which keep growing and live for several years are **perennials.** The best known and most useful examples of the perennials are trees. In these, the valuable portion is frequently the trunk or stem, because woody cellulose is accumulated there which forms timber for building, etc. A section through a large tree trunk

(Fig. 53) shows several structures, chiefly the inner hard wood or **xylem**, next the softer sap wood, and on the outside the bark.

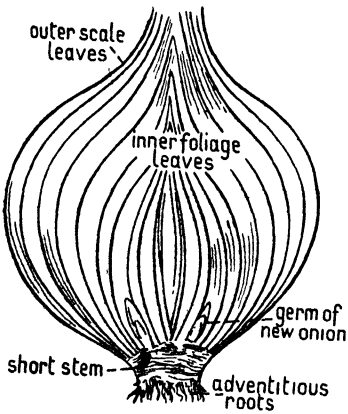


FIG. 52 —VERTICAL SECTION THROUGH AN ONION.

The xylem of a great number of trees is known as **timber** or wood, and from wood pulp we obtain paper and other cellulose products, such as artificial silk. The barks of various trees yield cork, vegetable dyes, and certain drugs, such as quinine and cocaine.

Certain trees when ' tapped ' by incisions reaching just beyond the bark yield valuable fluids from which important products are obtained, such as rubber. Many species of tree, particularly that called *Hevea*, supply this commodity, and they may exist mainly in the wild state, as in Brazil, or in cultivated plantations, the latter being particularly the case in the Malay States, Ceylon, etc. The milk-like fluid or **latex** contains about 30 per cent. of rubber, which is obtained by causing the latex to coagulate by a smoke-curing process, the coagulating rubber being wound upon a stick, or by a process of electrolysis. Other products obtained by tapping various trees are gums, resins, and various ' essential oils ' such as turpentine, eucalyptus oil, etc. Chaulmoogra oil, obtained from the seeds of Hydnocarpus trees which grow in southern India, Siam and China, is used in the treatment of leprosy.

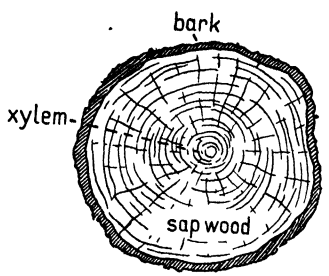


FIG 53 —HORIZONTAL SECTION THROUGH THE TRUNK OF A TREE.

Besides the trunks of larger trees, the stalks of smaller plants are of considerable importance, particularly those of flax, the

longer fibres of which are made into **linen**, a material of great antiquity and used long before the introduction of the cheaper material cotton, the shorter fibres being made into string and cord. Flax is cultivated either for the seed or for the fibre, the plant being pulled up and not allowed to mature in the latter case. Jute and hemp are other fibres used respectively for sacking and rope.

CHAPTER VI

SOILS AND THEIR RELATION TO PLANT LIFE

THE common **soil** or earth in which plants grow is a rather complex substance though it is primarily produced by the gradual wear and tear of the rocks below. Rain, wind, sunshine, and frost all help in breaking up the firm rocks into small pieces, and in this work of soil making, plants themselves assist in no small measure, since their roots penetrate small cracks and spaces and organic acids produced by them react chemically with some classes of rock material. A natural section seen in a quarry (Fig. 54) often shows the transition of fine surface soil to lower coarser soil, then larger lumps forming the **sub-soil,** and finally the massive, unbroken rock beneath.

The dark colour of most soils, and many of the valuable constituents of it, are due to decaying, or already decomposed, plant material. Whether this organic residue is derived from earlier generations of grasses or from any other smaller or larger kinds of vegetation, it is known by the general name **humus,** and it is this material which supplies most of the nitrogenous matter required as food by living plants. The nitrogen in humus is not, however, in the form suitable for assimilation straight away, and later we shall note the means by which it is made suitable for plant food.

Most rocks of the world are of the sedimentary kind, and of these by far the largest number are sandstones, clays and limestones. Sandstones generally contain some limestone particles, or as it is generally termed, **calcareous matter,** also some particles of clay. Similarly most limestones contain a little sand and **clay,** while clays may be calcareous or sandy. From this, it follows that a soil is usually a mixture of all three, but with varying

proportion of each depending upon the nature of the rock below. In limestone areas, rain water containing carbon dioxide reacts chemically with limestone, removing some of it by solution, so that the resulting soil contains a higher proportion of sand and clay than it would do otherwise

Each of these substances has its own work to do Sand grains help to keep sufficient spaces for water and air between

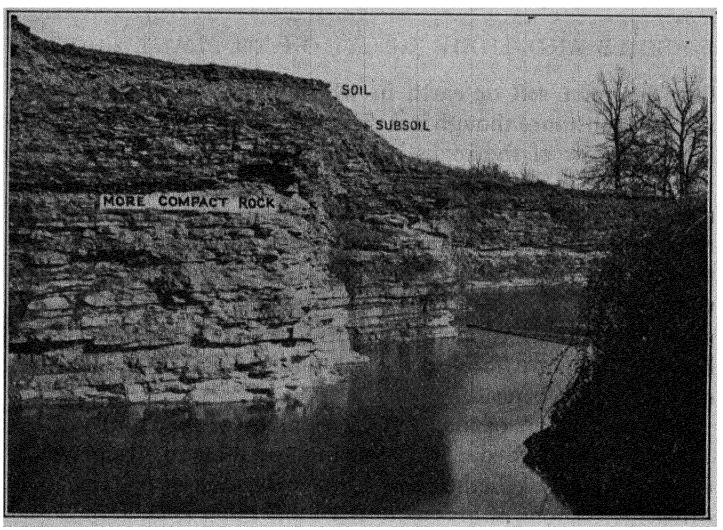


FIG 54 —A QUARRY
SHOWING TRANSITION FROM COMPACT ROCK TO SOIL
(By courtesy of the Director, Geological Survey)

the particles of soil, but if there is too much sand, as in a desert, the soil is far too porous and retention of water is inadequate Clay particles exert a moderating influence in this respect, but if this substance forms too great a proportion the soil is heavy, cold, badly drained, and not sufficiently aerated Another useful property of clay is its absorption and retention of substances formed when manures, potash, and lime are added to improve the soil Calcareous matter serves as a means of neutralising the organic acids produced by the decay of vegetable matter or humus, and assists in the formation of **nitrates.**

A good soil for general purposes, usually known as **loam**, has roughly these constituents in the following proportions: sand about 60 per cent., clay about 25 per cent., calcareous matter and humus each about 7½ per cent. The terms sand and clay are here used with their correct geological meaning, but they are often used to mean large and small particles of soil respectively, and this roughly agrees with the mineralogical significance, since the larger particles are normally composed of sand or silica and silicates, while the smaller particles are mostly of actual clay or hydrated silicate of aluminium. Another term often used in the description of soils is **marl**, which is given to a clay soil containing much calcareous matter.

Soils exhibit every gradation from light sands to heavy clays. The final product resulting from the breaking up of igneous rocks like granite and basalt is very similar to the soils obtained from the sedimentary rocks, since decay of felspar in igneous rocks produces clays, and the other constituents form 'sand.' The dark lavas are usually very rich in iron oxides. In addition to the sand, clays, and calcareous matter in soils, there are usually small proportions of many other substances containing iron, phosphorus, potash, sulphur, magnesium, and of course, there is always humus, and water.

RELATION OF SOIL BACTERIA TO THE PLANT'S SUPPLIES OF NITROGEN

With the exception of **carbon**, from carbon dioxide, and **oxygen**, both obtained from air, a plant receives its foods from the soil, and of these **water** is the most important, as it is not only a food itself but carries others in solution; it also distends the plant cells and tissues so that they are *turgid*, and thus keep the leaves etc., in extended positions. The leaves of a plant receiving insufficient water soon wilt or droop. Water and air occupy the interspaces between the grains of soil, usually as much as one-third or more of the whole soil, depending on the kind of soil, consisting of these interspaces. By means of these spaces the surface soil sucks up water from the lower layers of earth. Of the other foods which are carried in solution in the water, the most important is **nitrogen** (necessary for the formation of

proteins), which exists in the atmosphere and in humus, but in neither case is it in a soluble form How is its solution accomplished? Certain compounds of nitrogen termed **nitrates** are very soluble, and the nitrogen in humus must be converted to a nitrate before it can pass into solution.

The nitrogenous compounds in humus are of a complex character and are broken down into simpler compounds by certain kinds of bacteria which are present in soils in great numbers, many millions to every ounce of soil. As we have seen,

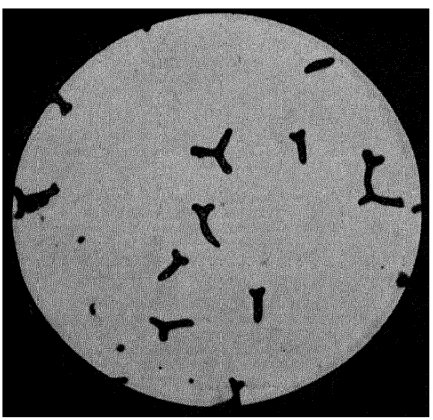


FIG. 55 —BACTERIA (*Bacillus radicicola*) FOUND IN THE NODULES OF LEGUMINOUS PLANTS (*Photomicrograph Rothamsted Experimental Station*)

bacteria are simple, very minute plants which multiply by division There are several of these useful organisms, and they work in different ways. Now certain bacteria cause decaying organic matter or humus to liberate ammonia, which is composed of nitrogen and hydrogen, and another particularly useful bacterium called *Nitrosomonas* converts ammonia into an acid containing nitrogen, hydrogen, and oxygen which is known as nitrous acid This reacts chemically with substances such as potash or lime in the soil, thus producing compounds called **nitrites.** Another bacterium, *Nitrobacter,* then changes nitrites

into nitrates which pass into solution and can enter the root hairs of a plant.

Other bacteria are capable of ' fixing ' ordinary atmospheric nitrogen ; that is, they can make it combine directly with other elements to form nitrogenous compounds. An important case of direct nitrification by the bacterium *Pseudomonas* is found in connection with plants of the pea and bean order, the *Leguminosae*. These bacteria enter the root hairs, multiply in large numbers, and so produce little nodular swellings on the roots.

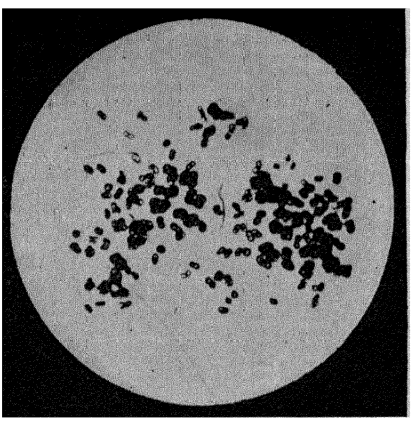


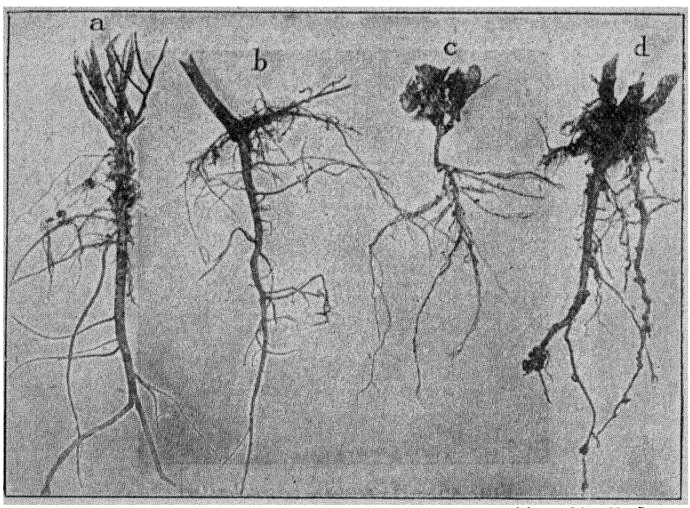
FIG. 56.—BACTERIA (*Azotobacter*)
FOUND IN ALL FERTILE SOILS.
(*Photomicrograph Rothamsted Experimental Station.*)

While they are there they ' fix ' nitrogen, but presently the plant absorbs them with the nitrogenous material they have formed.

Though these useful bacteria multiply at a great rate, they have their difficulties and their enemies. The acids which some of them produce are harmful to themselves ; hence the addition of powdered chalk or of lime, which neutralises acids, is beneficial. Then there are other bacteria, the *denitrifying* kinds, which take nitrogen away from compounds, thereby setting it free, and undoing the work of the others. This sort of thing occurs in soils which are badly drained and not supplied with sufficient air.

A constant warfare is being waged between the bacteria and

Protozoa, like *Amoeba*, which devour the minute vegetable organisms The soil teems with life, not only microscopic creatures, but also larger forms, many of them injurious to plants, such as wire worms (millipedes) and the larvae of insects which damage roots, but on the other hand many perform useful service in helping to keep the soil porous and well aired. The earthworm, which may be a nuisance in connection with our lawns, is really a friend to agriculturalists in general, since it



(*Photo Mr H James*)

FIG 57.—NODULES DUE TO BACTERIA
ON THE ROOTS OF *a* LUCERNE, *b* BROOM, *c* PEA, *d* LUPIN

turns the soil over by swallowing it and then discharging it again at the surface in the form of worm casts. Huge quantities of soil are thus turned over annually.

FERTILISERS, NATURAL AND ARTIFICIAL

In time a soil which was originally rich in nitrogenous matter and other potential plant food may become deficient and it becomes necessary to improve it.

Materials mixed with the soil to improve its condition are known as **manures** or **fertilisers,** and of these there are the natural

manures consisting of animal or vegetable matter, and the so-called ' artificial ' manures which include various chemicals such as sodium nitrate, calcium nitrate, ammonium sulphate, superphosphate, basic slag, etc. The most valuable of the natural manures is ordinary **dung** or **farmyard manure,** consisting of the waste products from various animals of a farm, and such manure is best when it is of a mixed character derived from horses, cows, pigs, and poultry. If plenty of this material were available, only the addition of some form of phosphate, such as basic slag, would be required to yield all the materials that plants require—nitrogenous matter, potash, and phosphate. But unfortunately the supply of farmyard manure falls far short of the demand, due largely to the replacement of horses by motor transport, even on farms themselves much of the work being done now by motor tractors ; hence the employment of great quantities of **artificial manures** or **fertilisers** in agriculture. Other forms of natural manure are obtained from decaying vegetation such as leaf mould, old grass cuttings, the residues of uprooted crops, etc., but these are mild compared with animal dung.

Farmyard manure when mixed with soils acts in three ways ; it increases the amount of plant foods, improves the physical condition or **tilth,** and keeps the soil warm as the result of fermentation, a fact that must not be overlooked, since the temperature has a considerable influence upon the rate at which most plants grow. Rotted manure which has been allowed to stand for some time is generally better than fresh, since the nitrogenous matter has already obtained considerable bacterial attention and more of it is in a form available as food. But not all of it is available at once, and it is an advantage to have part of the food rendered available some time after the application of the manure. This *delayed* effect is one of the chief properties of natural manure and is not found in connection with the chemical fertilisers, which are composed of material all available at the same time. One of the most valuable kinds of natural manure consists of the excreta of birds and known as **guano,** which collects as extensive deposits along the coast of Peru.

Continuous adequate supply of nitrogenous matter for plant life is very necessary, and the usual sources of nitrogen may

soon become exhausted, hence a serious 'nitrogen problem' has arisen.

Sodium nitrate or saltpetre is a natural mineral obtained from the ground in northern Chile, but even the vast supplies of this substance will eventually be exhausted; moreover, saltpetre is by no means suitable for all soils and crops. Within recent years successful processes have been established to 'fix' the nitrogen of the atmosphere by chemical means, and now large quantities of **calcium nitrate** and other nitrogenous fertilisers are produced by chemical means at Billingham and elsewhere. Another compound containing nitrogen is **ammonium sulphate,** now manufactured synthetically (see Chapter XXXVI) and produced as a by-product in the manufacture of coal gas. This, though soluble in water, requires considerable treatment from bacteria, and is apt to make soils 'sour' unless they are treated with lime periodically. Another substance termed **nitrolime** yields ammonia when treated with water in much the same way that calcium carbide yields acetylene when water is added.

In addition to nitrogenous matter, potash and phosphates are necessary, and in this respect soils differ a good deal, sandy soils often containing too little potash, while most soils, clay or sandy, require the addition of phosphates. The best potash fertiliser for most purposes is **potassium sulphate,** which occurs naturally as a mineral in Germany and is also manufactured.

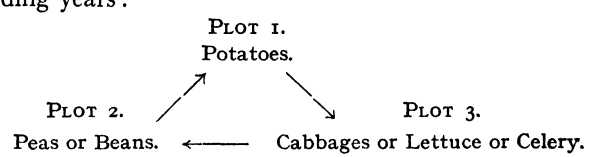
The natural mineral called **kainit,** also obtained from the deposits at Strassfurt in Germany, is a sulphate containing salt, too much of which is injurious to many plants, so that ordinary potassium sulphate is of more general value. The ash of burnt plants and wood is also valuable for its potassium contents.

The amount of phosphorus in soil is increased by the use of **basic slag,** which is a by-product in the manufacture of steel, and contains about 30 to 35 per cent. of phosphate. This material is best suited to wet clay soils, and another substance known as **superphosphate** is employed in the case of drier and more calcareous soils. Though not a manure in the ordinary sense, **lime** in some suitable form is immensely useful in agriculture. There are three well-known compounds of lime used for agricultural purposes—the carbonate, in forms known as

limestone and chalk; the oxide, commonly called lime; and the hydrate or slaked lime. Each of these substances is suitable for particular types of soil. Thus powdered chalk is generally used on sandy soil, but in all cases the results are similar; the lime compound neutralises humus acids, helps to break up the soil, and makes the formation of calcium nitrate possible.

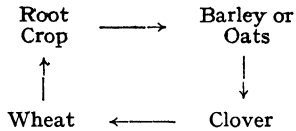
THE ROTATION OF CROPS

All plants are not alike as regards the depth to which the roots penetrate and the proportions of their food requirements, some needing more nitrogenous matter than others, some more potash, and so on. In certain cases, such as clover, peas, and beans, the ground is actually enriched by them as far as nitrogen is concerned, so that the next crop in the same ground reaps the benefit. If different kinds of crops having distinctly different food requirements are placed in successive years in the same plot of ground, the produce from that particular plot is much greater than if the same class of vegetable were placed repeatedly in it, and so exhausting the foodstuffs always in the same proportion. By proper observance of the **rotation of crops**, as it is termed, the maximum produce can be obtained from the soil, provided, of course, due attention is also given to manuring, etc. Many of us are concerned with getting the most from our kitchen gardens, and the following is an example of a very simple but effective three year garden rotation. This is the arrangement for the first year, and the arrows indicate the rotation of crops in the succeeding years:



Thus in the second year PLOT 1 should contain peas or beans, PLOT 2 should have cabbages or lettuce, and potatoes with good manure should be set in PLOT 3. Another shift all round occurs in the third year. A farmer being an agriculturist on a bigger scale is concerned mainly with crops not grown in kitchen

gardens, a typical four-course rotation consisting of root crops, then barley or oats, followed by clover, and lastly wheat.



Apart from the question of foods in the soil, rotations are valuable in other ways. Most diseases of vegetables are confined to particular kinds of plants so that a change of crop lessens the chance of disease being passed on to the next lot of vegetables set in the same plot of ground. Also, insect pests often live on a particular crop, so that a change gives them smaller chance of establishing themselves.

In **multiple cropping**, the same plot can be made to yield two or even three crops in the same year, a good double garden crop being early potatoes followed by brussels sprouts.

THE INFLUENCE OF WATER SUPPLY AND TEMPERATURE

The temperature of the ground, and of the air which touches it, is a very decisive factor of plant life Generally, *plants thrive better in warm soil than in cold.* Now the amount of rain received at any place is largely determined by the temperature of the atmosphere—cooler air generally means more rain than that occurring with warm air. For special reasons, however, large quantities of rain are associated with certain hot conditions at some places within the tropics, such as the Amazon Basin. Therefore in going from the equator to the poles, the types of vegetation existing on land near sea-level gradually pass from typical tropical kinds through sub-tropical and temperate types to small mosses, etc. (alpine flora), characteristic of the far north.

When the land rises above sea-level, the type of plant life is modified *as if the place were in higher latitudes than it really is.* High mountain ranges near the equator, such as the Andes in South America, bear vegetation which slowly changes in type

from tropical at the foot of the mountains to small alpine plants just below the snow line (Fig. 58). Thus in crossing the Andes, a traveller as he ascends, passes through successive **vegetation zones** similar to those he would traverse if he were to travel on low ground from the equator to the Arctic Circle.

At the same latitude and altitude, plant types vary according to conditions of soil, water supply, temperature, and light, so that definite **plant communities** occur, each community consisting of plants which are suited to local conditions. Thus the collective

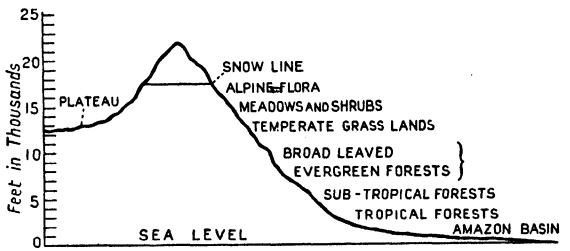


FIG. 58.

DIAGRAM REPRESENTING ZONES OF VEGETATION ON THE EASTERN SLOPES OF THE ANDES AT THE EQUATOR.

plant types or **flora** of meadows include various grasses, dandelions, plantains and others which can obtain a footing in spite of the grass which tries to monopolise the soil. On moorlands we find those kinds of plants, chiefly heather and gorse, which adapt themselves to exposed positions and to a limited available water supply; on low marshy ground there is an abundant flora, including marsh marigolds, marsh mallows, rushes, willows, and many others. Similarly woodlands, sandy coasts, and even rubbish heaps, support characteristic plant groups suited to the respective conditions. The study of plant communities, known as **ecology,** is rich in examples of plant adaptation to environment.

CHAPTER VII

INSECT LIFE AND ITS RELATION TO HUMAN ACTIVITIES

THE various forms of animal life are exceedingly numerous, and in structure range from the simple **Protozoa,** such as *Amoeba,* to highly complex types culminating in the human species. There are two great groups of animals, the members of one group possessing a vertebral column or backbone, hence called **Vertebrates,** while those in the other group, the **Invertebrates,** have no vertebral column. The insects, the study of which is known as **entomology,** constitute one of the higher groups of the Invertebrata, higher, that is, in structure and mode of life, than members of many other invertebrate groups, such as corals, sponges, and sea urchins.

Nearly all insects are capable of flight, which has endowed them with greater abilities in food seeking and in finding suitable places for the hatching of their eggs and the development of their young. Thus endowed with superior powers of adaptation, it is not surprising that the number of known species in the group is more th n a quarter of a million. Geologically, the group is a very old one, insect remains being found in rocks deposited during middle Palaeozoic times, some hundreds of millions of years before the earliest birds and mammals made their appearance. Fossil insects are usually found as impressions of wings, and from the study of these it is shown that the earlier types included ancestral forms of dragon flies, plant lice, bugs, and cockroaches, though true beetles did not appear until early in Mesozoic times, as did flies, ants, earwigs, and grasshoppers. Butterflies and moths appear to date from the Tertiary period.

Invertebrate animals that have jointed legs are known as **Arthropods,** insects forming a well-marked division of these since they possess six jointed legs attached to the middle part of the body. Each leg has several joints, and the last section often bears a pair of pincers or nippers, as in beetles and other carnivorous insects. Spiny processes, as in Mantis, assist in food capture, and a general hairiness of some insects, a bee's leg for example, happens to be particularly useful in the collection of pollen grains and the transference of these grains to female flowers in cross pollination.

STRUCTURE OF A TYPICAL INSECT

Examination of a housefly or a bee reveals the fact that the body of a typical adult insect (Fig. 59) consists of three distinct portions—head, thorax, and abdomen. In many cases, particularly beetles, the head is embedded in the thorax, but in others, such as bees, wasps, and flies, the three portions of the body are joined by very slender connections.

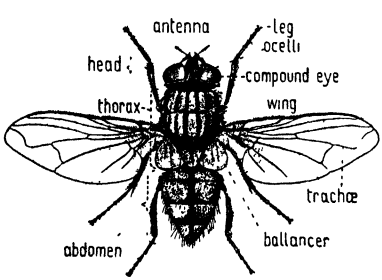


FIG. 59.—HOUSEFLY, WINGS EXTENDED
(By courtesy of the Director, British Museum Natural History)

The **head** bears the organs of vision, the 'feelers' or jointed **antennae,** and the structures corresponding to the mouths of larger animals. There are usually two large **compound eyes** separated by a space which is, in the housefly, broader in the female than in the male. As a rule the compound eyes are each composed of some thousands of minute lenses, so that the image formed by them must be a multiple picture quite unlike anything which we ourselves experience. There are also smaller simple eyes or **ocelli,** usually three in number, arranged like a triangle and situated more towards the middle and top of the head. The antennae vary considerably in length, being relatively short in the

house-fly and long in lacewings; sometimes they are smooth, in other cases hairy.

The mouths of insects usually possess a pair of upper jaws and another pair of lower jaws, the movements of such jaws being sideways, somewhat like the action of scissor blades, but the mouth structures vary according to the kind of food consumed. In general, mouths are adapted either for biting, as in beetles, or for sucking, as in flies, butterflies, and moths. Often the mouth is so small that only liquid food can be taken, and this is sucked up by means of a tubular structure called a **proboscis,** which in a housefly can be folded away when not in use. On the other hand, the larger stable fly, a different species, has a *non-retractable* proboscis which cannot be tucked away. In a bee the proboscis is used for collection of the honey-like nectar of flowers. Large numbers of insects are carnivorous and feed upon other insects, but many feed upon plants, as in the case of the Aphides or plant lice, which suck the sap of rose trees, etc. Cockroaches eat both animal and vegetable matter.

Next to the head is the larger portion of the body called the **thorax.** All of the six **legs** are connected to this, so are the **wings,** usually four in number, though in the housefly and many others the pair nearer the abdomen are very much reduced and known as 'balancers.' A few primitive types have no wings at all.

In insects there is no breathing organ comparable with the lungs of higher animals, but respiration is carried on by means of a network of tubes or **trachae** which extend all over the body and communicate with the outside air through pores situated between the segments or divisions of the body. In the wings these breathing tubes appear like a system of veins and the patterns formed by them are of use in classification. Alternate expansions and contractions of the body cause air to circulate through the trachae. There is a rudimentary cylindrical or sausage-like heart concerned with the distribution of a nearly colourless blood which moves freely in the body, that is, it is not confined in blood vessels.

The **abdomen** usually consists of nine horny ringed segments

or divisions, and does not bear any appendages or external structures except the stinging apparatus of bees and wasps, or the forceps-like structures in earwigs Some animals have no definite **nervous system,** but insects possess central nerves extending along the body and having usually eight centres or **ganglia** from which smaller lateral nerves proceed (Fig 60). In spite of the simplicity of this nervous structure, which is all that represents the complex system and brain of higher animals, many insects exhibit greatly developed instincts and some intelligence ; particularly is this the case in ants, bees, and other social insects which live as organised communities.

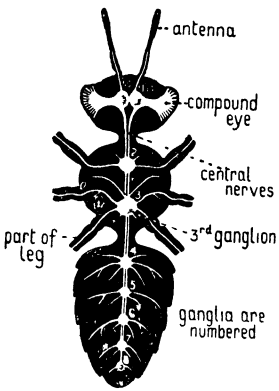


FIG 60 —THE NERVOUS SYSTEM OF A BEE

INSECT METAMORPHOSIS

The structures we have just considered are those of a complete or *mature* insect. A lamb is very obviously a miniature sheep, similarly a chick though small resembles its parent, but a young insect is nearly always quite unlike the creature it becomes in later life. The silk moth (*Bombyx Mori*) is a well-known example which will serve as an illustration of the changes in form that an insect undergoes during its development The female moth lays some 300 pale coloured disc-like **eggs** and dies soon afterwards From each egg, on hatching, there emerges a light coloured hairless caterpillar or **larva,** and this part of the creature's existence is known as the *larval stage.* This is the period of growth, the insect being very voracious, devouring many leaves, and storing up food material for the later stages characterised by development, not growth The silk ' worm ' attains a length exceeding two inches, casts its skin four times, and at the end of about four or five weeks spins a cocoon of silk

thread around itself and becomes a much less active and dark coloured **chrysalis** or **pupa.** On both larva and pupa the openings of the trachae are indicated by little round dots, but in most ways these earlier forms appear very different from the final product, the **moth.** At the end of another two or three weeks, a pale ashy moth, the perfect insect or **imago,** emerges from the chrysalis and the cycle of events is complete. These successive changes in form are known as **metamorphosis,** and the complete series of events which occur between the hatching of the egg and the death of the adult imago is called the **life history** of the insect (Fig. 61).

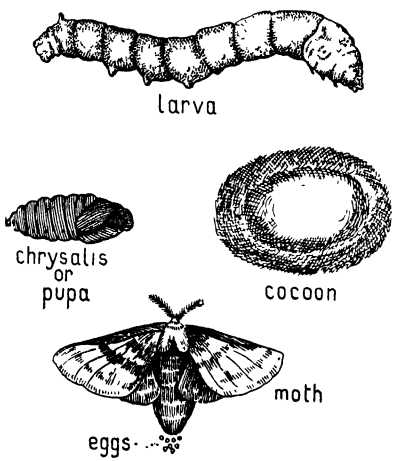


FIG. 61.—METAMORPHOSIS OF THE SILK MOTH.

Most insects pass through the stages — egg, larva, pupa, and imago, so that their metamorphosis is said to be complete, but in some cases there is not so much difference between the earlier and later stages of development, when the metamorphosis is said to be incomplete. Cockroaches, plant lice, bugs, locusts, grasshoppers, and earwigs are examples of insects having incomplete metamorphosis. There are many insects in which the earlier stages are adapted for a life in water though the later imago is fitted for existence in the air, dragon flies and mosquitoes being examples. There are others, such as the common water beetle, in which all stages are adapted to an aquatic life.

The metamorphosis of the silk moth is typical of normal insect development, even the spinning of the cocoon being a feature shown by many other insects; it is the *quality* of the silken fibre that has made this little creature a benefactor to mankind. The silk is secreted as a yellow fluid by two glands, one on either side of the caterpillar, and both glands lead to an opening known

as a **spinneret.** As the fluid emerges from the spinneret it becomes solid, and a single larva may spin as much as 1200 yards of silk. If the pupa is allowed to change into a moth the cocoon becomes damaged because the moth eats its way out. Therefore in countries where the silk-worm is cultivated on a large scale for the production of silk, the chrysalides are destroyed by steam, only a few being permitted to complete the life cycle for the sake of the eggs, and in these cases the silk is removed. The cultivation of this insect has proceeded in those countries where mulberry trees are numerous, since the leaves of this tree are the best kind of food for the larvae. The silkworm industry originated in China some forty centuries ago, and thence spread westwards via Constantinople into Southern Europe.

MOTHS, BUTTERFLIES, BEES, AND RELATED INSECTS

Moths and butterflies belong to the division of insects known as **Lepidoptera** (=scale wing), since their wings, often highly coloured and of very varied shapes, are covered with scales Butterflies are distinct from moths in having club-like terminations on their antennae. Many of this group are injurious, a well-known example being the White Cabbage Butterfly, the pale green larvae of which makes such havoc with cabbage leaves. Similarly the large caterpillar of the Hawk Moth devours potato leaves, the larvae of the Apple Moth feed on apples, those of the Magpie Moth attack blackcurrant and gooseberry bushes, while the Tineae include the small clothes moths which lay their eggs in clothing, the larvae later making holes in the fabric.

The great majority of insects are enemies of man, either destroying his crops or carrying disease to him or to his domesticated animals, but the honey bee, a member of the **Hymenoptera** (=membrane wing), so called on account of their thin transparent membranous wings, is useful to man for the production of wax and honey.

The general anatomy of the complete bee (*Apis mellifica*) has already been described, but one or two additional features must be noted. There are four gauzy wings, the hinder pair smaller

than those in front and fixed to them, while in flight, by means of a series of minute hooks. This arrangement ensures the proper vibration of the wings in unison. At the end of the abdomen the **stinging apparatus** is situated (Fig. 62), and consists of a barbed sting protected by a sheath, and connected to a glandular arrangement which secretes the poison. The barbed nature of the sting means that it can be used once only, as on that occasion it is detached from the body and causes the bee's death. The males are not provided with a sting.

The bee's proboscis, a hollow, tongue-like structure, is used for sucking the sweet fluid nectar from the nectaries of flowers. This

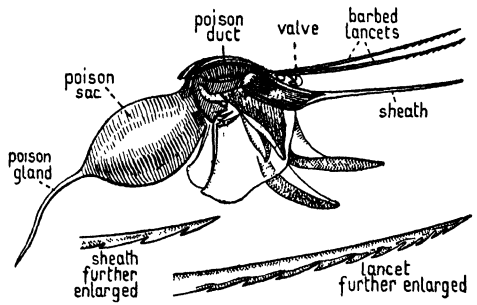


FIG. 62.—THE STINGING APPARATUS OF THE HONEY BEE, GREATLY ENLARGED.

substance passes from the proboscis into a small honey bag within the bee where it undergoes certain changes so that when it is later discharged into the waxen chambers within the hive, it has become honey. Pollen mixed with honey forms the food intended for the larvae hatched from eggs laid by the queen bee.

In its life history the bee passes through the usual stages; its metamorphosis is complete. Each egg has a waxen cell to itself, and produces a smooth, legless larva which grows for a time and then spins a cocoon and becomes an immovable chrysalis in which the parts of the bee can be seen more clearly than in the larva. About twenty days after the laying of the egg the imago or bee emerges from the chrysalis.

Apart from the collection and preparation of honey, bees are particularly interesting because of their *social habits*. In a

community there are three classes of bees (Fig. 63), the female or **queen bee**, the **workers**, and the males or **drones**. The queen is concerned with the production of eggs, a small number of special ' royal ' eggs being placed in special cells and developing into new queen bees later on. Only one queen can be tolerated in a hive, so that when these royal princess bees reach maturity, the old queen pairs with a male, goes off with a swarm of workers and founds a new colony elsewhere. One of the royal princesses becomes queen and her sister princesses are murdered. The workers, sometimes described as **neuters**, but really imperfectly developed females, are the mainstay of the bee organisation.

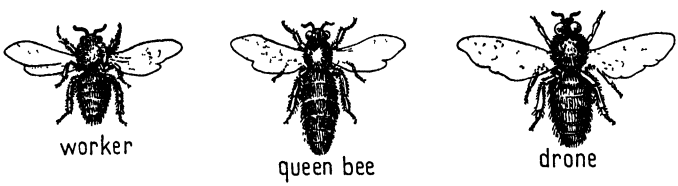


FIG. 63.—THE THREE TYPES OF HONEY BEES INHABITING A HIVE.

While some are making wax, which is secreted on the under side of their bodies, and with it construct the honeycomb composed of many six-sided chambers, others are collecting nectar and preparing honey, and still others are attending to the needs of the larvae. As we have seen, many cells are used for the rearing of the young insects and others are put aside for royal bees, but some are employed as receptacles for the storage of honey really meant for the young bees but, as in many other cases, appropriated by man for his own use. The wax is also a useful substance.

Though the workers only live for a few months, a queen bee may live from three to five years. The males or drones are slightly larger than the workers, their function being that of fertilisation of eggs laid by the queen. They do no work, and at the end of the summer when food supplies are running short they are killed by the workers which, though smaller, are far more powerful, since the drones have no stinging apparatus.

There are other bees besides those concerned with honey, the

large 'bumble bee' being a different species, so also is the solitary leaf-cutting bee. Certain insects assume an appearance similar to that of a more formidable species as a means of defence, such **mimicry** being illustrated by the Drone Fly, which appears very much like a bee though it is really a harmless fly.

Wasps are in many respects similar to bees. They have stings, often build honeycomb-shaped nests, but of vegetable fibre not wax, and some of them prepare a poisonous substance analogous to honey. The common English wasp and the Hornet, a larger type, are social insects, and like the bees consist of females, males, and workers. Though they act as scavengers, they are mainly a nuisance and many of their larvae are destructive to the leaves of trees.

Other social members of the Hymenoptera are the **ants,** which lead a communal existence as well organised as that of bees. Here again there are developed females whose main duty is to provide for the continuation of the race, males, and undeveloped wingless females, the workers, which construct underground habitations, collect food, and attend to the young. The workers also lay eggs, but these produce only males, all females whether queens or workers coming from eggs laid by the queen ants. Some of the workers having very large heads are known as **soldiers.** In the process of metamorphosis, the eggs yield small white larvae which later spin cocoons and become white pupae, from which the perfect insects are ultimately set free.

It is unfortunate that a group of creatures so capable and so well organised should be harmful. In tropical countries they are so numerous as to be a plague, and their activities in collecting leaves etc., for construction of their subterranean galleries does great damage to vegetation. These dark coloured ants must not be confused with so called **white ants** or **termites,** which are not really ants but belong to the **Neuroptera** (=nerve wing), a division of insects including dragon flies and May flies. The termites are characteristic of hot countries, build large hills, often sixteen feet high or more, and they are a greater nuisance than the true ants, often reducing wooden structures to the condition of mere shells. Teak is one of the few timbers which can withstand their attack.

One or two other species of Hymenoptera must be mentioned. The **Ichneumon flies** deposit their eggs inside the caterpillars or larvae of other insects, particularly those of butterflies and moths. This is done by the egg-laying structure or **ovipositor,** which punctures the skin of the victim and lays the eggs therein. The Ichneumon larvae presently develop and feed upon the substance of their host, which is thus destroyed. As a contrast to this good work is the deposit of eggs by the **Gall flies** in young oak trees, leading to the formation of **oak apples.** These swellings, called galls, are due to an irritant fluid deposited at the same time as the eggs. An Ichneumon fly may even pierce these galls and deposit an egg inside the gall fly larva within. Another fly, the **Fir-Wood Borer,** has a long ovipositor by means of which she bores a hole in fir trees and lays her eggs there, with the result that the larvae do great damage by making long burrows in the wood.

THE HOUSE FLY (Musca domestica)

Flies having two large wings are included in the group of insects called **Diptera** (=two wings). As explained earlier, the housefly really has four wings but two of them are so small as to be ineffective as organs of flight. In this group are also included gnats or mosquitoes, daddy longlegs, and fleas, the last having only rudimentary wings, so that their legs have become very strong and adapted to jumping.

The main facts concerning the life history of the housefly and its relation to disease are of extreme importance to mankind. The female fly, or rather flies, since many of them like to lay their eggs at the same time and in the same place, deposits her white eggs in fresh stable manure or, failing that, in household rubbish (Fig. 64). The fly will not use an old manure heap unless fresh material has been added to it. In warm weather the eggs change to white larvae or maggots in about twenty-four hours, but two or three days are necessary if the weather is cool. In circumstances favourable to growth, the white legless maggots are fully grown and measure about half an inch at the end of four or five days. The maggots then change into pupae which become darker in colour as the time approaches for the

mature fly to emerge. The length of time taken by the changes from larva to pupa, and from pupa to fly, is determined mainly by the temperature; in cool weather the pupa stage may last three or four weeks though in warmer conditions only a few days are necessary. When the larvae are about to change into pupae they usually seek some cooler spot in the soil away from the manure heap in which to complete their metamorphosis. Some-

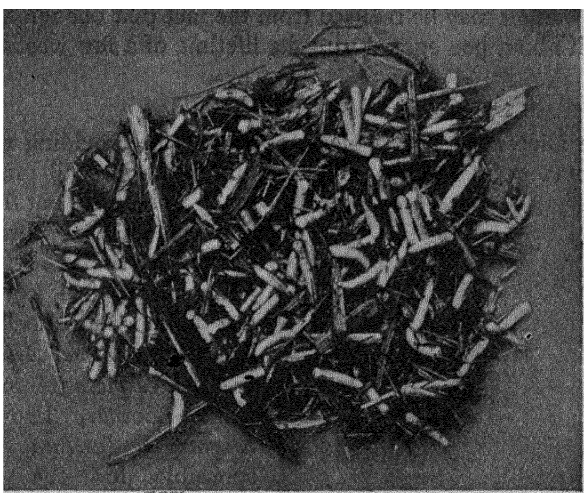


FIG. 64.—LARVÆ OF HOUSEFLIES IN MANURE.
(By courtesy of the Director, British Museum: Natural History.)

times the brownish pupae are found behind loose wallpaper or in other odd places.

By reason of the materials in which the eggs are deposited, it is not surprising that the *housefly is a deadly carrier of diseases, among which are cholera, typhoid fever, dysentery, and summer diarrhoea.* Flies pass from manure heaps (particularly in insanitary country districts) direct to food meant for human consumption and carry germs of disease on their feet and on the hairy surfaces of their bodies. They also swallow refuse and eject it again as excreta, the evil effect of which is obvious.

The best means of prevention of this germ distribution is the improvement of sanitation, particularly in rural areas. Stable and farmyard manure heaps should be turned over frequently, so that the eggs deposited near the top are then at the bottom and, being there subjected to greater heat of fermentation, are likely to be destroyed Household refuse should be kept covered, and ash bins emptied frequently, while articles of food should be adequately covered, and fly traps used extensively The extent of the danger may be realised from the fact that one female may deposit about 900 eggs during its lifetime of a few weeks.

MOSQUITOES

The Diptera are particularly obnoxious in providing us with unwanted germ carriers. The small insects we call gnats are really **mosquitoes,** but the dangerous members of this group are chiefly found in tropical and sub-tropical countries. Certain mosquitoes belonging to a group named *Anopheles* are the carriers of malaria, while another, known as *Stegomyia fasciata,* is responsible for the spread of yellow fever. Other species are connected with the tropical diseases known as elephantiasis and dengue fever

FIG. 65.—A MOSQUITO
Anopheles maculipennis.
Female This mosquito is the principal malaria carrier in Europe
Photo. by J F Marshall, Director, British Mosquito Control Institute, Hayling Island, Hants.

As is usually the case, the female mosquitoes are the source of trouble, since the male is not a blood sucker and lives upon the sap of plants. The larvae of mosquitoes are small 'wrigglers' which live in water, though they have to come to the surface to breathe (Fig. 66) These ultimately change into pupae, but, as in the case of house-flies, temperature and moisture conditions determine the length of time required for the change

into the complete insect. It may take only a few days or it may require months. Unlike most chrysalides, those of mosquitoes are very active and soon change into the complete insect, merely a few days being sufficient. Some mosquitoes lay their eggs on water and others in dried-up ditches where water collects in winter.

Malaria and yellow fever are due to blood parasites carried by mosquitoes from one person to another, and in both diseases the parasite *must* enter first a mosquito and then a human

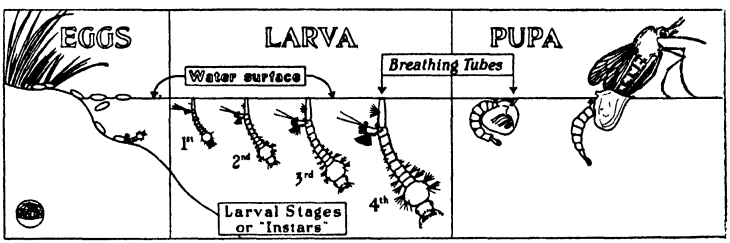


FIG. 66.—THE METAMORPHOSIS OF A MOSQUITO, FROM THE EGG TO THE COMPLETE INSECT.
(Diagram by J. F. Marshall, Director, British Mosquito Control Institute, Hayling Island, Hants.)

being in order to complete its own development. Medical researches on mosquitoes and disease are mentioned in a later chapter.

THE FLEA (Pulex irritans)

Though fleas have only rudimentary wings, they are classed with the Diptera. There are other differences between flies and fleas, the latter having both head and abdomen embedded in the thorax, while the eyes are much less developed than in flies, some species of fleas being blind. The body of a flea is tall and thin, as if it had been compressed from the sides, and in this respect it is rather unusual. The lip and jaws of this insect are long, narrow, and like a saw, and when they interlock they form a tubular structure through which blood is sucked from a victim.

In proportion to its size a flea has a large stomach, and when the

insect is infected with the bacilli or germs of the horrible disease called bubonic plague, the stomach eventually becomes choked with the bacilli (Fig. 67). In this condition the thirsty flea sucks blood towards the stomach at the entrance of which it mixes with the bacilli and is then discharged back into the wound in the victim, who will probably develop plague in consequence. The disease develops in rats, and then infects fleas, particularly the Asiatic rat flea, which carry the disease to man. Though hundreds of different species are known, eleven kinds are capable of transmitting plague, five of these being British types.

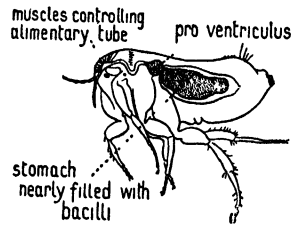


FIG 67.—A FLEA IN AN ADVANCED STAGE OF DISEASE DUE TO GERMS OF PLAGUE
(By courtesy of the Director, British Museum Natural History)

In their life history fleas pass through the usual stages of metamorphosis (Fig. 68). Oval waxy-looking eggs develop in about ten days into white bristly, legless and blind larvae. These spin cocoons and change into chrysalides which yield the perfect fleas often quite suddenly on account of vibration or other disturbance. Eggs are usually laid upon the bodies of the hosts —rats, mice, squirrels, etc. It is a strange fact that whereas some fleas prefer the blood of mammals, others will take only that of birds, and so on.

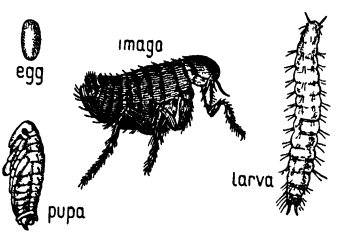


FIG 68 —METAMORPHOSIS OF THE COMMON FLEA
(By courtesy of the Director, British Museum Natural History)

BEETLES AND COCKROACHES

While the Diptera exert their evil influence in connection with disease, many of the **Coleoptera** (=sheath wing) or beetles, attack our plant foods or reduce timber to the condition of a sponge

by the burrowing habits of their larvae. In this group the metamorphosis is complete. In a typical beetle the front pair of wings are composed of a horny substance called **chitin**, and are known as **elytra**, their function being that of protection for the hind wings, which are the only ones which move during flight. The head is embedded in the thorax and possesses jaws adapted to a carnivorous diet, though many eat leaves of oak trees, etc., the common cockchafer being one of these. Another species, *Zabrus*, eats ears of corn, but often it is the larvae which causes most damage.

The destructive work of various larvae include the formation of 'worm' holes in furniture by a species called *Anobium*, the riddling of woodwork by larger types such as *Xestobium*, the destruction of apples by the small apple weevil and of the vine by the vine weevil. Other weevils attack corn, coconut palms, oak and birch leaves, and pine trees, while the potato beetle is a serious pest in connection with potatoes. It would be indeed a long list which included all the varieties of Coleoptera which are our enemies, but there is nearly always an exception, and in this case there is the little scarlet ladybird, one of the best friends of the gardener, since it eagerly devours the aphides or plant lice found on rose trees and other plants. A few, such as the carrion feeders or *Necrophaga*, also do good in disposing of dead frogs, mice, birds, etc.

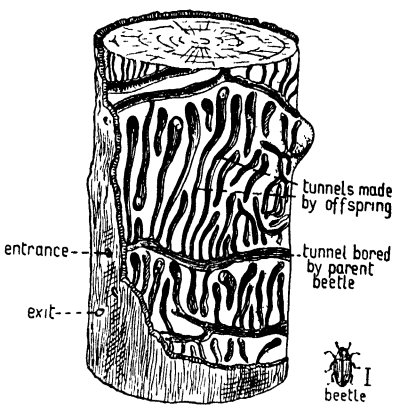


FIG. 69.—PART OF A TREE RIDDLED BY A BEETLE AND ITS LARVAE.

It must be noted that the ordinary cockroach is not a beetle but belongs to another order, the **Orthoptera** (=straight wing), in which the metamorphosis is incomplete. This order also includes grasshoppers, crickets, locusts, and earwigs. Cockroaches are both loathsome and destructive. The males have

small wings but the females are wingless and lay their eggs in cases, about three dozen eggs in one case. The most destructive of the whole group are the migratory locusts which descend in swarms upon cornfields, etc. in tropical and subtropical countries, and in a short time the whole of the vegetation is destroyed. The related grasshopper is a comparatively harmless creature which makes a chirping sound by rubbing its legs against the wings. In the crickets the sound is caused by one wing rubbing another.

There are other orders of insects which cannot be described here, but enough has been said to show how great a power for evil is this group of animals. One or two are helpful, but if an estimate of insect work is drawn up, there is an enormous adverse balance far outweighing any good that the honey bee, the silk moth, or the ladybirds do for us. But it must not be imagined that no headway is being made in the control of insect pests. In New Zealand, Australia, California, and elsewhere, certain other insects which destroy various pests are being cultivated and then liberated in great numbers to wage war against the pests. An example that has attained considerable success in New Zealand is *Aphelinus*, a species of wasp, which has kept the apple-tree pest, called woolly aphis, under control. Attempts are being made to introduce insects which will effectively control other aphides, earwigs, pear slugs, and many other injurious creatures. The good work done by cultivated insects is not restricted to the destruction of other insects, for successful work is also being done in the destruction of noxious weeds. One of the most widespread injurious plants of Australia is the prickly pear, and this is now being attacked by the cochineal insect and related species, which have been imported from California, where they are an important natural agent in controlling the spread of prickly pear.

CHAPTER VIII

SOME INHABITANTS OF SEA, RIVER, AND POND

THERE is little doubt that Life originated in the sea. The development of limbs and of lungs are examples of adaptation to life on shore, and it is generally believed that the ancestral amphibia, a group now represented by frogs, toads, and newts, were the first to make the great change from an aquatic to a terrestrial life. At the present day, after hundreds of millions of years of organic evolution, the sea is still the habitat of the great majority of invertebrate animals and of fish, the lowest division of the vertebrates.

SIMPLE MARINE ORGANISMS

Marine invertebrate types range from Protozoa to the cuttle-fish and nautili. An interesting example of the Protozoa is *Noctiluca*, which is a cause of phosphorescence in the sea at night, though in the daytime, even in a darkened room, the phosphorescence is not noticeable. Enormous numbers of minute organisms, collectively known as **plankton**, live near the surface of the sea, and where they vary in numbers according to seasonal changes, in temperate latitudes they are more numerous in summer. Characteristic of late winter and again of autumn are the myriads of tiny plants called **diatoms** (Fig. 70), the ultimate source of food for most marine animals. These organisms secrete an enclosing shell-like structure made of silica or flint, and on their death the minute shells sink to the ocean floor, forming there a widespread deposit called **diatom ooze.** Small floating animals which similarly secrete siliceous shells are the **Radiolaria,** and a number of **Foraminifera** construct calcareous or limestone shells. A constant rain of

these shells upon the ocean bed produces Radiolarian and Foraminiferal oozes respectively (see *Globigerina*, Chapter III).

More advanced organisms living near the surface of the sea on the crests and peaks of submerged mountains are the **coral polyps,** animals having a definite body cavity for food digestion, and in outward appearance somewhat similar to small sea anemones found in pools along the English coasts. But whereas the anemones are wholly soft and jelly-like, the coral polyps secrete calcareous plates which remain after the death of the organism and consequent decay of the soft parts. Corals may

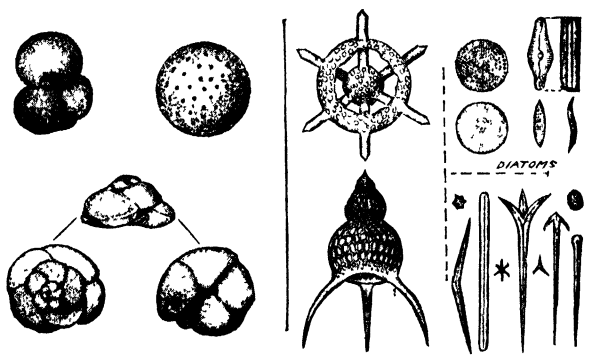


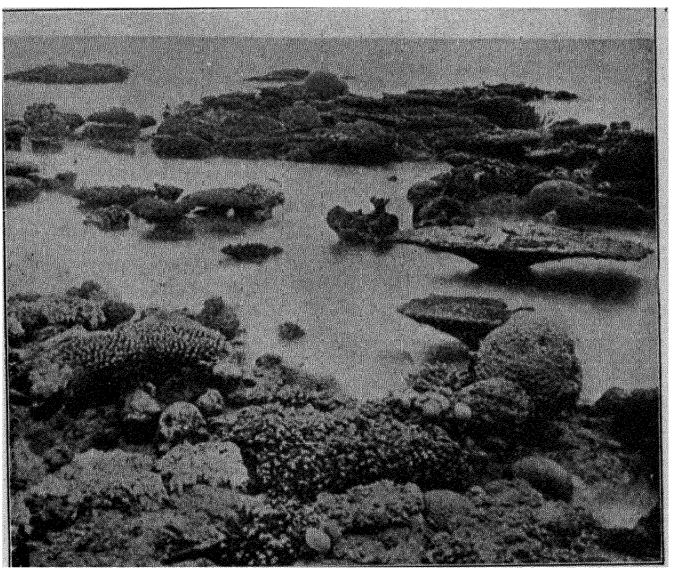
FIG 70 —FORAMINIFERA, RADIOLARIA, DIATOMS, AND SPONGE SPICULES

be simple, that is solitary individuals, or may occur united together in immense colonies which form coral reefs, the white and pink skeletal structures of which constitute the coral of commerce

Modern reef-building corals are found to require certain conditions of temperature and pressure. They can thrive only in warm, shallow, and clear salt water, and if the assumption that reef builders of former geological periods required similar conditions is legitimate, the presence of extensive reef material in the Carboniferous and other limestones yields considerable information concerning the climate, depth, and condition of the sea existing at the time of deposit.

The harder of these old coral limestones take a good polish

and form excellent ornamental stone, the well-known Derbyshire marble being a very fine example. The Torquay limestone of South Devon is another, but the yellow Corallian limestone found around Oxford is much less durable, a fact which accounts for the crumbling surface condition of some of the old buildings in that famous city.



(*Photo by W. Saville-Kent.*)

FIG. 71.—A CORAL REEF, OUTER BARRIER, AUSTRALIA.

Sponges are simpler animals living as separate individuals on the sea floor, and there are others which inhabit fresh water. The bathroom sponge, found in the Mediterranean, is a skeletal structure made of the horny substance called **chitin,** of which our finger nails and hair are also composed. During life the chitinous skeleton supports a mass of jelly-like material having innumerable channels termed canals, and the movements of small hair-like structures, or cilia, cause streams of food-bearing water to pass through the sponge. In other sponges the skeletal framework is composed of minute needle-like bodies called

spicules (Fig. 70), which may be composed of either flint or limestone. It is obvious that such types of sponge are unsuited to domestic purposes.

Flint nodules of various shapes and sizes are found in the Upper Chalk of England and elsewhere, and it is generally believed that this siliceous material was originally in the form of sponge spicules and Radiolarian shells, and that these organic structures were dissolved in the sea water and then re-precipitated in nodular forms. Economically this substance is of great importance, being powdered and used in the manufacture of china, porcelain, and flint glass. The nodules are often employed as road metal or as building material, while in prehistoric times primitive man acquired great skill in shaping his knives, arrow heads, and skin scrapers from them.

It should be clearly understood that when we speak of the skeletal structures of sponges and corals, we do not mean that they are in any way comparable with the skeleton or backbone of a vertebrate animal. Many invertebrate animals secrete a calcareous shell or covering mainly for protective purposes, and these shells may consist of two parts hinged together as in **bivalves**, or may be all in one piece as in snails and other gasteropods. In all cases the calcareous material is obtained from salts dissolved in sea water and replenished by dissolved limestone carried from the land by rivers. Most sandy beaches are strewn with disconnected valves or shells of marine molluscs; the **oyster** of commerce is an example of a well-known mollusc. The edible oyster (*Ostrea edulis*), is found in English waters, principally the estuary of the Thames, at Whitstable and Brightlingsea. Many millions of oysters are consumed annually, and the industry is protected by legislation making it illegal to sell oysters during the breeding season between May 15 and August 4. The **common mussel** is another bivalve used as an article of diet.

The calcareous matter of shells is secreted layer upon layer, and should such a deposit occur around some irritating nucleus between the fleshy part and the inner surface of the shell, a rounded growth of concentric layers is formed. In the pearl oyster, an inhabitant of the Indian ocean, these growths, or **pearls**, are perfect in form and are composed of that variety of

calcium carbonate known as aragonite. The most important pearl ' fishery ' is in the Persian Gulf.

CRUSTACEA

Most creatures of the sea which are of value to us are used as articles of diet, an important group of such animals being the **Crustacea,** another division of the Arthropoda, since they, like insects, have much jointed legs. The group includes lobsters, crayfish, crabs, shrimps, prawns, barnacles, and woodlice, all of

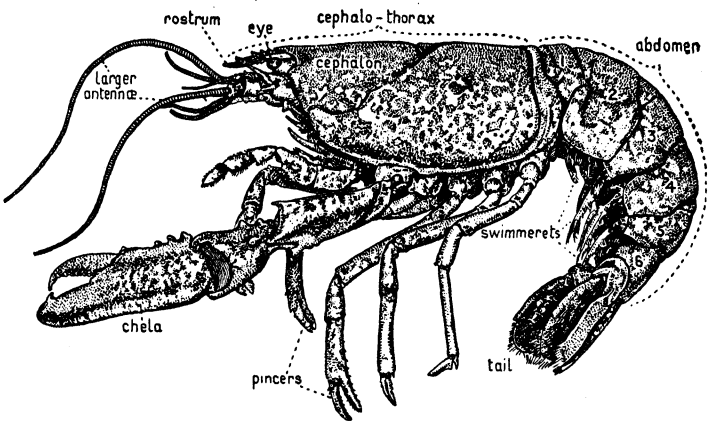


FIG. 72.—THE COMMON LOBSTER.

them possessing a hard outer crust or covering giving the name to the group. The **common lobster** is caught in large numbers, particularly in the summer months when many thousands are delivered every day at Billingsgate Market in London. The smaller crayfish found in rivers is structurally very similar, so that a broad general description of a lobster will apply to both. The main portion of the body is composed of the **cephalo-thorax** (Fig. 72), so called because it contains the head or *cephalon* embedded in the thorax, and the abdomen, which has six jointed segments and a fan-like tail. The two compound eyes are borne on little stalks and protected by the projecting *rostrum.* Below the eyes are situated two pairs of antennae, one pair long, the

other short. Lower down are the small mouth and the jaws. Attached to the cephalo-thorax are five pairs of jointed legs, the first pair bearing huge pincers or *chelae*, the second and third pairs also having smaller pincers in true lobsters; in this respect the true lobster differs from the so-called Spiny Lobster which has no pincers on these legs.

Most of the abdominal segments are furnished with appendages called *swimmerets*. The whole calcareous armour is continuous though thinner and flexible at the joints. The rigid nature of this casing necessitates periodic changes so that the animal can increase in size. When a lobster moults, it emerges completely from its shell which is cast aside whole; the new shell formed within the old one is soft and adjustable at first, but soon hardens

The structure and arrangement of the internal organs of the lobster are fairly complicated, but since similar organs or their equivalents recur in many other animals described later, it is as well to make a preliminary consideration of organs and functions here, without too much detail.

It may be said of most animals, at this or higher stages of complexity, that they possess a few systems of organs, each concerned with some process vital to the living organism as a whole.

In the *circulatory system* of the higher animals, a contracting and expanding muscle, the **heart,** pumps blood through the arteries and vessels so that it can be brought into contact with all the cells of the body; the blood carries nourishment to the cells, brings oxygen to them whereby chemical changes are initiated yielding energy for the life processes of the cell, and removes carbon dioxide and other waste products which are formed.

The *respiratory system*, or means by which the process termed breathing is carried on, enables the blood to renew its supplies of oxygen and to discharge the carbon dioxide it gathers up during its journey through the body tissues. Quite as important is the *digestive system*, the function of which is to prepare food in the **stomach** so that it is properly absorbed or digested in the **intestine.** Digestion of food is necessary for the maintenance of vigour at all periods of life and for the increase

of bodily material required for growth during the immature stages.

The sense organs or *nervous system* enables an animal to see and feel its prey, to control the movements of its limbs and body, and to correspond with its environment in other ways, such as smell, taste and hearing. The nervous system is associated with instinct and intelligence, which are based on sense experience.

In lobsters, as in fish, the breathing or **respiratory organs** consist of **gills,** not lungs, since the latter are quite unsuited to respiration in water. The gills consist of thin plume-like membranes containing blood-vessels which permit oxygen dissolved in the water to pass by osmosis through to the blood, and the carbon

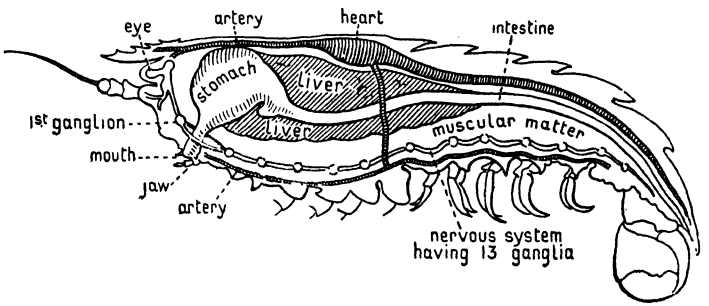


FIG. 73.—THE INTERNAL ORGANS OF A LOBSTER.

dioxide to pass out from the blood to the water. Fig. 73 being a section through the middle, does not show the gills, which are at the sides of the head. The elongated heart pumps nearly colourless blood to the gills through a system of arteries which divide into smaller vessels called capillaries.

The main parts of the **digestive system** include a sac-like stomach, a long intestine and a large liver, which is a gland secreting digestive fluids passed into the intestine in order to assist in the process of food digestion.

The **nervous system** consists of a chain of thirteen pairs of ganglia or nerve centres connected by nerves extending along the body and sending out nerves in other directions. The two larger ganglia nearer the eyes are the most important and control the greater part of the animal. Though no special organ of

taste has been found, a lobster smells and hears, the organ corresponding to ears being situated in the basal joint of the smaller antennae or antennules. The remaining parts of the body are composed of muscle, which forms the edible portions. The organs of reproduction are very similar to those of many other animals, the young being derived from eggs.

In general structure, **shrimps** and **prawns** are very much like lobsters on a small scale. Shrimps when boiled are brown, but prawns are pink and of a larger size. The common shore crab is so built as to resemble the product which would be obtained if lobsters could be stretched sideways and contracted lengthways. There are other differences, the most noticeable being the very short antennae in the crab.

Among the higher invertebrates are the Cephalopoda (=head footed), which include the cuttlefish, *Octopus*, *Nautilus*, and the extinct *Ammonites* and *Belemmites* found as fossils in rocks of Mesozoic age. The common cuttlefish or *Sepia*, which is not a fish at all, has two large eyes, and a beak-like mouth surrounded by two long arms or tentacles and eight shorter ones, all supplied with suckers. There is no outer shell as in *Nautilus*, though there is a soft white porous internal 'bone.' A characteristic feature is the 'ink sack' or gland which secretes the pigment called sepia used by artists. This fluid is ejected into the water, so darkening it, and forming a protective screen around the animal.

FISHES

A serious weakness in the geological record consists of the absence of evidence concerning links connecting the invertebrate animals with the vertebrates. Fossil primitive fish-like creatures are found in early Palaezoic rocks, but these remains consist merely of skin armour which belonged to creatures lacking a lower jaw and paired fins, the latter in fish corresponding to the limbs of land animals. A vertebral column, if such existed, must have been very soft and incapable of fossilisation. Even at the present time there are two main groups of fishes, the **Elasmobranchii**, which have vertebral columns composed only of cartilaginous matter or gristle, and the **Teleostei**, which possess

true bony vertebrae. Sharks and-dog fish, types we could very well do without, are examples of the elasmobranchs, while the great majority of edible fish—salmon, trout, plaice, herrings, and a host of others are members of the Teleostei. The earliest remains of true fishes are found in an old formation called the Silurian, the elasmobranchs coming on the scene a little before the others. In addition to the cartilaginous skeleton, primitive features exhibited by modern elasmobranchs include the absence of a covering for the gills, and a *heterocercal* tail, that is, one composed of two lobes of unequal size.

The general structure of a typical bony fish may be understood by consideration of a well-known example, the **trout**

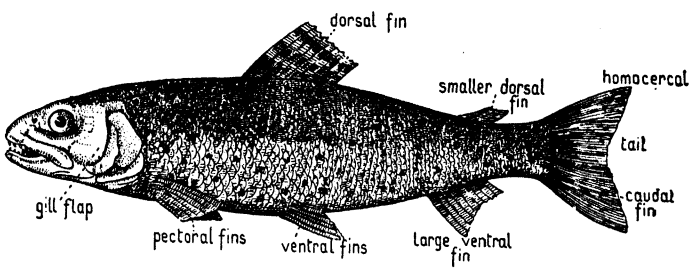


FIG. 74.—TROUT
SHOWING THE ARRANGEMENT OF FINS AND SURFACE MARKINGS.

common in our rivers and lakes (Fig. 74), but the family is by no means confined to fresh water, since some varieties are found in the sea. The body of the trout is elongated and graceful, has no neck, and is terminated by a *homocercal* tail, *i.e.* one having two equal lobes (Fig. 74). The head portion contains large eyes without lids, nostrils connected with the sense of smell but in no way connected with breathing, a wide mouth furnished with pointed teeth, and the respiratory gills, which are protected by a flap. The process of breathing is performed without effort; a current of water enters at the mouth, passes over the gills and emerges at the gill slits. A fish looking upstream with its mouth open has the necessary work done by the current of river water. The sense of hearing is experienced by means of an

internal ear or labyrinth corresponding to our own inner ear structures.

On the body there are various projecting membranous structures called **fins**, in most of which the membranes are supported by bony rays which are not attached to the vertebral column. Fins vary in number, size, and position in different fishes, those in the trout consisting of a large caudal fin, commonly called the tail, a pair of pectoral fins, another ventral pair, a larger fin nearer the tail, and on the upper or dorsal surface a large dorsal fin, and a smaller one having no bony support.

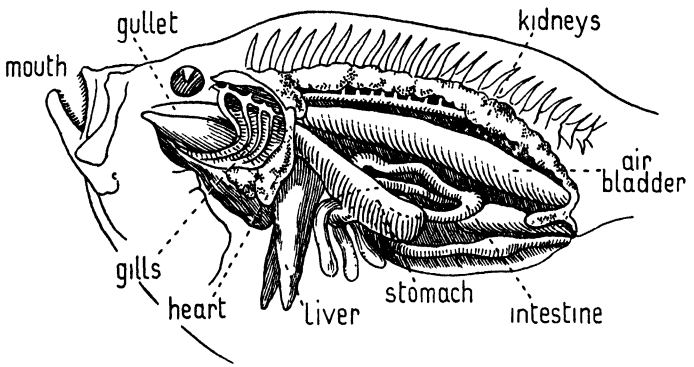


FIG 75.—CHIEF INTERNAL ORGANS OF A FISH (PERCH).

The functions of fins are connected with locomotion and balance, the caudal fin being the chief means of propulsion through the water, while the pectoral fins act as a brake checking, when necessary, the creature's speed. The other fins preserve the general balance. The body is covered with small grey scales kept smooth and slippery by a slimy substance excreted through pores along each side of the fish. Numerous red spots are characteristic of a trout's external ornamentation.

The internal organs as a whole are fairly similar to those of a lobster and perform similar functions (compare Figs. 73 and 75). Breathing is by means of gills, where cool red blood exchanges gases, oxygen and carbon dioxide, with the water flowing out by the gill slits. A fish's heart contains two communicating

chambers, one, the **ventricle,** expelling blood along the arteries to the gills, and the other the **auricle,** receiving the blood returning from the gills and other parts of the circulatory system. The heart is thus simpler than that of a reptile, which has one ventricle and two auricles, and still more primitive compared with the mammalian heart, which possesses two ventricles and two auricles.

The mouth communicates with the stomach by way of a long gullet or **oesophagus,** and a long intestine is looped in order to adapt itself to limited space. The **liver** performs the usual work of manufacturing a fluid which assists digestion in the intestine and also stored food substances obtained from the blood. The **kidneys** are linear, not rounded as in many other animals, but do similar work in removing waste products from the body. A special structure characteristic of most fish is the large **air bladder,** which adjusts the buoyancy of the animal but is not connected with respiration. The nervous system is more highly developed than that of a lobster and consists of a definite though small brain connected with various sensory nerves which enable the animal to perceive things (see, smell, hear, etc.), and motor nerves which control the movements of the muscles, etc. As in other animals, it is the muscular material that constitutes food for human consumption. The organs and muscles are supported by the skeleton consisting of a large number of separate bony sections or vertebrae connected together by cartilage. The rays or spines which support the fins are separate from the vertebral column.

Though the trout is much prized as an article of diet because of its flavour, the **salmon** is considered even more of a delicacy. This fish when fully grown is about three feet in length, though some may be longer than this and weigh as much as 80 lb. The salmon lives in the sea during winter, but ascends the rivers in spring in order to lay its eggs there, though some live permanently in lakes and rivers. The young salmon are known as **parr** and closely resemble trout in their surface markings, but when they are about two years old they become more silvery and are then termed **smolts.** The smolts go down to the sea in early summer and are then known as **grilse,** but after one or two winters in the sea they return to the rivers to breed, after which

the fish is called a **kelt.** A salmon may lay eggs once only, or three or four times, and the length of its life is usually less than ten years During its visits to fresh water a salmon takes very little food, but when in the sea it is very voracious, devouring small fish of all kinds. The best British salmon fisheries are in the rivers of Scotland, particularly the Spey and others flowing to the North Sea, though the fish usually frequents rivers facing

(*After J A Hutton*)

FIG 76 —TROUT (above) AND SALMON PARR (below)

the west, as in the Shannon, the Cheshire Dee and the rivers of North Devon

The migrations of the salmon seem insignificant when compared with the journeys undertaken by the **eel** during its extraordinary life history. The common serpent-like eel lives most of its lifetime in fresh water, rivers and ponds of Western Europe, but in late summer the older eels leave their places of residence, descend streams and rivers, cross land if necessary to reach these streams, and then, making their way into the Atlantic, they proceed far out to some deep part, believed to be somewhere near the Azores Here they lay their eggs, which eventually yield tiny, thin, flat and glassy creatures very unlike eels, and known

as **Leptocephali** (Fig. 77). These proceed eastwards, taking two or three years over the journey, and slowly changing in shape; then as young eels or **elvers** they proceed upstream to countryside ponds, where they live the main portion of their lives as ordinary eels, returning again to the sea in order to lay their eggs, never to return. Eels breed only once, and always in the ocean.

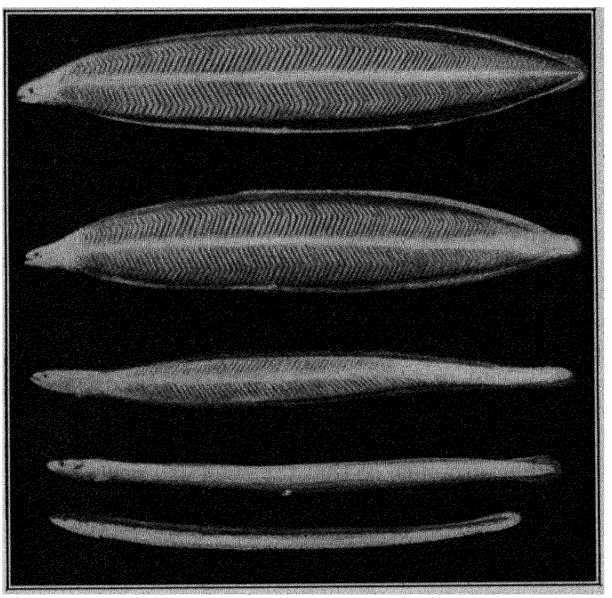


FIG. 77.—THE METAMORPHOSIS OF THE COMMON EEL.
(*After Dr. J. Schmidt, of Copenhagen.*)
(By courtesy of the Director, British Museum: Natural History.)

Though these are examples of *migratory fish* which spend part of their time in salt water and part in rivers, there are many families which inhabit only salt water, and others peculiar to fresh water. Among the latter are the British fish known as carp, barbel, chub, the little minnow, dace, roach, bream, and perch. The fierce, armoured pike is one of the few remaining examples of the Ganoid fishes, a group much more numerous far back in geological time. The sturgeon is a related marine type.

Among the typically marine types are the members of a very useful family called the *Clupeidae*, which includes herrings, sprats, and pilchards. Of these the first place of importance is easily taken by the **herring,** which inhabits deep water but comes near the shore periodically for breeding purposes. Immense numbers exist in the Atlantic, and their visits to the shores of Great Britain are constant, so that great quantities, more than 400,000 tons a year, are caught. Herrings are salted and packed in barrels. **Bloaters** are herrings which have been lightly salted and smoked, while in the case of **kippers** the fish have been split open before being ' cured.' **Sprats** are small fish of this family, and as in the case of herrings, they are salted and packed in barrels, but without having their digestive and other organs removed. Immature **pilchards** of the Atlantic and Mediterranean are beheaded, though the internal organs are retained, and are then salted and immersed in hot olive oil, the tinned product being the ' sardines ' of commerce.

The enormous quantities of fish consumed as food are nearly all derived from marine kinds, another family, the *Gaddidae* supplying us with large fish—cod, haddock, and hake. More than one million pounds worth of **cod** is landed at British ports every year. These fish frequent elevated portions of the sea floor as feeding grounds, so that the chief cod fisheries are those of the Dogger Bank in the North Sea, and of the submerged banks off Newfoundland and Iceland. **Hake** is quite common off the coasts of Devon and Cornwall. In spite of the enormous quantities of fish caught, the numbers available remain good on account of the extraordinary reproductive powers of these animals, a female cod's **roe** containing several millions of eggs. Few of these become adult fish, however, by reason of the destructive processes at work in the sea resulting from the struggle for existence.

Another interesting and useful group is that of the ' flat ' fish or side swimmers, among them being **sole, plaice,** and **turbot.** These spend most of their time lying on the sea floor. The under surface is white but the upper surface is coloured and contains the eyes, which are thus one above the other, as these fish swim on their sides.

Though food is the main commodity obtained from fisheries, there are some important by-products, notably **cod liver oil,** also **fish meal** and **fish manure** obtained from the heads, internal organs and otherwise waste parts generally. The chief fishing ports of Great Britain—Grimsby, Hull, Fleetwood, and Aberdeen —all have works producing these by-products. **Isinglass** is a substance obtained from the air bladder of the **sturgeon,** one of the few living representatives of an armoured type of fish referred to above. The chief sturgeon fisheries are in the Black Sea, and the isinglass imported from Russia is used for the manufacture of jelly and the refining of ale. The roe of the sturgeon supplies the delicacy known as **caviare.**

Whales are not fish, and the useful products obtained from certain species are considered later in a chapter dealing with mammals.

THE FROG

Life in a pond is perhaps not so varied as in the sea, but nevertheless there is a very mixed fauna ranging from microscopic protozoa at one end of the scale to amphibians—frogs and newts—at the other end. Larvae of many insects, water beetles, dragon flies and others, water bugs, the little jelly-like Hydra, the fresh-water mussel corresponding to the marine bivalves, pond snails, fish, and other creatures constitute a mixed crowd, many of which prey upon some of the others. The highest type of animal life found in this collection is the **common green frog** (*Rana temporaria*), classed as an *amphibian* because it can live both on land and in water. During the winter it hibernates, that is, it ' winters,' or remains inactive in the mud at the bottom of a pond.

The structure of a frog is in many ways much more advanced than that of a fish; for example, the **skeleton** is much more developed, having definite limbs instead of fins (Fig. 78). In addition to the short central *spinal column* composed of nine *vertebrae*, there is a *shoulder girdle* consisting of shoulder blades or *scapulae* and other bones connected with those of the fore limbs. Similarly there is a corresponding *pelvic* girdle at the other end connected with the bones of the hind legs. There is a breast bone

or *sternum* in front, but there are no ribs to protect the internal organs.

If we examine the **limb bones** of a frog we find that they are composed of bones equivalent to those in the legs and arms of higher vertebrates. The front legs consist of the upper arm bone or *humerus* which articulates, that is, it is connected by a joint, with the radio-ulna, a compound bone consisting of the radius and ulna fused together. These are followed by several *carpel* or wrist bones which are in turn succeeded by the jointed bones of the four fingers and a rudimentary thumb. In the hind legs there is an arrangement of longer bones consisting of a femur or thigh bone, followed by another long bone, or rather two fused bones, the *tibia-fibula*, so called because it represents the separate tibia and fibula of the lower leg in most vertebrates. The *tarsal* or ankle bones are elongated, and there are five large toes and one small extra one called the *calcar* (spur), these toes during life being connected by a skinny membrane which forms an excellent swimming apparatus.

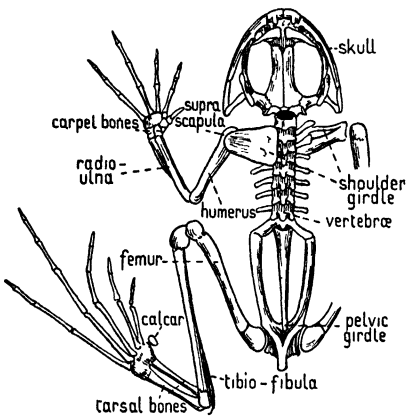


FIG 78.—THE SKELETON OF A FROG

The **skull** consists of a very large number of bones and is far too complicated to be considered in detail here, though one or two more apparent features should be noted. The two large spaces indicate the position of the eyes, and two smaller spaces farther to the front mark the position of the nasal openings. The lower jaw is very broad and has no teeth, though the upper jaw is furnished with many pointed teeth used for holding food but not for mastication. The frog has a long flexible and sticky tongue hinged at the front of the mouth, which is used for catching insects, etc.

The more important **internal organs** are here illustrated by a sketch (Fig. 79), in which the various parts are named in a manner similar to that used in the illustration of the internal arrangements of a fish, so that a comparison can be made without a detailed description. It must be noted, however, that **breathing** is performed by means of *lungs*, not by gills, in the adult frog. The **nervous system** is on a more advanced scale than that of a fish, but any adequate description is beyond the scope of this book.

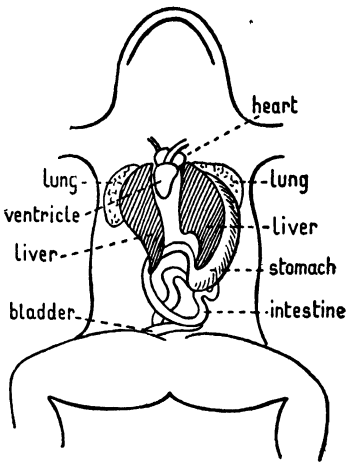


FIG. 79.—CHIEF INTERNAL ORGANS OF A FROG
SEEN FROM THE UNDER SIDE.

In its life history the frog undergoes some very interesting changes or metamorphoses (Fig. 80). In late spring the female lays hundreds of eggs in water and these swell into a slimy mass of rounded bodies collectively known as **spawn**. In the case of the toad, a related animal, the spawn is in the form of chains, not clusters. Each dark spot in the centre of a rounded gelatinous mass is an **embryo** from which a **tadpole** emerges in about fourteen days' time. At first these dark little creatures have no mouths and feed upon foodstuffs stored within the body. At this time they breathe by external gills and cling to objects by means of a pair of suckers on the under side of the head. In a few days' time a mouth is formed, so that they can feed upon vegetable matter, and internal gills form, while the external ones disappear. The hind legs now appear, and later the front ones develop at the same time as the lungs are being formed. For a time both gills and lungs can be used for breathing, but in the latter case the tadpole comes to the surface to inhale. Later, the skin is cast off and with it the gills are lost, so that the animal then breathes only by lungs; also its food changes from vegetable to animal

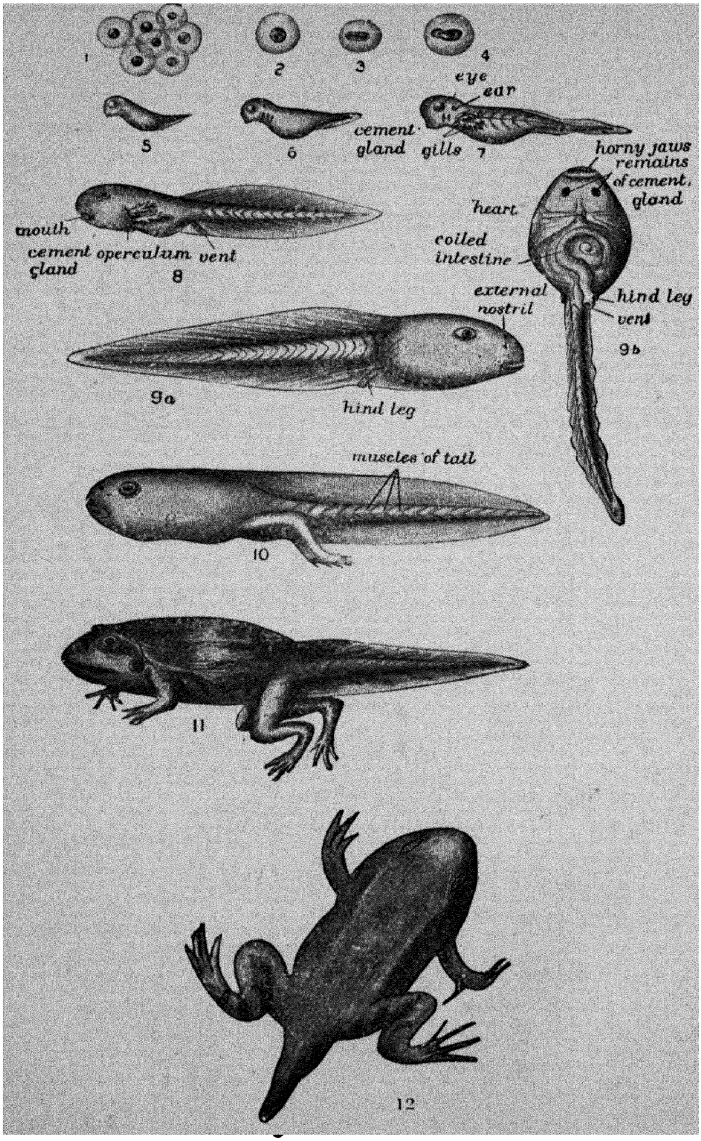


FIG 80.—THE METAMORPHOSIS OF A FROG.

NUMBERS REFER TO SUCCESSIVE STAGES

matter. In the final stages of development the hind legs become large and strong, the tail is absorbed, and the complete frog adapts itself to a life mainly on land generally about three months after the eggs are laid. The frog is a useful friend to a gardener, as it lives on slugs and insects.

The development of **toad tadpoles** proceeds along lines very similar to those of the frog, but in the case of **newts**, which are also amphibians, the eggs are laid singly, the tadpoles are pale coloured, the front legs appear earlier than the hind limbs, and the tail is retained in adult life.

CHAPTER IX

BIRD LIFE

THE conquest of the air by birds and insects has given these groups of animals considerable advantages over less fortunate creatures which remain on the ground. The more obvious advantages of flight are escape from enemies, a wider field and greater facilities for food collection, and a quick journey to far distant warmer climates when food becomes scarce owing to the approach of winter in higher latitudes.

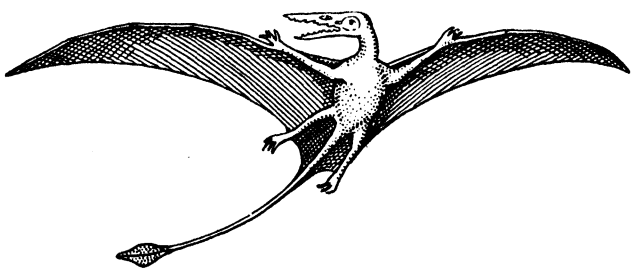


FIG. 81.—A PTERODACTYL OR FLYING REPTILE OF THE MESOZOIC PERIOD.

As we should expect from their well-developed or specialised structures, birds are a fairly late product of evolution and cannot boast such ancient lineage as that of insects. The oldest known fossilised bird remains have been found in a fine grained lime-stone, the Lithographic 'Slate' of Solenhofen in Bavaria, which is of Jurassic age (*i.e.* Middle Mesozoic). The remains of this primitive bird, called **Archaeopteryx**, show that it possessed feathers, but had teeth and other features inherited from the reptilian ancestral types from which birds are believed to be

descended. Flying reptiles, called **Pterodactyls,** existed a long time before the appearance of true birds, the remains of small species of pterodactyls being found in certain dark coloured limestones of earlier Jurassic age forming portions of the south coast of England at Lyme Regis, and inland in Dorsetshire, Somersetshire, and other districts (Fig. 81). In later rocks of chalk age, in America, remains of the huge flying reptile, the **Pteranodon,** show that these creatures developed an expansion of twenty feet from the tip of one wing to that of the other, but as in so many other cases, mere bulk proved a disadvantage, and the race became extinct.

ADAPTATION TO LIFE IN THE AIR

Flying animals, whether pterodactyls, birds, or bats, may be regarded as machines heavier than air, so that considerable force has to be exerted to raise and sustain them in the air In this respect these animals are like aeroplanes. The force is obtained by muscular contraction, the muscles concerned being those of the arms, which in flying animals are very well developed and supported adequately by suitable bony framework. In the process of flight, the arm in conjunction with the air itself form an arrangement known as a lever (see also Ch. XIV). In any lever there are three components, the weight to be lifted, the power, and a fulcrum When you catch hold of a horizontal bar above your head, and pull yourself up, your body is the weight, your muscles supply the power, and the bar is the fulcrum.

Similarly, there is the weight of the bird's body, the power of the arm muscle; but what constitutes a fulcrum? The air itself, particularly that portion of it *just under the outer edge and tip of the wing* is the fulcrum. So rapid are the wing beats, sometimes as many as 200 per minute, that the air offers considerable resistance, and the bird literally knocks the air and rebounds upwards as the result. In some early attempts at human flight artificial wings were attached to a man's arm, but such a method was doomed to certain failure since the human arm is not adaptable for such use, and the muscles are far too weak in proportion to a person's weight.

A bird is a master in the art of using air resistance, so that it soars upwards, glides horizontally, or swoops downwards just as it desires. The tail feathers constitute the main steering gear.

Now consider the general structure of the wing or arm in each of the three cases—pterodactyl, bird, and bat, the last named being a mammal (Figs. 81 and 82).

In each there is a humerus or upper arm bone, next the radius and ulna, forming the forearm, then the hand, the part which shows such variation in the three types. The pterodactyl had a skinny membranous wing supported by an enormously developed fifth finger and attached to the leg, and in some species to the tail as well. There were four other rudimentary fingers

FIG. 82.—THE ARM AND HAND OF A BAT COMPARED WITH THOSE OF A BIRD.

not concerned with flight. A bat also retains the primitive five-fingered hand, but four of the fingers are greatly enlarged and share the work of supporting a membranous wing which, like that of the pterodactyl, is also connected to the legs and the tail.

In a bird the hand is better adapted to the requirements of flight; it is highly *specialised*, consisting of one well-developed finger and parts of two others. The case is somewhat similar to the foot of a horse, which has one highly specialised toe and mere long splinters representing two other toes. The large finger of a bird corresponds to digit number two of any animal still having the primitive unspecialised hand with five digits. Perhaps the most remarkable feature of this adaptation to flight is the possession of feathers, which are so beautifully arranged as to form a perfectly air-tight sail when the wings are extended.

A typical feather has a central shaft or stem, on either side of which there is a web-like vane composed of very numerous thin

and flat structures called **barbs**. The barbs interlock with one another by means of minute hooks termed **barbules**. In flightless birds, such as the ostrich, where an air-tight arrangement is not required, the barbules are not developed properly, there is no interlocking, and the feathers are consequently of a more 'fluffy' or discontinuous character. Marabou feathers, used as articles of dress, are similarly degenerate types of feather known as semi-plumes. At the base of a feather there is a hollow shaft known as a quill.

In most birds, the larger feathers which cover the body and so determine its general outline, are known as **contour** feathers, and these connect with the body along definite tracks. Smaller feathers hidden beneath the larger ones are called **down** feathers; those obtained from certain birds, particularly water species, such as the swan and the eider duck, are of commercial value. In some birds, for example pigeons, the down feathers are completely absent.

The plumage of birds is periodically shed in the process known as moulting, which corresponds to the shedding of scales by reptiles. Many birds moult twice in a year, during spring when the smaller feathers only may be discarded, and again in autumn when a complete change of covering occurs, giving rise in some cases to distinct seasonal variation in appearance.

Some birds, such as swallows and martins, moult only once, while others, like the ptarmigan, moult three times in a year. Various species exhibit considerable variation in the period and frequency of moults during their first year when growth is required.

The bird's great superiority in powers of flight is an example of advantage gained by specialisation, and as we shall see, the wing is by no means the only part of a bird that has become specially adapted to certain functions. The digestive system is arranged to suit certain kinds of food, and the feet are so formed as to be particularly suitable to perching, climbing, wading, running, or swimming as the case may be. But for the present let us return to the study of the bony framework.

SKELETAL STRUCTURES

Many of the bones are porous or cellular, which combines strength with lightness, and often these cavities are in direct communication with the respiratory or breathing system so that such bones themselves are aerated (Fig. 83). In most birds the humerus or upper arm bone is pneumatic, and if this bone be broken it is possible by blowing down it to inflate the lungs of a dead bird if the windpipe is first tied up.

If we examine the skeleton of a common fowl (Fig. 84), we find that its component parts are somewhat similar to those of a frog, though in some ways it shows considerable advances in complexity and specialisation.

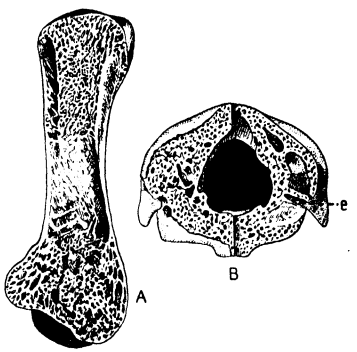


FIG. 83.—SECTIONS THROUGH (*A*) THE FEMUR OF AN OSTRICH, AND (*B*) THE SKULL OF A CARINATE BIRD.

In the fowl the vertebral column is much longer, having a large number of vertebrae in the neck and several in the tail, the furthest being fused into a bone called the **pygostyle** which forms an adequate support for the tail feathers.

The **sternum** or breastbone of a frog is relatively small, but that of a fowl is very large and has a prominent crest or **keel,** the whole forming an excellent support for the powerful muscles necessary for flight.

In ostriches or other flightless birds, the keel is much reduced or absent altogether; it is not required. The breastbone is also connected to five pairs of ribs which join with other ribs attached to the backbone, though there are a few *free* or false ribs connected to certain vertebrae but not to the sternum.

The ribs attached to the backbone bear oblique extensions, called **uncinate processes,** which form little cross bars from one rib to another, thus affording additional support.

The shoulder blades are long and narrow, while the collar

bones or clavicles unite to form the peculiar V-shaped bone popularly known as the 'merry-thought.' In the pelvic region the girdle bones are fused together to form an elongated compact mass. Forming the hind limb are a stout **femur,** followed by a compound bone, due to the fusion of the tibia and fibula, though separate knob-like terminations indicate the true character of

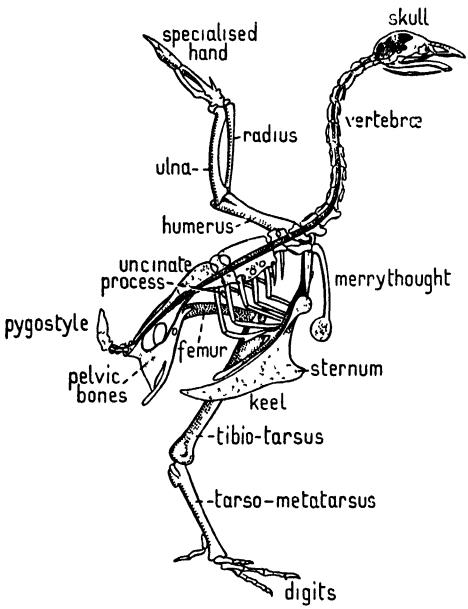


FIG 84.—THE SKELETON OF A FOWL

this bone, and a still lower compound bone, the **tarso-metatarsus,** often miscalled the 'leg.' This bone is really equivalent to the ankle bones of mammals, and is connected to four jointed toes, the first one being directed backwards, the others forwards. This arrangement of toes is that also found in the Passeres or perching birds, a group that includes most of the small birds seen in our gardens.

It may be as well to consider now the various other arrangements of feet adapted to different kinds of work (Fig. 85). In

most land birds the feathers extend right to the toes, though in the common fowl and others of its class (*Gallinacea*) scales cover the tarso-metatarsus. Climbing birds such as the cuckoo have rather long toes, two directed forwards, the other two backwards. Swimmers like the duck are furnished with web-like processes between the three front toes and extending as far as the very tips. Compare the very much smaller webbing between the

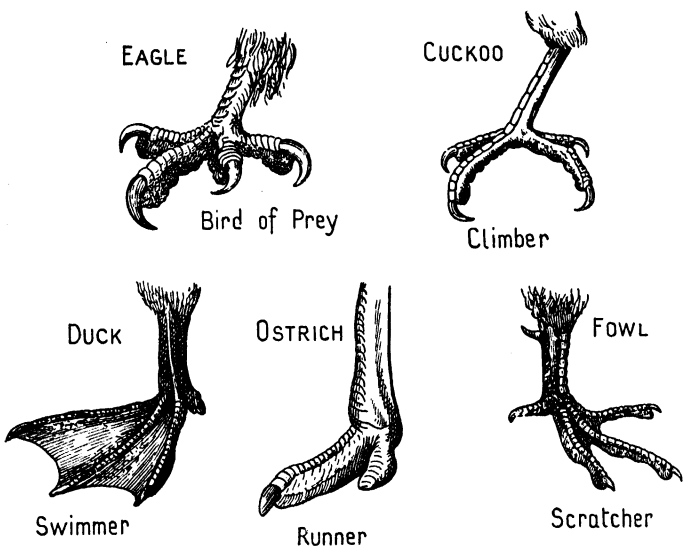


FIG. 85.—TYPES OF BIRDS' FEET
ADAPTED TO VARIOUS FUNCTIONS.

toes of a fowl. In cases such as the pelican where the feet are used for steering, the webbing embraces the fourth toe as well. Waders like the stork have long legs with toes having little or no webbing between them. The ostrich and its allies have powerful hind limbs having only two toes, an arrangement more convenient for running, and one toe, furnished with a nail, is much longer than the other (compare the one toe of the horse).

Birds of prey, illustrated by the eagle, are furnished with four large toes, each bearing a powerful claw.

We have now briefly considered specialisation of hands and feet, and the skull furnishes other examples, the beaks being adapted to the mode of feeding A bird's skull is composed of a large number of bones, but those forming the cranium or brain

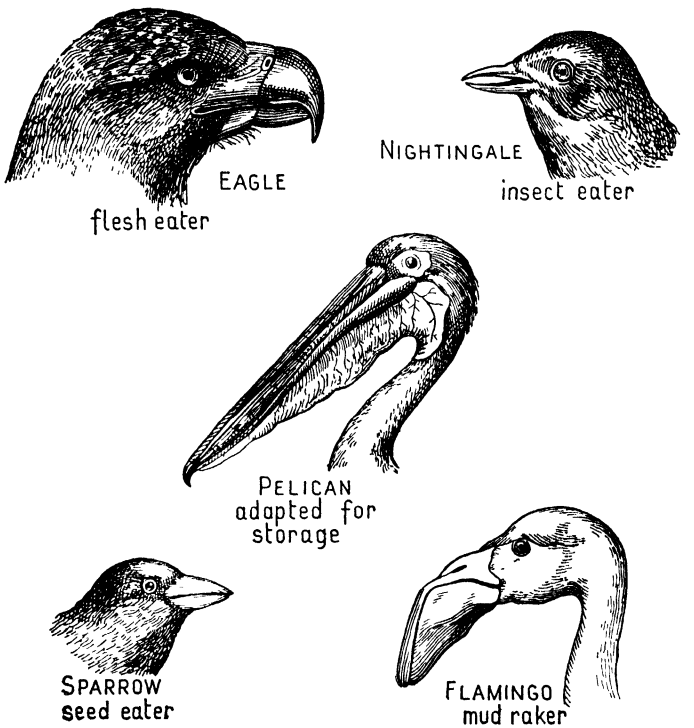


FIG 86.—TYPES OF BIRDS' BEAKS
ADAPTED TO VARIOUS FORMS OF DIET

case fuse together in adult life so that the lines of division or sutures seen in a mammalian skull are absent except in young birds. The junction of the head with the neck is made by means of rounded bones called **condyles,** and birds resemble reptiles in having only one condyle, whereas in mammals there are two.

The bones of the face are prolonged to form beaks which are covered by a horny substance, which in some cases has a rough saw-like edge, though nothing analogous to teeth is found in any modern bird. Eagles, vultures, and other birds of prey have strong hooked sharp beaks capable of tearing flesh (Fig. 86), though some birds, notably the parrot, use a curved beak, not for tearing food, but as an assistance in climbing. Insectivorous birds, such as the nightingale, possess rather long thin pointed beaks, while those of seed eaters, the common sparrow for example, are shorter and wider. Ducks and others which search for food in water have very wide beaks, while the peculiar bent mandible of a flamingo is adapted to searching for food in the mud. The pouch attached to the lower jaw of a pelican serves as a means of storage, the food being consumed when desired.

INTERNAL ORGANS

The digestive system of a bird is rather different from that of the frog or that of a mammal. **Saliva,** the juice which operates in the mouth of most animals, plays no part in the digestive process of a bird. There is a wide and long gullet or **oesophagus,** a lower portion of which is expanded considerably, forming a cavity known as the **crop** (Fig. 87). Here the food is retained for some time, softened, and then passed into a still lower cavity, called the **proventriculus,** which is really a second expansion of the gullet where glands prepare digestive juices and pour them upon the food. From the proventriculus the food is passed to the **gizzard,** the function of which is mechanical, the food being reduced to small particles. This is a strong muscular organ having a thick horny lining and capable of grinding up hard food such as nuts; small stones, etc., are deliberately swallowed to help in the process. Thus the proventriculus and the gizzard together do chemical and mechanical work analogous to that done by the stomach and teeth of most other animals. The food being thus prepared proceeds along the fairly long and tortuous **intestine** where most of it is absorbed. As in other animals we have considered, a large **liver** secretes a bile-like fluid and passes it into the intestine, and another glandular organ, the **pancreas,**

situated at the upper end of the intestine, supplies a fluid which, like bile, is concerned with the complex chemical processes of digestion.

Breathing is performed by very spongy lungs which communicate with certain air sacs placed near the top and sides of the body cavity, and as has been stated above, many cavities within the bones are also included in the air circulation. The windpipe of a bird is peculiar in consisting of a series of bony rings The voice in mammals is produced by the **larynx**, but in birds it is produced in the **syrinx** at the lower end of the windpipe.

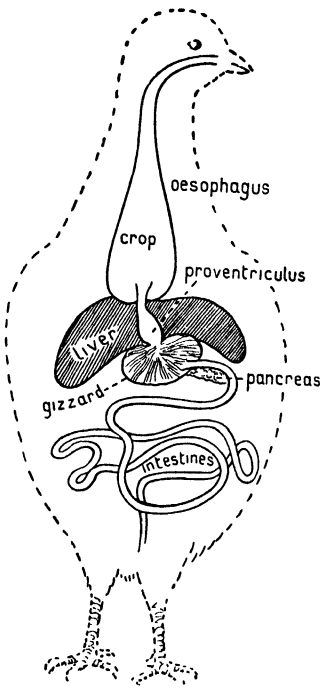


FIG 87.—THE DIGESTIVE ORGANS OF A BIRD (DIAGRAMMATIC)

Both the circulatory and nervous system are very much more advanced in type than that of a reptile. As in mammals, the heart contains two ventricles and two auricles, which means that the impure or venous blood does not mix with the pure arterial blood (Chapter X). The blood temperature is considerably higher in birds than in any other animals, and may be as high as 112° F., as in the swallow. This high temperature, which accompanies a high degree of vitality, must be maintained, so that an inactive life due to hibernation is not possible; birds which cannot procure food in winter migrate to a warmer country.

The brain, though better developed than those of lower vertebrates, is smooth and rounded. Certain senses are particularly well developed, eyesight being better than in any other class of vertebrate animal. The eyes, which are large in proportion to the size of the body, are protected by movable eyelids and by a

transparent membrane. A special feature consists of a ring of bony, overlapping plates, forming an adaptable aperture in front of the eyeball so that focus can be adjusted to far distant objects, the range of vision being thereby greatly increased.

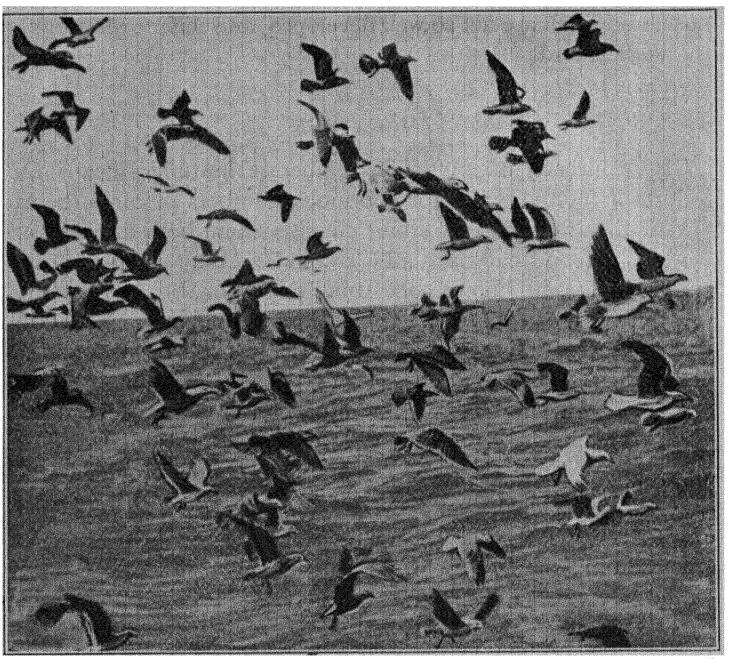
Hearing is acute, but there is no visible external ear, the opening to the internal ear, situated a little lower and behind the eye, being covered by feathers. The other senses of touch, taste, and smell are not so well developed, and differ considerably in different birds.

MIGRATION

The approach of winter in temperate latitudes means the failure of food supplies for enormous numbers of birds, hence vast hordes migrate to warmer climate where both animal and vegetable food materials still abound. Many centuries ago certain facts were known concerning migration, but owing to the difficulty of the problem, we are, even now, unable to understand the subject entirely. A few salient facts have been definitely established, however.

The fundamental reason for migration is lack of food, birds themselves being as a rule able to withstand mere fall in temperature since they are warm blooded and provided with a thoroughly efficient protective covering of feathers. Such birds as do not migrate are endowed with special ability for obtaining such food as may be obtained in winter. For example, grouse feed on the needle-like leaves of coniferous trees or burrow in the snow for their food. Birds which remain in a region throughout the year are known as **residents,** one of the most common British residents being the bird known as the hedge sparrow, though it does not belong to the sparrow family. Some of the pied wagtails afford another example. But the great majority of birds are migratory, and it may reasonably be asked why they do not remain all the year round within the tropics where it is never winter. The excessive heat of some lands may be nearly as injurious as considerable cold, since leaves become parched and insect life is scarce in less watered tropical regions.

In the more favoured tropical areas there are already enormous numbers of residents, and these would naturally be seriously affected by the settling of countless millions of birds now inhabiting temperate latitudes. These temperate types must pass from such latitudes, northern or southern as the case may be, to corresponding latitudes in the other half of the earth as



(Photo. by Messrs Wyles)

FIG 88.—GULLS ON THE WING

seasonal variation occurs. In general, most species which live in high latitudes north will in northern autumn migrate to fairly high latitudes south, and the greatest distance is traversed by such birds as the Arctic tern, which passes from the Arctic to the Antarctic circle, a distance of more than 9000 miles Most British migrants winter in South Africa.

Local geographical conditions may modify the general rule;

for example, the climate of the British Isles being maritime or less extreme than that of mid-Europe, some species which are migratory there may remain as residents in Britain. Vast hosts of larks, thrushes, etc., which summer in Central Asia, move westwards in winter to the milder climate of Western Europe without much change of latitude. In high, mountainous regions a descent from great altitudes to lower levels brings about the necessary alteration in conditions, and a journey to the south is then not necessary. Again, snipes, redwings, woodcocks, etc., which spend summer within the Arctic Circle. are satisfied with winter conditions in the British Isles without proceeding any farther south. But these cases may be considered as variations of the general rule due to certain causes.

The general great trek southwards takes place *en masse*, millions making the journey together, and often flying at an altitude of 10,000 feet and at a rate of 120 miles per hour, though the speed is largely influenced by prevailing winds. Many birds become exhausted and fall to the earth, and it is these stragglers that tell the experienced ornithologist that vast hordes are on the wing, since the altitude of flight is often so great as to render the flying hosts invisible. The migration instinct is communal in character, and the journeys are made at certain times and along definite routes, though the return is not always by the same way as that of the outward voyage. Much of the journey may be taken at night, and sometimes, when the host is flying low, some favoured lighthouse keepers obtain a view of dense feathered legions attracted by the glare.

ECONOMIC ASPECTS OF BIRD LIFE

A simple statement of accounts estimating the amount of harm done by many birds as against the benefits obtained from various species is not easily made. It often happens that the same species is harmful in some ways and beneficial in others. Thus the thrush and the blackbird are destructive with regard to fruit but also destroy slugs, insects, and other garden pests. Some birds are almost wholly a nuisance, and among these must be placed the true sparrow, which destroys grain and damages the

shoots of young plants, though another type of bird called the hedge sparrow, the diet of which consists of insects and worms, does work of a beneficial character. Undoubted enemies of agriculture are the members of the crow family, particularly the raven, which is quite capable of killing small or weakly sheep, and the behaviour of crows and rooks is not much better.

When we consider the larger birds of prey, we again find that some are harmful, others are beneficial. Though some of these, the condor for example, eat carrion or dead bodies, they are not above sheep stealing. On the other hand, the South African secretary bird eats snakes, while the kestrels, buzzards, and owls feed upon rats, mice, and insects, thus performing a useful service.

Though the feathers of the ostrich, goose, and others are of value commercially, the more obvious beneficial part played by bird life in human affairs is as a source of food, and most, though not all, of this food material is supplied by the group known as **game birds,** which includes the domestic fowl. Most members of this group—pheasants, woodcock, grouse, partridge, ptarmigan, etc.—are too well known to need description, but it must be observed that though some, such as the partridge, are natives of Great Britain, many of them were originally introduced into Britain from other countries. The common pheasant came from Asia Minor, while both the ring-necked pheasant and the golden pheasant have been imported from China. The turkey is a native of North Mexico, and the ordinary fowl is considered to be descended from the wild jungle fowl of India. In order to insure against the extinction of the more prized game birds, pheasants, etc., special **game laws,** which make it illegal to destroy these birds during certain parts of the year (the breeding season) are enforced.

Enormous supplies of poultry and turkeys are obtained from birds cultivated on farms, etc., the Christmas demand for the latter being now so great that many birds are imported from France and elsewhere on the Continent. Other birds not in the same group are geese and ducks.

In addition to the flesh of the fowl, goose, and duck, their eggs are of great value as a food material.

An account of the development of the chick within the egg is quite beyond the scope of an elementary book, but the chief structures of a fowl's egg just after it has been laid should be observed (Fig. 89). The chief part or **embryo** from which the young fowl will develop is in the central yellow portion or **yolk,** which contains a **germinal vesicle** or nucleus. Surrounding the yolk is a thin **vitelline membrane** separating the yolk from the

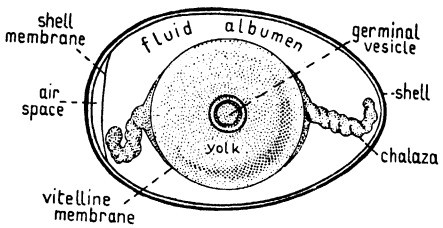


FIG. 89.—SECTION THROUGH AN EGG OF THE COMMON DOMESTIC FOWL.

outer albumen or **white of egg** in which it floats. As the yolk rolls over to keep the germinal vesicle near the top when the egg is moved by the sitting hen, it is protected by two whitish cords or **chalazae** which act as shock absorbers. Between the outer shell and the albumen is another thin membrane which contracts near the less pointed end of the egg, leaving an air space. The albuminous material is stored food matter for the young developing embryo, and in consequence the chick can, unlike some creatures, complete its development before it leaves the egg ; there is no need for any subsequent metamorphosis.

CHAPTER X

THE RABBIT AND OTHER MAMMALS

THE animals which are of the greatest use to mankind belong to a very large and varied group called **mammals**, a name due to the fact that the young of animals in this group are fed by their mothers' milk. That docile and well-known creature, the cow, is a mammal, and cow's milk has become an almost universal article of food amongst civilised peoples. Goat's milk and that of one or two other mammals are also employed at times as a food for human consumption.

Enormous numbers of animals of different species belong to this great group—cattle, sheep, cats, dogs, rabbits, mice, horses, elephants, lions and others far too numerous to be mentioned, but all of them possess certain common characteristics that differentiate them from birds, amphibians, and other forms of animal life described briefly in previous chapters. All mammals with the exception of some of the types which have become adapted to life in water, possess four limbs; all have a blood temperature higher than of fish and reptiles, but generally lower than that of birds; and most are characterised by skins of a hairy nature.

The development of hair or fur is a mammalian mode of adaptation to climate, and to some extent corresponds to the development of feathers by birds; and like the plumage of birds, fur often adapts its colour to the surroundings, this affording some protection to its wearer. Relatively a few mammals living in hot climates dispense with hair and have fairly smooth though very thick skins, for example, the elephant, rhinoceros, and hippopotamus. On the other hand, monkeys, kangaroos, tigers, and most others occupying hot lands, still retain hairy skins,

though it may be observed that the thickness of these furry coverings generally increases as the climate becomes colder, so that the regions where hunting for furs is carried on are chiefly those in high latitudes or near the polar regions—around the Hudson Bay in North America, for example.

Our knowledge of the early history of the mammalia is meagre owing to unfortunate gaps in the geological record, a matter which, however, may be improved by future discoveries It is believed that the earliest known mammal remains consist of the tooth known as *Microlestes*, found in rocks of Triassic age, and supposed to have belonged to a creature related to the low order of mammals which includes the kangaroo of modern times. Much better specimens, consisting of complete jaws and teeth of somewhat similar small animals, have been obtained from certain fine grained rocks of Oolitic age, but specimens of more advanced mammals, which may be regarded as the early ancestral types of our cattle, etc., make their appearance in the relatively young tertiary rocks.

Strata of such age in various parts of the world—the Himalaya, North America, Patagonia, Egypt, etc.—have supplied much material in the shape of fossil bones and skulls, which has enabled experts to trace the family history of several important mammals, including the horse and the elephant

Numerous valuable collections of later or pleistocene mammalian remains have also been obtained from various river gravels and caves, such as Kent's Cavern near Torquay, and in some cases the still more interesting flint implements of primitive man have been found associated with the remains of animals against which he had to contend.

The class Mammalia is so great that only a very brief résumé of certain facts concerning some types can be given in a book of this scope. The main sub-divisions or orders of the class are as follows, those mentioned first being the lowest or least highly organised types.

The Monotremes, including the ant-eater and the peculiar duck-billed platypus of Australia.

The Marsupials, or animals of the kangaroo kind.

Edentata, or toothless mammals of the sloth kind.

Sirenians—manatees and dugongs.
Cetaceans—whales, porpoises, and dolphins.
Ungulata, or hoofed animals, including cattle, sheep, deer, horses, etc.
Rodents, or gnawing animals, such as mice and rats.
Carnivora—flesh eaters, including lions, cats, dogs, bears, etc.
Insectivora—moles, shrews, hedgehogs, etc.
Chiroptera (*i.e.* hand winged), bats.
Primates—lemurs, monkeys, apes, and man.

In spite of this formidable array of orders, it is possible to select one example and study its organs and functions, which may serve broadly as a type for all the mammalia. For example, the mammalian heart is constructed on a similar plan whether it is the small one of a mouse or the large one in an elephant. Similarly, the apparatus of digestion is, on the whole, much the same in various members of the group, and exceptional cases, such as those of the ruminants, will be noted later.

THE RABBIT

The type usually studied by students of biology is the common rabbit, and one cannot do better than consider, without too much detail, the internal machinery of this creature in order to obtain an idea of the structure of mammals generally. Consider first a few elementary facts concerning the vital processes of digestion, circulation, and nervous control.

In the **digestive system** various parts corresponding to similar organs in a frog are easily recognisable, though the digestion and other functions in the mammalia are more complicated or highly organised than they are in amphibia, etc. Grass and other vegetable food is taken into the mouth, where it is mixed with the fluid digestive juice known as saliva secreted by glands within the mouth. Saliva plays an important part in digestion.

The food then descends the gullet or oesophagus and reaches the large curved stomach. The oesophagus passes through the diaphragm or muscular partition separating the digestive organs from the lungs and heart. Muscular contractions of the

stomach roll the food about, and gastric juices secreted by little glands are mixed with it, after which it is passed into the small intestine, a long, tortuous pipe named ' small ' because it is narrow compared with the wider larger intestine below. Near the top end of the small intestine, ducts permit the bile manufactured by the large, many-lobed liver, and stored in the gall bladder, to be mixed with the food, which is now like thick soup and known as **chyme.**

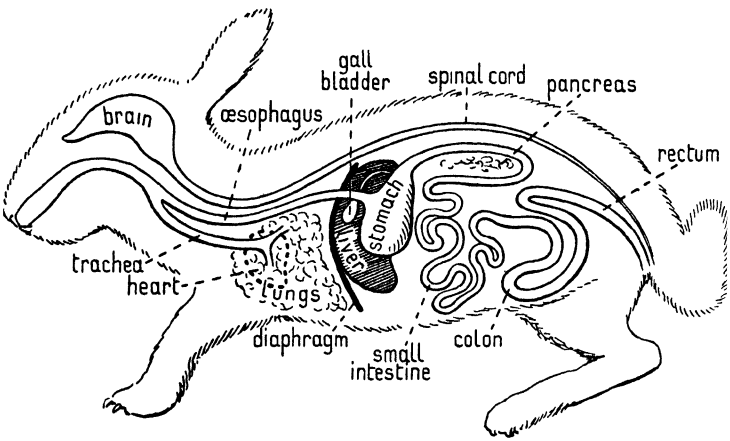


FIG 90.—THE INTERNAL ORGANS OF A RABBIT.
(DIAGRAMMATIC)

The chemical changes which occur within the body are complex and varied; in fact the organs, particularly those of digestion, form a chemical laboratory of a very advanced character. Other fluids are added to the food material by the pancreas, a branching glandular organ. The large intestine is mainly composed of two portions, the colon and the rectum, the latter being connected with an exit for undigested material. Muscular contractions force the chyme along the intestines, and as it passes along, the available food-stuff is absorbed by means of great numbers of little projections called **villi** bearing blood vessels.

The intestines form a pipe system which, if straightened out, would be more than fifteen times as long as the rabbit's body.

A great length of intestine affords opportunity for the thorough absorption of available food-stuff.

The absorbed matter enriches the blood, which then takes nutriment to all parts of the body. The outstanding feature of the **mammalian circulatory system** is the four-chambered heart having two ventricles and two auricles, an arrangement which

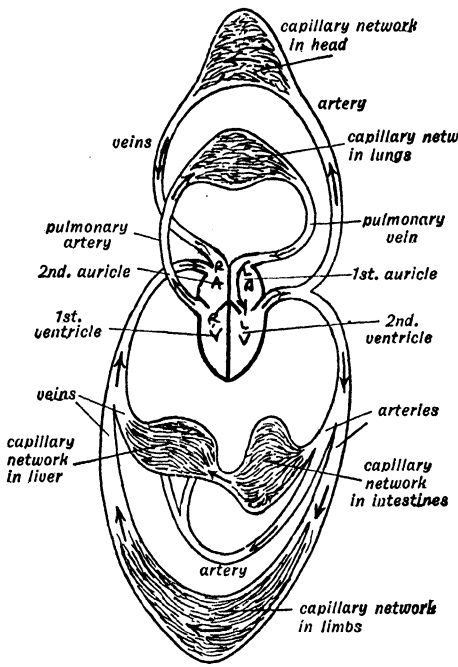


FIG. 91.—DIAGRAM REPRESENTING THE MAMMALIAN HEART AND CIRCULATORY SYSTEM.

means that the impure blood never mixes with the pure blood, as it does in many of the lower animals (Fig. 91).

The heart is a strong muscular organ roughly resembling a rounded and blunt cone, having the chambers called **ventricles** situated at the posterior or blunted end, and the two **auricles** placed anteriorly or in front. A ventricle communicates with a right auricle on the same side of the heart, by means of a

valve which ensures that the circulation of blood is kept in the right direction. Starting from the first ventricle, the blood is forced by muscular contraction along the pulmonary artery to the lungs. Here it is purified and returned through the pulmonary veins to the first auricle. The blood then passes into the second ventricle, from which it is forced along several arteries to all parts of the body other than the lungs. Finally, it returns by way of various veins to the second auricle and passes thence into the first ventricle again.

Certain important differences between arteries and veins must be noted. In arteries, the blood is being forced under pressure away from the heart, whereas in veins the blood is returning at much lower pressure to the heart. If an artery is cut, the blood spurts out like a fountain, worked by a regular but intermittent pump, but when a vein is severed the blood flows more slowly. Arteries branch repeatedly, eventually forming very minute vessels called **capillaries** which ramify through almost all parts of the body. Veins unite, forming a network of tubes conveying the blood back to the heart. The blood itself is composed of a fluid called the **plasma,** in which float many flat round coloured discs called **red corpuscles** and fewer white (colourless) bodies of indefinite shape known as **white corpuscles.**

The colouring matter of the red corpuscles is called **haemoglobin** and easily absorbs and gives up oxygen as required.

The lungs consist of a mass of air tubes divided repeatedly, until finally there are very small tubes each ending in a little sac or **alveolus.** Here oxygen from the air passes through the thin walls and enters the blood, while carbon dioxide goes in the other direction and comes out with the exhaled breath. The kidneys are two rounded glandular organs the duty of which is to remove water and **urea** from the blood.

The nervous system of a rabbit, as other animals, acts as a kind of sensitive telephone exchange controlling the movements of the various parts and the functions of various organs. The brain acts as a kind of central exchange, receiving messages or impressions by way of the **sensory nerves** and sending replies which work muscles, etc., by way of a different set called **motor nerves.** The brain of any mammal is a delicate and most com-

plicated organ, but in that of a rabbit, as in those of others, well-defined parts can be recognised—a front large portion called the **cerebrum**, and a back portion, known as the **cerebellum**, from which a long spinal cord extends down through the backbone or vertebral column. From the spinal cord various nerves branch and extend through the body.

SKELETAL STRUCTURES AND MODE OF LIFE

The skeleton of a rabbit in a broad general way resembles that of a frog, though there are some important differences, such as the much greater number of vertebrae (45), in the backbone or vertebral column, which ends in a tail (Fig. 92). The fore arm, which is smaller than the hind limb, consists of an upper arm bone or humerus followed by two bones, the radius and ulna, which

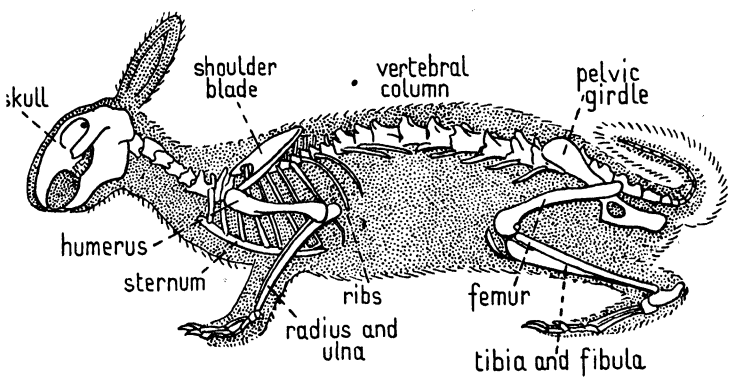


FIG. 92.—THE SKELETON OF A RABBIT.

together form the lower arm. These two bones are placed much nearer together than they are in a man and do not permit a rabbit to rotate its hand in the way a man can do. The rabbit's wrist is composed of numerous small bones, and then follow five digits or fingers, so that the hand (as in man) is said to be primitive or not specially developed, as that of a horse is for a particular purpose.

In the back limb of a rabbit it is easy to recognise the large

femur followed by the tibia and fibula forming the lower leg. Then come several small ankle bones connected to a foot consisting of four toes, since the great toe is absent. The foot is not quite so primitive as the hand. The size of limbs generally bears some relation to the amount of work performed by them, and in this respect the rabbit is no exception. Rabbits push themselves forward by means of their strong hind limbs; they leap rather than run, and the long outer legs reach the ground at positions beyond, or in front of, the fore legs each time the animal propels itself forwards. Other features of the skeleton that must be noted are the pectoral girdle in front, consisting of scapulae or shoulder blades, and the small clavicles, connecting with the sternum a breastbone which supports seven of the twelve pairs of ribs. All the ribs, of course, are joined to the backbone.

Near the hind limbs is the pelvic girdle, consisting of certain bones which become *ankylosed* or fused together in the adult rabbit.

Now consider quite briefly some modifications of the vertebrate skeleton to suit the needs of certain types living different kinds of lives. For example, compare the fore limbs of a rabbit with those of a bird and a bat described in the preceding chapter. The rabbit possesses the primitive five-fingered hand, and the limb as a whole is not highly specialised or specially adapted to a particular purpose. But in a bird's fore limb there is only one well-developed finger and fragments of two others in the hand. Such a limb is well adapted for the process of flight. So is that of a bat, but in a different way. Here the fingers themselves are greatly developed and support a leathery sort of wing, and though the primitive number five is retained, the fingers themselves are specialised and by no means primitive. If we consider the hind limbs, it may be observed that those of a rabbit are specialised to some extent, since they are large and particularly suitable for the mode of locomotion practised by the animal. But they are not nearly so specialised as are the feet of a horse. In this case each leg bears a foot having just one long well-developed toe, and merely splinters of bone representing two other toes on either side of the large specialised toe.

The foot of a horse has during countless generations of descent become particularly well adapted to speed in running. Members of the horse family were not always like this; fossil remains show that they commenced with five toes, then had four, later three, and now possess only one toe properly developed (Fig. 93). It may be more correct to say that one toe has become over developed at the expense of the others.

While considering the limbs of a horse it should be noted that the wrist (front limb) and ankle (hind limb) are very long, the

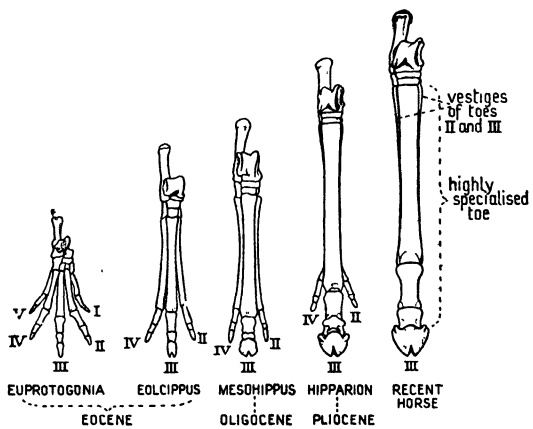


FIG. 93.—THE EVOLUTION OF THE HORSE'S FOOT.

joint often mistaken for a knee really being the junction of the wrist with the lower end of the radius and ulna. The true knee is higher up nearer the body.

Perhaps the most interesting part of the bony framework of any mammal is the skull or hard covering which protects the brain, bears the organs of vision and hearing, and contains the teeth, the apparatus by means of which food is taken into the mouth and ground small enough for the process of digestion.

The skull, together with the lower jaw of an animal, affords evidence of its mode of life, and for this reason it also suggests many probable characteristics of the animal's bodily form. The teeth provide the chief clue concerning animal behaviour. The

rabbit's skull is elongated and is jointed or *articulates* with a lower jaw bone. Both the upper and lower jaws bear teeth, some incisors or chisel-like teeth in front, then a gap, followed by flatter pre-molars, and molars or grinding teeth behind. There are no sharp-pointed canine teeth as found in dogs, cats, and other flesh-eating animals The **dentition** or set of teeth of a rabbit shows that the little creature is a vegetarian, feeding on grass, small roots, etc., and it is described as **herbivorous.** Because of its gnawing habits, it is called a rodent, and such creatures as mice, rats, and others having roughly similar dentition and living on the same type of food, are also classed as rodents Though inoffensive in the sense that it does not prey upon other animals, the rabbit is destructive to roots, etc., and the rate at which it breeds has caused it to become a great pest in certain countries, particularly Australia,

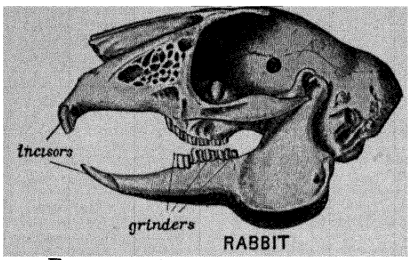


FIG 94 —A RABBIT'S SKULL

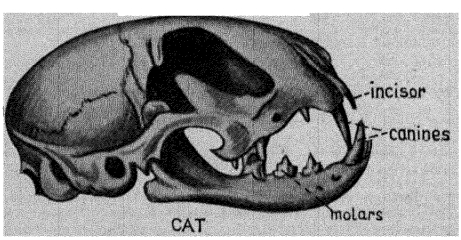


FIG 95 —A CAT'S SKULL

where a few rabbits, originally introduced as novelties or pets, produced many millions in a few years

Now compare the skull and dentition of a rabbit with that of a cat or dog (Figs. 94 and 95). In the case of either of these flesh-eaters the teeth are relatively few, but all of them are sharp and pointed, some, the canines, being more pointed than the others. But even the back teeth or molars are somewhat

pointed and bear sharp edges. The teeth are all adapted to the purpose of cutting and tearing the flesh of other animals, and a creature living on such a diet is said to be **carnivorous** (*i.e.* flesh-eating).

Though a pet dog or cat may now appear inoffensive enough, it is descended from wild ancestors which lived a very active, predaceous life, that is, a life occupied by searching for prey. The teeth and jaws of a carnivorous animal are highly specialised, so are those of an elephant, but these are large and almost flat, being used as grinding mills for roots and branches of trees. An elephant is herbivorous.

Members of the carnivora—lions, tigers (cat family), bears, wolves, and foxes (dog family), and others—are all agile, their limbs and general structure being adapted properly to the type of life they have to live. As a rule, even their feet are padded, so that they may creep about silently, and in many cases the claws are withdrawn into sheaths when not required for active service. While this class of animal has many obviously offensive characteristics, it is the class that yields us nearly all the **furs** used as articles of clothing, rugs, etc. The skins of lions, tigers, and bears are used mainly as rugs, but different species of wolf, fox, skunk, and otter, and the smaller animals, ermine, sable, and martin, supply most of the materials used by the furriers and clothiers in the manufacture of fur coats, stoles, necklets, etc. The colour of the fur of many animals changes during the year to suit climatic variations in surroundings, and it is the white winter coat of the ermine that is so highly valued.

Seal skin, obtained chiefly from sea lions, sea bears, and to a lesser extent from true seals, is of considerable value, and these large marine animals also belong to the carnivora though they are not so active bodily as the others.

Seal hunting for the skins is carried on in the ice-floe regions of the North Atlantic, and a species of seal is also found in the Caspian Sea. Sea bears or sea lions, which are not true seals though closely related to them, yield the best furs, and are hunted in the South Atlantic off Patagonia and the Falkland Islands, but they are not found in the North Atlantic. Many

animals of this kind are plentiful in the North Pacific however. Much of the cheaper fur of commerce is really rabbit skin 'doctored' to look like something else. Some other rodents, particularly the squirrel, yield more valuable fur, while the coat of the little insect-eating mole is highly prized.

SEA-FARING MAMMALS

The largest surviving land mammal is the elephant, now found only in Africa and India, though formerly its ancestors roamed all over the northern hemisphere: remains of the mammoth are found in Siberia, N. Europe, and N. America. The elephant is an ungulate or hoofed animal though it has the primitive five toes, the skull and dentition being the specialised portion of its anatomy. Many of the bones of the skull are cellular or contain hollow spaces, so that they are light yet strong enough to support the massive tusks. Elephant tusks, which are greatly enlarged incisor teeth, are much prized as ivory, that from other animals, such as the walrus, being of inferior quality. Apart from their ivory, elephants are employed for hauling timber, etc, but largely on account of man's interference they are rapidly diminishing in numbers.

Now at first sight there appears to be little connection between elephants and whales, but if we look into the subject of the ancestry of these types we find a good deal of evidence to suggest that whales and other sea-going mammals may be descended from elephant-like creatures that took to a lazy life floating in the rivers, their bulky bodies being supported by the water. Weeds and other plants along the river-side could be used as food. It is a rule of nature that limbs or organs that are not properly used shall eventually dwindle away, or at any rate become less and less pronounced in successive generations; and this is exactly what is found by examination of the fossil evidence. Remains of animals have been obtained which show the limbs of elephant-like creatures in various stages of diminution. At the Natural History Museum, South Kensington, are specimens of such connecting links called *Zeuglodon* obtained from Eocene rocks in America and Egypt. A greater amount of fossil

evidence is available in the case of the sea cows or Sirenians, a connecting link with land animals being the *Halitherium*, the remains of which are found in tertiary rocks at Darmstadt in Germany (Fig. 96).

In these, the hind limbs have almost disappeared, while the fore limbs are represented by the humerus together with the radius and ulna, but there is no hand. It is generally believed that the Cetacea or whale family have originated in a similar manner from another group of marine animals.

Though whales have smooth skins and bodies outwardly resembling those of fish, they are true mammals, being warm blooded, breathing by lungs, and giving milk to their young.

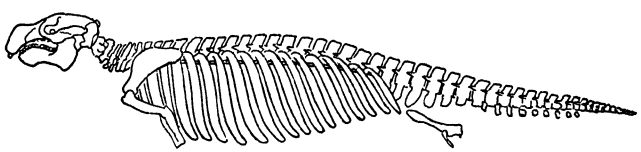


FIG. 96.—SKELETON OF *Halitherium schinzi*.
(By courtesy of the Director, British Museum: Natural History.)

There are several species of whale, some of more commercial value than others. Two of greater importance are the **Greenland** or **Arctic right whale,** found in northern seas as the name suggests, and the **Sperm whale,** inhabiting warmer seas within or near the tropics (Fig. 97).

The Greenland whale and a similar related form of the Antarctic region usually attain a length of about 50 feet and weigh about 220 tons. As in most animals of this group, the head is very large and extends about one-third of the entire length of the body. The nostril is placed at the top of the head, and during exhalation quantities of water vapour in the breath give the impression that the animal is spouting sea-water. One of the chief features of this species is the intricate arrangement of long, thin flexible plates of **baleen** or whale bone found within the mouth. There are hundreds of these plates forming a kind of sieve, preventing large objects from being swallowed. This whale has a relatively small stomach and feeds upon small molluscs, etc., caught by the simple process of keeping the

mouth open as the monster moves through the water The food being of this nature, there are no teeth in the jaws of the Greenland whale The whale bone (not really bone, of course), together with the fatty, oil-producing substance termed **blubber** found on the back and sides, are the materials for which the animals are hunted.

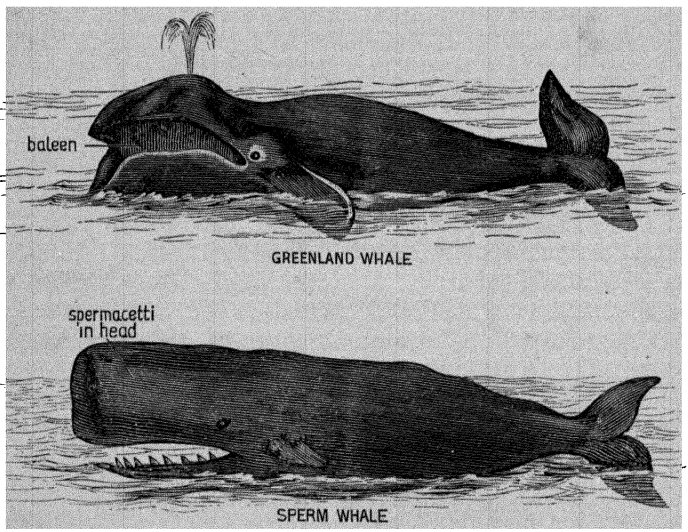


FIG 97 —TWO OF THE MORE IMPORTANT SPECIES OF WHALE

The Sperm whale or *cachalot* differs from the Greenland species in the absence of the complicated baleen structures Its food consists of larger material, including cuttle-fish and other molluscs, and ordinary fish The shape of the head is also different on account of the large mass of fatty matter above the front portion of the skull A nasal opening or blow-hole is situated near the front of the head A large number of conical teeth on each side of the lower jaw make this animal a much more formidable creature to hunt than the Arctic variety

Oil, obtained from the layer of fat surrounding the body, and **spermacetti** wax, obtained by refining the oily matter of the head, are the chief commercial products. The whales as a class are

gregarious, that is, they go about in herds or ' schools ' sometimes containing thousands together. They have their enemies, however, the **Grampus**, or killer whale, a fierce member of the group attacking and devouring the others, even the larger Greenland and Sperm varieties.

The size of Cetaceans varies greatly, ranging from the huge **rorqual** attaining 85 feet, down to the **dolphin**, which is generally less than four feet in length. Several species of whale inhabit the British seas, the variety most often seen being the common **porpoise**, attaining an average length of 5 feet, the presence of which is undesirable since it feeds on useful small fish, such as herrings and pilchards. A certain amount of oil can be obtained from it, but the animal is not of much use commercially. So-called porpoise leather is obtained mostly from a larger animal about 12 feet long, called the **White whale**, and found in large numbers in Arctic waters. Only rarely is this kind of whale seen so far south as Scotland.

USEFUL HOOFED MAMMALS

Food, leather, wool, and certain products such as glue and bone ash, are the indispensable commodities we owe to the hoofed animals or ungulates. The group includes a great number of species : mountain goats, deer, camels, rare members of the horse family, hippopotamus, etc., which many of us may never see except perhaps in zoological gardens or a museum ; but, on the other hand, everyone is familiar with cows, sheep, horses, and pigs, types which constitute the chief sources of our animal products. All these animals have hoofed feet, those of the horse having simply one hoof at the end of a single toe, but most of the others having two hoofs (which look like one split in two) at the extremities of two of the toes. As mentioned above, the elephant has five hoofs on each foot, and a rhinoceros has three. The domestic pig differs from most of the other members of the group in possessing a full set of teeth containing all types—incisors, canines, pre-molars, and molars—indicating that nature intended it to eat a mixed diet. The pig is **omnivorous**.

On the other hand, cattle, sheep, and horses possess teeth that are not quite so numerous and are particularly adapted to chewing vegetable matter. The digestive processes of cattle, sheep, deer, and some other ungulates (but not horses) are peculiar, and these animals are known as **ruminants.** A cow's stomach, or that of another ruminant, consists of four parts, or, as it is sometimes described, a cow has four stomachs (Fig. 98). The food, commonly grass, is taken into the mouth and passed to the largest compartment of the stomach. After a while it is passed forward to the second chamber, where it is rolled up and sent back to the mouth to be thoroughly chewed. This secondary chewing is the ruminating process which is performed at leisure after the animal has taken in a sufficient store of material.

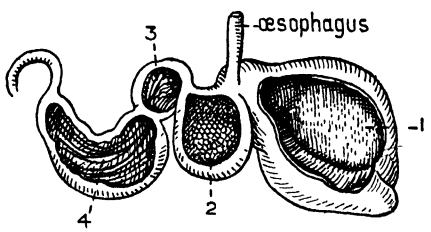


FIG. 98.—THE STOMACH OF A RUMINANT.
COMPARTMENTS NUMBERED IN ORDER

The food is then sent back to the third part of the stomach, where it receives attention from digestive juices, and eventually reaches the fourth partition, where it is finally prepared for digestion in the intestine. There is no need to discuss here the obvious importance of the different varieties of food obtained from these ungulates.

The horns of cattle are hollow and permanent, whereas those of deer are shed periodically. Both horns and hoofs are made into various useful substances, such as combs, imitation tortoise-shell, knife handles, glue, etc. Leather consists of the skins freed from hair and treated to some special process, either **tanning** or **tawing,** in order to render the material proof against natural putrefaction or decay which would otherwise occur, since animal skin like flesh is subject to decomposition, unless preserved in

some way. In the process of tanning, so called because the skins are placed in solutions containing **tannic acid** obtained from certain vegetable substances, such as oak bark and chestnut, the hides are first cleaned to remove blood stains, etc. ; they are then softened by treatment with lime, so that the hair and outer skin or epidermis can be scraped off. This preliminary process, in which bacteria play a part, is known as depilation and lasts from 8 to 12 days according to the type of skin, softer material requiring a longer time. The hair, etc., having been removed mainly by machinery, the skins are then immersed for some time in the tanning solutions. Later they are treated to a **currying** process, which consists of adding oil and grease, and the article called leather is the final product. In the other process of tawing, the skins are submitted to the action of mineral salts, such as alum and salt, together with flour and white of egg. A special and rapid process, known as chrome tanning, consists of immersing the skins in a solution of sodium dichromate.

The stronger leathers are made from the hides of cattle exposed to all sorts of weather, and among the favourite breeds are those known as **shorthorn** and **Hereford.** The skins of sheep, goats, and calves yield lighter and softer leather, employed for the upper parts of boots, gloves, and light articles. Though nearly all leather is obtained from these mammals, other kinds are produced from the skins of lizard, crocodile, etc., and are used for fancy goods and even for ladies' shoes.

The world's supplies of wool for clothing are obtained from sheep and the closely related animal the goat. There are several species of wild sheep inhabiting the mountain regions of Asia, Mediterranean Europe, the Rockies of North America, etc., but wool is obtained from domesticated varieties. Of these domesticated types two classes may be recognised—those with horns, such as the **Dorset** and **Norfolk** sheep, and the **merino,** originally introduced from Spain, and those without horns, including such varieties as **Cotteswold** and **South Down** sheep. The merino is specially famous for its fine quality wool and the South Down is bred mainly for the excellent meat it makes.

Fine silky wool is obtained from certain goats, particularly the **alpaca,** which with the llama inhabits the mountains of Peru, and

attempts, more or less successful, have been made to introduce the alpaca into Australia and elsewhere.

The **Cashmere** goat of India and the **Angora** goat of Asia Minor are two other kinds noted for the quality of their wool. It will be observed that the fabrics sold as cashmere, alpaca, and merino are named from the animals supplying the raw material.

CHAPTER XI

THE HUMAN BODY AND ITS EFFICIENCY

THE bony skeleton supporting the human body is constructed on a plan very similar to that of the skeleton of a typical mammal such as a rabbit or a cat (Fig. 99). Thus the fore limbs of a cat and the arm of a man contain similar bones — humerus, radius, ulna, wrist bones, and digits, though the shape and proportions differ in the two cases. In both cases these limbs are supported by bones forming a shoulder girdle, and similarly the leg bones are connected to others forming a pelvic girdle. In man, as in other mammals, ribs connected to the back bone (and some of them to the breast bone) serve to protect certain internal organs, including the heart and lungs.

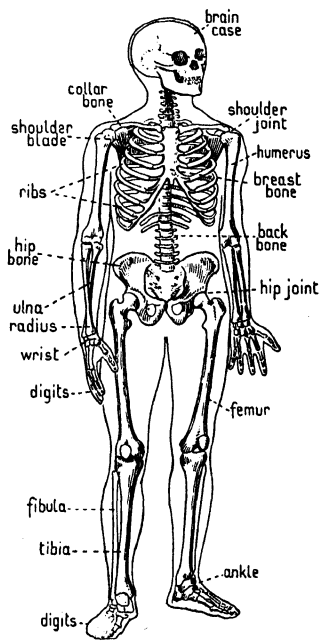


FIG. 99.—THE HUMAN SKELETON.

The similarity between the human skeleton and that of another mammal is, of course, most marked when a comparison is made with that of an anthropoid or man-like ape, such as a gibbon or chimpanzee. The general plan of one is much like that of the other, but the chief differences which account for

man's structural superiority include the straight femur or thigh bone, and the erect poise of the head upon a gently curving backbone.

These features enabled man to walk in an erect position, so that his hands could be used for grasping and manipulating external objects. By this means much knowledge of his surroundings was gained, and in a great many ways man's correspondence with the objects around him was more thorough and intimate than that of animals not erect and not so free to use their hands. An increase in brain power and intelligence was bound to result from the possession of these structural advantages, and it is in the formation of the skull and lower jaw that man differs most from the apes. A comparison of the skull of a chimpanzee with that of a man (average European) shows that in the latter the brain case is much larger, with a pronounced forehead rising at a high angle from the scarcely noticeable ridges above the eyes. In the adult ape, the brain case is small, the forehead is low, slopes backwards at a relatively low angle, and there are pronounced ridges above the eyes. In man the lower jaw or mandible is not so prognathous, that is, it does not protrude so far in front of the face as it does in the chimpanzee. This remark applies to the jaw as a whole, and it should be observed that a pronounced chin is a definite human characteristic.

The teeth of man, particularly the canines, are not so offensive or pugnacious in character as those of an ape, since greater intelligence substituted cunning for physical violence, human teeth being used mainly for eating purposes and not as fighting weapons. This, of course, applies more to modern man than to some of the earlier types represented by fossilised remains of great antiquity.

REMAINS OF PREHISTORIC MEN

One of the most fascinating and important studies in natural history seeks to find an answer to the question—What is the origin of the human race? We naturally look to the fossil evidence to supply a solution to this problem, but unfortunately

the amount of such evidence is relatively small, since the discovery of human remains is accidental and of rare occurrence. The superior cunning of primitive man generally enabled him to avoid dangerous situations in which his body might be buried and so preserved, and skeletons to be fossilised must have been buried, since even bones gradually decompose and pass away as dust if left exposed to air.

Cunning did not always avail, however, and very occasionally human remains—bones, portions of skulls, teeth, and so on—are dug from old river gravels, cave earth, or other rocks which are geologically young, though of great antiquity when measured by ordinary historical units of time. The length of time separating us from the Pharaohs of ancient Egypt is extremely small compared with the hundreds of thousands of years which have elapsed since these fossilised human remains were entombed in their resting places. In some cases flint implements—scrapers, spear-heads, etc.—and teeth or bones of animals are associated with human remains, and these objects help to solve the question of the relative age of the rocks in which such remains have been discovered.

The most ancient and primitive man-like remains, which appear to be more ape-like than human, were discovered in **Java** by Professor Dubois some years ago. These objects, discovered in an old river gravel probably of late Pliocene age, included portions of a skull, some teeth, and a thigh bone or femur. The specimen has been called *Pithecanthropus erectus*, a name meaning the erect man-ape, and it is generally considered that the animal may be a link connecting the gibbons with man.

In the year 1912 the late Mr. Charles Dawson found portions of a skull and lower jaw in an ancient river gravel at **Piltdown** in Sussex (Fig. 100). Animal remains, teeth of certain early elephants, and both flint and bone implements found in the same gravel suggest that the deposit is of early Pleistocene age, that is, considerably younger than Pliocene rocks, but still very ancient. The glacial periods, during which ice covered northern Europe and palaeolithic man inhabited Southern England, were also of Pleistocene age, but the specimen found at Piltdown represents a much earlier stage in human development than that to which

the glacial man belonged. The Piltdown man has been named *Eoanthropus dawsoni* (the dawn-man of Dawson), and is certainly the oldest and most primitive type of undoubted human remains yet found.

The Piltdown specimen includes most of the bones forming the brain case, and though those of the face are absent, there is

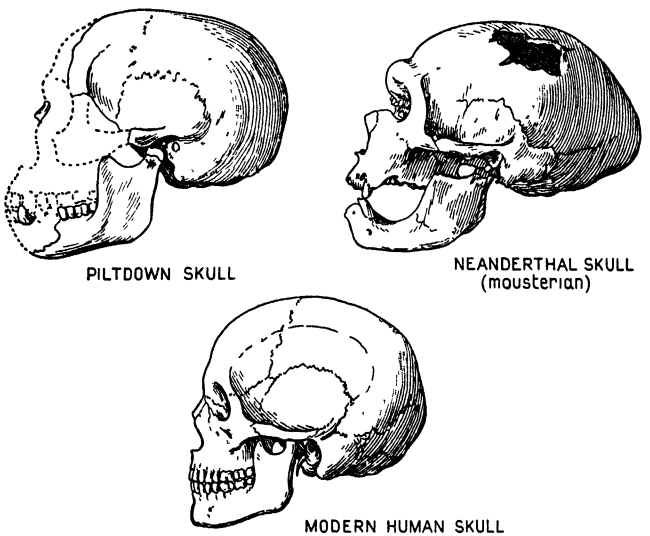


FIG. 100.—TYPES OF HUMAN SKULL.
(By courtesy of the Director, British Museum Natural History)

sufficient of the skull to show that it was essentially human in character.

A plaster cast of the brain case shows that in size the brain exceeded that of a native Australian, but was considerably less than that of an average modern European. The cast also shows that the *convolutions* or coiled appearance of the brain surface were not so complicated as in modern man, and it is this feature, the complexity of the convolutions, that appears intimately associated with degree of intelligence. Size alone is not very significant. For example, it has been estimated that the brain of the distinguished German statesman Bismarck was at least 600 grams

heavier than that of the famous mathematician Leibniz, who may have been the intellectual superior of Bismarck. The lower jaw of the Piltdown man is decidedly ape-like in character, so that the specimen really represents a race of beings related to both apes and man.

A lower jaw of decidedly human but primitive character was found near **Heidelberg** in Germany in 1907. It, also, was discovered in a river gravel, together with remains of elephant, bear, and other Pleistocene animals, and it is believed that Heidelberg man lived nearly as long ago as the man of Piltdown.

Remains of men of somewhat later times known as the **Mousterian** period are fortunately more plentiful, at any rate more of them have been unearthed. Though the name Mousterian is derived from Le Moustier in France, where remains have been found in a cavern, the most famous of Mousterian specimens is known as the **Neanderthal man,** since it was found in a cavern in the Neanderthal, near Dusseldorf in Germany. This discovery was made so long ago as 1857, and since then many other remains of similar primitive men have been discovered in various parts of Europe, particularly at **Spy,** near Namur in Belgium, and at **La-Chapelle-aux-Saints** in south-west France. It is interesting to note that all of these Mousterian specimens were obtained from caves. From the collective evidence we are able to state that Neanderthal man was generally of short stature, not so erect as modern man, and possessed a skull characterised by a fairly low receding forehead and prominent ridges above the eyes.

Human remains found in caverns and gravels of later Pleistocene age show that the later man of the old stone age (Palaeolithic) approximated closely in structure to modern man. Specimens of these later types are none too numerous, and it is to be hoped that future discoveries will add considerably to our knowledge of the subject.

THE MECHANISM OF MOTION

Microscopic examination shows that bones of the skeleton, as all other parts of the body, are composed of cells, but in this case the cells are impregnated with hard substances—phosphate and

carbonate of lime—and they are softer in early childhood than in adult life. Where bones meet there is a joint, which may be simply an immovable junction as in the bones of the skull, or may be a movable joint as that of the knee or elbow. So far as motion is concerned, movable joints are a necessity, and are usually formed by a terminal knob-like part of one bone fitting into a cup-like hollow in another bone. For example, the top of the femur or thigh bone fits into a rounded cavity called the *acetabulum* (vinegar pot) in one of the large bones of the pelvic girdle. In other cases a joint, such as that at the elbow, resembles the hinge of a door.

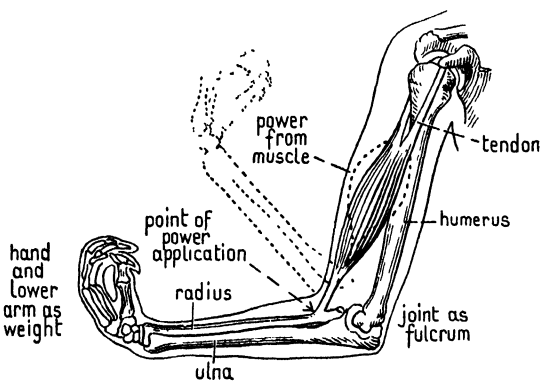


FIG. 101 —THE HUMAN ARM AS A LEVER

Attached to the bones, usually by tendons, are **muscles**, which consist of bundles of fleshy fibres, capable of contraction or shortening when required. By such contraction the bones, and therefore the limbs and other parts of the body, are moved, thus enabling us to do various things. A well-known movement of the arm may be taken as a typical example. When the forearm is raised towards the upper arm, it is operated by a large muscle called the *biceps*, the upper end of which is connected to bones by two tendons, one to the shoulder blade, the other to the humerus (Fig. 101). The lower end of this muscle is connected to the radius of the forearm, and upon the contraction of the muscle the forearm is raised. Upon relaxation of this muscle and the

contraction of another on the outer side of the arm, the forearm is lowered again. It will be observed that the muscle and bones together form a lever with the elbow joint acting as a fulcrum (see Chapter XIV).

The movements of the leg are brought about in a very similar manner, muscles and bones together acting as levers of various classes according to the movement. Other muscular contractions cause the motion of the head, the neck, the hand, and so on.

Except in the case of certain nervous disorders, all of these movements are voluntary or controlled by the will, hence the corresponding muscles producing such movements are known as **voluntary muscles.** But there are others which perform their work without any conscious effort of the will and therefore called **involuntary muscles.** The chief examples of these are the heart, the muscles of the stomach, and those of the intestines which force the food matter along the alimentary or digestive tract. The movements of these involuntary muscles are rhythmic, and we are not conscious of their action.

Now, muscles whether voluntary or involuntary are controlled by **nerves.** The various movements and forms of physical work that we perform constitute our round of daily activities. Life consists very largely of muscular action, and the involuntary muscles perform functions that enable the voluntary muscles to do what we wish them to do. Without the control of the nerves, the muscles would be like a collection of independent pieces of mechanism and the body would be like a battleship that had lost its control station.

THE CONTROL STATION OF THE HUMAN BODY

The complete nervous system may be considered to consist of two portions—the **cerebro-spinal system,** which includes the brain and the spinal cord with their connected nerves, and the **sympathetic system,** composed of nerves and larger masses of nervous substance called ganglia. A disorder such as blushing is due to a disturbance of the sympathetic system. These nerves and ganglia extend along the front and sides of the vertebral column, and nerves proceeding from them control the movements

of the involuntary muscles concerned with the action of the heart, intestines, and so on, as well as all muscular movements.

Of the cerebro-spinal system the largest portion is the brain, which is protected by the skull and consists of three parts—the **cerebrum,** the smaller brain or **cerebellum,** and the spinal bulb or **medulla oblongata** (Fig. 102).

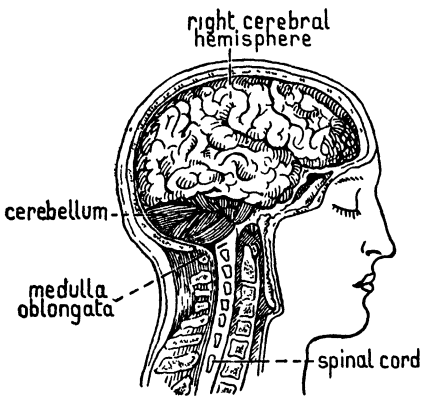


FIG. 102.—SECTION THROUGH THE HUMAN BRAIN.

The large brain or cerebrum occupies most of the brain case, and is composed of two large masses of nervous material known as the **cerebral hemispheres.** Though separate at the surface, they are connected further down within the brain. The surfaces of these hemispheres are thrown into many ridges and intervening depressions which turn this way and that, forming the convolutions, the complexity of which appears to be associated with the degree of intelligence. The human cerebrum has more complex convolutions than those in the brain of an ape, and most of the lower animals, birds, reptiles, etc., have smooth rounded brains, without convolutions.

Consciousness and all that it embraces—thought, will, the emotions, memory, sight, hearing, sensations of pain, etc.—are all intimately associated with a layer of **grey matter,** about $\frac{1}{8}$ inch in thickness, forming the outer portion of the cerebrum. Should this grey matter be injured by accident or altered by organic disease, the mental faculties suffer in consequence, but we must be on our guard against any premature assumption that consciousness is a *product* of chemical or physiological changes taking place in the brain substance. It is quite as reasonable to suppose that the conscious personality is a reality which makes use of the brain as a suitable physical medium for correspondence

with a material world, and that an injury to the brain, the instrument of communication, merely impairs such correspondence with the outside world of ordinary matter. These are subjects that have exercised the thoughts of the greatest intellects of all times, and we are still far from solving these problems.

The interior mass of the cerebrum is composed of white nervous matter, but in the spinal cord the conditions are reversed, the grey matter being surrounded by white substance. The medulla oblongata continues downward as the spinal cord passing through a hole called the *foramen magnum* at the base of the skull. From this part of the brain nerves proceed to various parts of the cerebrum, and it is of great interest to note that the nerves cross over or proceed so that the right side of the brain controls the left side of the body and *vice versa*.

The interesting question arises—are certain faculties, such as speech and vision, controlled by special parts of the cerebral matter; in other words, are there *localised areas of control* in the brain? Examination of the brains of numerous dead persons who, during life, suffered from certain disabilities—defective speech, for example—has shown that certain faculties, such

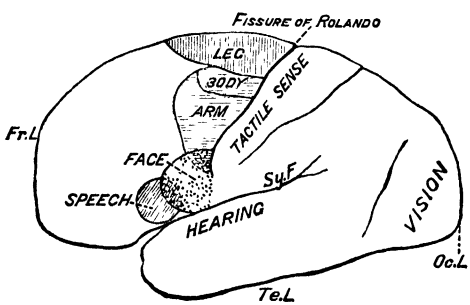


FIG. 103.—LOCALISED CENTRES OF CONTROL IN THE BRAIN.

THE FRONT OF THE BRAIN IS TO THE LEFT.

as speech and vision, are controlled by definite areas of the cerebrum (Fig. 103). Similarly, certain other parts of the cerebral hemispheres are connected with the motor nerves operating the arms, legs, etc. But though the functions of some parts of the

brain are known, as shown in the illustration, there are still large areas of the cerebrum the exact functions of which are still unknown

The structure of the eye and ear are described in later chapters (XXV and XXVI), and here we are concerned with the general mode of operation of the nervous system.

Nerves are of two kinds, the **sensory nerves,** which extend to the outer surfaces of the body and transmit impressions to the brain, and the **motor nerves,** which send messages from the brain to various muscles so that they move when required. Thus, if you run a needle into your hand the sensory nerves there send a message (painful sensation) to your brain, which then switches on to the correct motor nerves and sends an impulse along them so that your other hand attempts to pull out the offending needle.

The cerebellum or little brain " is concerned with the co-ordination of the actions, nervous and muscular, by which the movements of the body are carried on " In the medulla oblongata and spinal cord are situated centres of nervous tissue connected with ' reflex ' actions, which consist of movements that take place automatically, such as breathing and walking. Once started a person continues walking, though his mind is occupied by thoughts quite independent of his bodily motion.

THE SOURCES OF BODILY ENERGY

Muscular and mental activities, of which our lives are so largely composed, are accompanied by an expenditure of energy, and in order to continue, new stores of energy must be obtained. Energy is obtained from the consumption of food, just as the energy which enables a steam engine to work is obtained from the combustion of coal in the fire box, and the consumption of food is really a cool form of combustion, the oxygen necessary for the process being obtained from the air which enters the lungs.

The digestive system consists of a very long system of tubes which extend right from the mouth to the lower end of the large intestine, together with some very important glands or organs which manufacture certain fluids required for digestion. The chemical processes of digestion commence as soon as food enters

the mouth, where the teeth masticate or break it up, and where the **saliva**, an alkaline fluid secreted by glands below the tongue and in the face, mixes with it. Though the saliva has no action upon proteins or food-stuff such as meat and fish, it contains a ferment called *ptyalin*, which has the power of changing the starch of carbohydrates—potatoes, bread, etc.—into sugar, which is soluble and fitted for absorption into the system. The habit of 'bolting' food is injurious, because the saliva does not get a reasonable chance of acting upon starchy foods, and because the teeth do not have time to break up the food sufficiently.

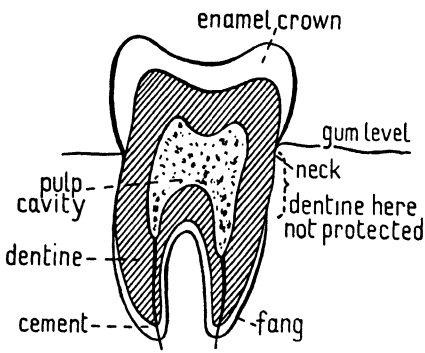


FIG. 104.—A VERTICAL SECTION THROUGH A HUMAN MOLAR TOOTH.

In early childhood we are supplied with a set of 'milk' teeth, which are later replaced by a second permanent set, 32 in number, including 4 incisors, 2 canines, 4 pre-molars, and 6 molars in the top, and a similar number in the lower jaw. In the centre of a tooth is the soft pulp containing nerves and blood vessels. The larger portion of a tooth is composed of dentine, which is covered by hard enamel on the top or crown, and by cement around the fangs (Fig. 104). But just at the level of the gum the dentine is not covered, and it is just here that bacteria obtain a footing and set up decay unless the teeth and gums are frequently cleaned.

The condition of the teeth is a matter of great importance, since decayed teeth cannot do their work properly and also cause

poisonous matter to be absorbed by the blood, and this kind of self-poisoning leads to bad general health and lack of tone.

When the food has been properly masticated it is pushed by the tongue into the **pharynx,** a muscular bag at the top of the gullet or oesophagus. At the same time the **epiglottis** prevents any material going the ' wrong way ' into the air passage connecting with the lungs. The upper end of the gullet contracts and forces the food a little lower, then that part of the gullet contracts forcing the food still lower, and so on, until it reaches the stomach. This type of muscular contraction which proceeds from one part of the tube to the next part, and so on successively, always in one direction along the tube, is called **peristalsis.** The food after it has left the stomach is also forced along the intestines by peristalsis.

The entrance to the stomach is nearly central (Fig. 105), and a muscular valve or **sphincter** at the end of the gullet contracts and regulates the entry of food into the stomach. The left or cardiac (heart) end of the stomach is dilated or much widened compared with the other or **pyloric** end, where another sphincter regulates the entrance of the chyme or prepared food into the small intestine. The strong muscular stomach is lined with a mucous membrane supplied with blood vessels and a great number of minute glands which secrete the **gastric juice,** a fluid mostly water but containing hydrochloric acid and an enzyme called **pepsin.** The acid which is present in small quantity, about 0·4 per cent., causes the action of the salivary enzyme ptyalin to cease, hence the importance of mastication so far as starchy food is concerned. The pepsin causes the protein substances—meat, eggs, etc.—to be converted to soluble substances called **peptones,** and there are other enzymes which act upon fats. The stomach by means of its muscular contractions churns the food and thoroughly mixes it with the gastric juice, so that after some time, say half an hour, the resulting soup-like material or chyme is ready to be passed into the intestine.

The pyloric sphincter permits only a little at a time to pass forwards, and the action of the stomach continues for some hours until it is time for another meal, when the feeling of hunger warns a person that more food is required.

The upper end of the small intestine is known as the **duodenum** and contains the duct through which the bile secreted by the

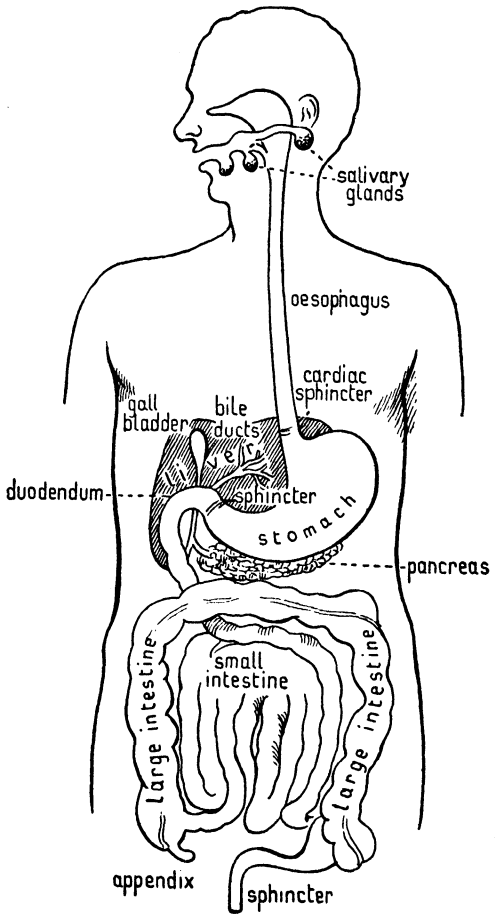


FIG. 105.—DIAGRAM OF THE HUMAN DIGESTIVE SYSTEM.

liver, and the pancreatic juice prepared by the pancreas pass into the intestine. The bile as it comes from the liver is yellow and thin, but later it turns green and becomes thicker. It is stored

in the **gall bladder**, from which it is discharged into the intestine as required. These fluids act upon the chyme by emulsifying the fats in it, that is, breaking them up into minute globules, and by renewing the digestive process of converting starchy matter to sugar, a process that was arrested in the stomach on account of the acid nature of the gastric juice. The addition of fluids from the liver and pancreas renders the material alkaline again.

The food matter is now ready for absorption, and this is accomplished by immense numbers of projections on the inner wall of the intestine termed **villi.** These are furnished with capillary blood vessels which absorb sugar and organic acids, and other minute vessels called **lacteals** which absorb fatty substances. In the larger intestine the process is continued to some extent, though there are no villi, mainly water being absorbed, so that the residue becomes more solid and compact. Any material not absorbed, particularly fibrous vegetable matter, is expelled periodically from the intestine.

There are two muscular sphincters, one at either end of the large intestine, the upper one controlling the passage of food from the small to the large intestine, the other regulating the expulsion of solid waste products from the body In all there are about 30 feet of intestines, so that they are much coiled and looped in order to fit into the abdominal cavity. They are held in position by a membrane called the **mesentery.**

TYPES OF FOOD AND VITAMINS

It will have been gathered from the description of digestion given above that, chemically considered, there are three classes of foods—**proteins, carbohydrates,** and **fats.** To these certain purifying mineral salts must be added, and of course water.

Proteins are composed of carbon, hydrogen, oxygen, and nitrogen, with some phosphorus and sulphur; they are the source of all the nitrogen which our food contains. As nitrogenous matter is absolutely essential to the building up of new flesh and tissues in a growing child, and to the replacement of nitrogen eliminated by persons of all ages, some sort of protein *must* form part of any person's diet. Nitrogen is eliminated or

removed from the body as urea in the liquid urine expelled periodically. The chief foods of the protein class are lean meats of various kinds, fish, game, eggs, the casein of milk and cheese, and certain vegetable seeds, particularly peas and beans.

Carbon is oxidised and expelled from the body as carbon dioxide in exhaled breath, and to replace this, carbohydrates and fats are eaten. These foods—potatoes, bread, butter, dripping, salad oil, etc.—are mainly energy producing (by oxidation of carbon) and enable us to do our daily work and maintain our bodily temperature; but it must be understood that proteins also assist in the production of heat, just as carbohydrates and fats to some extent help in flesh building. There is one food, namely milk, which contains all the substances required, even vitamins obtained from the grass eaten by the cow, but for all persons except very young infants a general mixed diet is necessary.

It is estimated that in his daily round of activities an average man loses about $\frac{3}{4}$ of an ounce of nitrogen and $9\frac{1}{2}$ ounces of carbon, besides water and salts. This material loss must be made good, and then there is the loss of heat to be considered. The amount lost daily and therefore the amount that must be made good by the average adult is about 3000 calories, and it must be remembered that these *physiological* or *large* calories are each equal to one thousand of the smaller calories employed in experimental physics.

What sorts of food, and how much of each, does a person require in 24 hours? The answer to this depends upon how old the person is, and what sort of work he does. Young children require much protein, but, though growing, do not require so much general food as an active adult, and very old people require much less than growing children. Again, a man engaged in heavy manual work needs more than one occupied by work of a sedentary nature, a clerk for example. The daily requirements of an average manual worker include about $\frac{3}{4}$ lb. of lean meat, or its *nitrogen equivalent* in other forms of protein (*e.g.* cheese), carbohydrates equivalent to $1\frac{1}{2}$ lb. of bread, a quarter of a pound of butter or other form of fat, some mineral salts, and at least 3 pints of water. A person need not drink this quantity since many foods contain water in combination.

People living less strenuous lives should eat less than these proportions, and though malnutrition is usually caused by under-feeding, there is considerable illness caused by over-feeding, particularly among middle-aged people living sedentary lives. If the human machine is over-loaded it ceases to run smoothly, the excretory organs have too great a demand made upon them, and the person suffers from self-poisoning.

Sometimes too much of one kind of food may be taken, or stimulants may be taken under the impression that they are foods. The best known stimulants are tea and alcohol, and these substances merely whip up the flagging energies, but one has to pay for it later. No actual food is obtained from these: merely temporary stimulation. Similarly, coffee is a stimulant, but there is a certain amount of food in cocoa.

Now, a person may take plenty of food and yet be ill or under nourished if the materials eaten do not include the necessary amount of certain substances to which the name **vitamins** has been given. Vitamins have not been isolated, but observations and experiments with diet compel us to conclude that certain foods contain minute quantities of some substances which exert a necessary influence upon digestive processes. Without them food is not absorbed properly. Several vitamins have been shown to exist, but some are of more importance than others.

Vitamin A is very necessary for young growing children, for a deficiency of it is the cause of rickets and general debility. This vitamin occurs in milk, butter, suet, the yolk of eggs, herrings, and liver. Both liver and eggs contain all classes of vitamins and are therefore among the very best kinds of food. Cod liver oil contains about 250 times as much Vitamin A as does butter.

Vitamin B, a lack of which produces anaemia (poorness of blood), lack of vigour, nervous debility, and intestinal troubles, occurs mainly in eggs, liver, kidneys, fish roe, heart, wheat, rice, peas, and beans.

Vitamin C is present only in living tissues, hence is obtained from fresh vegetables and raw fruits, oranges, tomatoes, lemons, etc. Tinned and bottled fruits are deficient in this vitamin, and its absence in diet is the cause of scurvy.

Vitamin D is similar in its effects to Vitamin A, and the lack

of it in food leads to rickets and other diseases. In sunless climates it must be included in the diet in order to preserve good health. Milk and butter provide the most important dietetic sources of this vitamin. Cod liver oil is strong in the vitamin, but its unpleasant taste makes it unsuitable for many people. It has recently been found, however, that the vitamin can be produced in a highly concentrated form from a purely crystalline substance, ergosterol, by acting upon it with sunlight or the radiations from a mercury vapour electric lamp, which is rich in ultra-violet rays. Vitamins A and D are now available in concentrated form in solutions, extracts, and pellets and other preparations without having to depend upon cod liver oil, milk, or butter for them.

A word must be said here about cooking. Food is cooked so that it may be softened, made palatable so that it excites the flow of saliva and gastric juice, and preserved when it is cold. Cookery also destroys parasites should any be present. But in some ways cooking may be injurious. Baking destroys vitamins, though boiling may not do so, but in that case they may escape in water strained away from vegetables. The common practice of adding sodium carbonate to vegetables should be avoided, since vitamins are destroyed by such alkaline substances. Finally, it must be stated that one vitamin cannot be substituted for another; all classes must be contained in the food if health is to be maintained.

THE DISTRIBUTION OF FOOD WITHIN THE BODY AND THE REMOVAL OF WASTE PRODUCTS

As we have seen, food substances are absorbed by the blood in minute vessels in the intestines, hence it is the medium by which nutriment is taken to all parts of the body. As in the rabbit, the blood of man consists of a fluid or plasma containing enormous numbers of red cells or corpuscles, and a smaller number of irregularly shaped 'white' corpuscles (Fig. 106). These corpuscles are short lived, the red ones lasting about a fortnight; the white cells last a little longer. New corpuscles originate in the marrow of the bones.

The red corpuscles are coloured by haemoglobin, which contains iron, and are round biconcave discs having no nuclei They play an important part in taking up oxygen from air in the lungs and carrying it to various parts of the body where oxygen is required The white or colourless corpuscles (**leucocytes**) appear to operate in connection with resistance to disease. Many of them are constantly changing their shapes, and, as Amoeba envelops food, so these corpuscles wrap around microbes and impurities in the

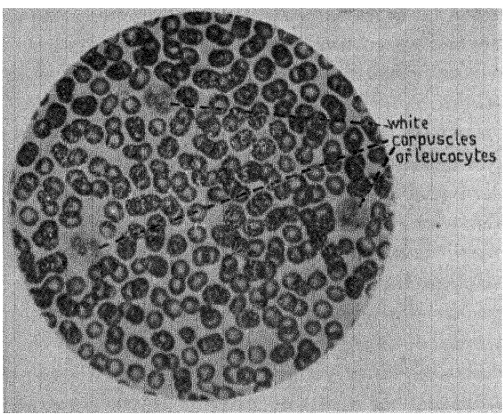


FIG 106 —A DROP OF HUMAN BLOOD HIGHLY MAGNIFIED

blood There are other substances in the blood which assist in resisting diseases, and among these are anti-toxins which neutralise poisons or toxins The blood thus acts as a policeman as well as a food carrier

When blood issues from a wound it clots, or coagulates, which is not the same thing as ordinary drying The blood coagulates because the plasma separates into a fibrous substance called **fibrin** and a yellowish liquid known as **serum.** The fibrin gathers up the corpuscles and the serum is passed to the outside of the clot In the case of small wounds and scratches the clotting process soon prevents further bleeding, and the application of certain substances such as chloride of iron helps in rapid coagulation

The total amount of blood in an adult body is about 9 pints, and this is kept pulsating around the system of vessels by the heart. The number of heart beats per minute vary in different persons, an average number for a person at rest being 70. At such a rate of pulsation, about $2\frac{1}{2}$ pints of blood are sent from the left ventricle into the arteries in one minute. Brisk physical exercise and some emotional excitements increase the rate of pulsation.

The four-chambered heart of the rabbit and the circulation of the blood through the arteries and veins have been briefly de-

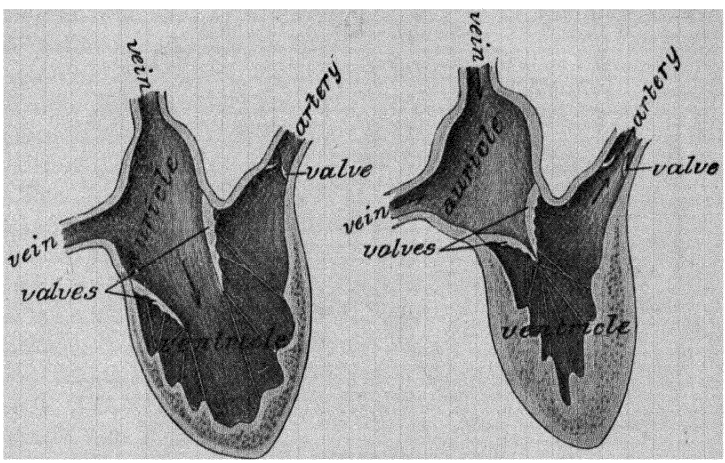


FIG. 107.—SECTION THROUGH ONE SIDE OF THE HEART, SHOWING BLOOD PASSING FROM THE AURICLE TO THE VENTRICLE (LEFT) AND BLOOD BEING FORCED BY VENTRICLE THROUGH ARTERY (RIGHT).

scribed in the previous chapter, and as it is similar to the heart and circulatory system of the human body, an elementary description of this circulation need not be repeated here.

The discovery of the circulation of the blood was made by **William Harvey,** an English physician, who studied first at Cambridge and then at Padua in Italy, where he obtained his M.D. degree in 1602. By careful experiments upon animals and observations upon the valves of the heart, he traced the circulation, and though, at first, other physicians did not accept his theories, his teaching has revolutionised the science and art of

medicine His discovery constitutes one of the great milestones along the roadway of human progress.

Now the blood is contained within a system of vessels, and we must briefly consider how nutriment passes from the blood to the bodily tissues. A fluid substance called **lymph,** which is formed from the blood material and resembles blood without the corpuscles, passes through the walls of the vessels, and by this means the cells and tissues outside of the blood vessels obtain

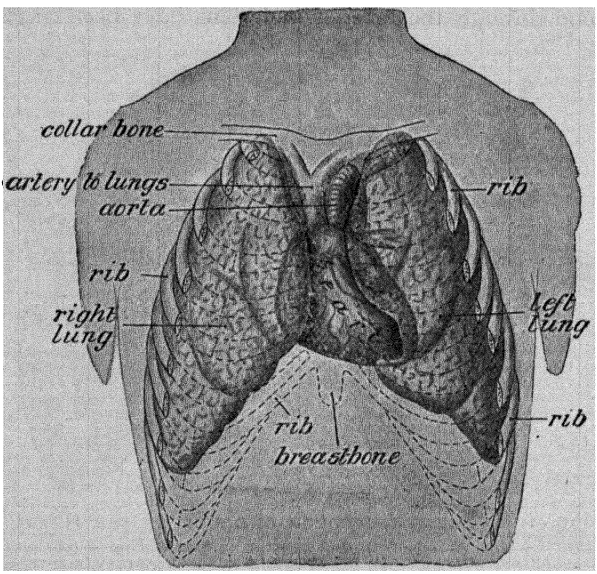


FIG 108 —THE THORAX, SHOWING POSITIONS OF THE HEART AND LUNGS

their nutriment The lymph eventually returns to the blood vessels taking impurities with it Thus the lymph acts as an agent working between the blood on one hand and the various cells and tissues on the other The lymph is collected into vessels called lymphatics, but the precise way in which the reunion between blood and lymph is accomplished cannot be described adequately here.

The blood is purified by means of the lungs, the kidneys, and the skin.

The act of breathing, or respiration, is caused by movements of the **diaphragm**, a muscular partition separating the thoracic cavity above from the abdominal cavity below, and the intercostal muscles between the ribs also assist in this work. The rhythmic contraction and relaxation of these muscles vary the size of the thoracic cavity so that an action like that of a bellows is obtained.

The two lungs consist of a branching series of tubes which eventually become a great number of minute passages terminating in little sacs or alveoli. The **trachea** or windpipe gives off two main branches or **bronchi**, one for each lung. The gases, oxygen and carbon dioxide, pass in and out of the blood by diffusion (see Chapter XV) through the walls of the capillary vessels of the lungs.

The kidneys are two large bean-shaped organs, each about 4 inches long, and situated near the back of the abdominal cavity. The blood passing through vessels in the kidney gives up water and urea, a nitrogen compound formed by decomposition taking place in the proteins of the body. The solution containing the urea and certain salts is called urine. Each kidney connects with the urinary bladder by means of a narrow tube called a ureter, along which the urine trickles. A sphincter at the neck of the bladder can be relaxed, permitting the urine to be expelled from the body.

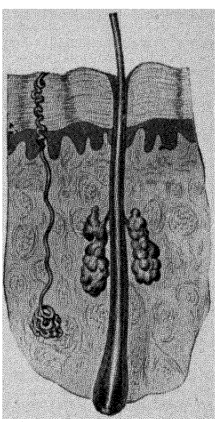


FIG. 109.—HIGHLY MAGNIFIED SECTION OF SKIN, SHOWING SWEAT GLAND AND DUCT (LEFT), AND HAIR WITH OIL GLANDS (RIGHT).

The skin, as the kidneys, is an excretory organ, that is, an arrangement for throwing certain waste products from the body; and of course it serves as an outer covering for the body. There are two layers forming the skin, an epidermis above and the dermis below. The dermis contains little projections or papillae, blood vessels, and nerves. The skin all over the body contains numerous small openings, each connected by a little tube with a **sweat gland** which secretes water (sweat) containing a small percentage of salt (Fig. 109). The skin is always giving off this

solution, but only during violent exercise or in very hot weather is it inconveniently noticeable. By evaporation of this perspiration the heated body is cooled, so that its temperature is properly adjusted. When the skin excretes a lot of water there is less work for the kidneys to do, but in colder weather the kidneys do more excretory work and the skin does less. Hair and nails are modified portions of the epidermis.

There are numerous other glands in the body, each manufacturing some fluid that has an important bearing upon health and disease, and these will be noted in the next chapter.

CHAPTER XII

MAN'S FIGHT AGAINST DISEASE

MAN has achieved marvellous progress in engineering, industrial chemistry, agricultural biology, and many other branches of knowledge, but by far the greatest benefits that science confers upon mankind are those which enable him to wage a more or less successful war against disease of body and mind, and to increase the average length of healthy life, thus bringing us nearer to the ideal—the greatest happiness to the greatest possible number of individuals.

While realising that workers in the field of medicine and surgery are generally our greatest benefactors, we must not overlook the fact that some of the foremost champions in the lists against disease and ignorance have been, not physicians, but men who would now be called biological chemists, as will be noted later. Indeed, chemistry, physics, biology, and many other subjects, all help in the fight against illness and premature death.

The mechanism of the human body being of a most delicate and complex nature, it is not surprising that at times portions of the mechanism may get out of order, thereby producing ill health. When some part of the body ceases to work properly, though that part is not actually diseased, the person suffers from a **functional disorder,** which under proper care and treatment may right itself, and the mechanism work properly as before. Many forms of nervous trouble are functional derangements of this kind, but perhaps the best known example is ordinary indigestion, due to the gastric juice being either too acid or not acid enough. The stomach does not then function correctly, and in consequence the food is not properly prepared for

assimilation. Medicines can be taken to counteract the condition of the gastric juice, and after a short time the patient usually returns to normal health. But in more serious cases indigestion may result from some actual change taking place in the cells of which the stomach or other organ is composed, and the person is then suffering from a definite **organic disease**, perhaps gastric ulcer, and, of course, the skill of a physician is necessary to diagnose, that is, determine, whether a case is functional or organic in character. There is a very great number of organic diseases, many of which can be communicated from one person to another.

When a disease is passed by contact from a patient to another person the disease is said to be *contagious*. Diphtheria may be communicated in this way. But in many of the worst forms of illness, particularly in those known as fevers—cholera, diphtheria, typhoid, influenza, scarlet fever, smallpox, etc.—the disease is transferred from one to another without bodily contact, when it is said to be *infectious*.

In the process of infection, insects often play a very important rôle. Thus, certain mosquitoes carry the malarial parasite, fleas communicate bubonic plague, the housefly spreads typhoid, and so on (Fig. 110). In other cases, germs in the exhaled breath of a diseased person affect the air so that others breathing that air are infected with the particular form of illness, for example, consumption and scarlet fever. In particular cases, articles of clothing, books, etc., are capable of carrying infection, hence the necessity in these cases of either disinfecting these articles or destroying them. Civilisation, in causing large numbers of people to collect in towns, has assisted in the spread of certain diseases, influenza, for example, but on the other hand, improved knowledge of cleanliness and sanitation has very much lessened the ravages of other diseases, such as typhus, which are fostered by the presence of dirt and

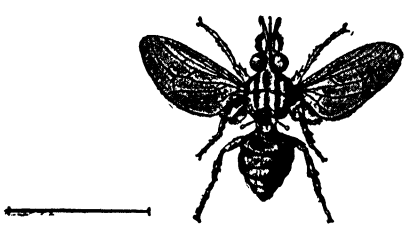


FIG. 110.—TSE-TSE FLY, THE INSECT WHICH INFECTS PERSONS WITH SLEEPING SICKNESS

insanitary surroundings. Though rural districts gain in respect to fresh air, and less chance of infection, many lose heavily on account of their antiquated methods dealing with sewage and refuse disposal.

The onward march of civilisation is rapidly tending towards less infantile mortality and greater average length of life, and in order to realise this fact vividly, we have only to consider the condition of medicine and surgery at the time of Napoleon.

OUR DEBT TO SCIENCE

At the end of the eighteenth century practically nothing was known about **bacteriology** or the study of bacteria and other disease germs. That meant that there was no proper knowledge of the cause of the great majority of diseases, and in a large number of cases there was no specific treatment. If diseases are to be treated and prevented the causes must be known.

The rôle played by insects—fleas, mosquitoes, bugs, etc.—was not even suspected, and consequently personal and communal hygiene (health study) was of a low standard. The importance of fresh air was not understood, consumptive and other patients being kept in carefully closed rooms with disastrous consequences. Similarly, the true value of sunlight and ultra-violet rays was not realised.

Nothing was suspected about the influence of certain glands, such as the thyroid, on bodily and mental health. The correct relative values of various types of food and the existence and great influence of vitamins were unknown; consequently deficiency diseases—rickets, scurvy, etc.—due to the consumption of food not containing sufficient vitamins, were rife in towns, particularly among the poorer members of the community.

There was practically no State control of housing, mines, factories, schools, etc., control that has, in modern times, produced most valuable results in general public health.

Surgery was in a similar rudimentary condition. Its state of development can be gathered from the fact that a surgeon was frequently a barber or a chiropodist as well, and was generally

considered much inferior to a physician. To-day, surgery is an art requiring a most exact knowledge of anatomy and considerable manipulative skill, and every medical practitioner must qualify in both medicine and surgery. In the times we are speaking of there was relatively little surgical practice, and many operations, particularly those upon the abdomen, were almost invariably fatal, and consequently not often attempted. Amputations, that is the removal of limbs, were effected, but the stump was either left to take its chance of becoming septic (*i e.* poisoned) or dipped in tar. As there was very little knowledge of disease germs, the cause of blood poisoning was not understood, consequently there was no **antiseptic surgery,** that is, surgery in which the hordes of injurious germs ready to enter and poison a wound are thwarted by certain disinfectants called antiseptics. Then, blood poisoning often followed an operation and the patient died; now, the patient usually recovers

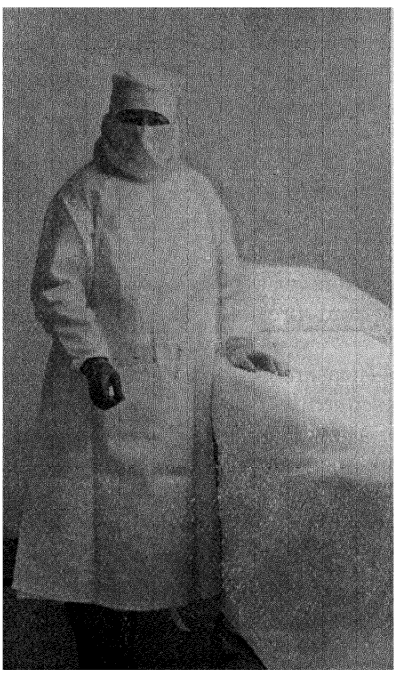


FIG 111 —A MODERN SURGEON IN STERILISED CLOTHING,
INCLUDING RUBBER GLOVES NOTE THE WHITE WASHABLE WALLS AND MARBLE FLOOR OF THE OPERATING THEATRE
(*Photo by Mr B Hunt*)

Operations in those days were awful ordeals compared with operations now, when merciful insensibility is produced by the use of some form of **anaesthetic** (no pain or feeling). Prior to 1840 the patient was commonly given narcotic draughts or excessive doses of alcoholic liquor, so that a sort of stupor was

induced. Even blows on the head were inflicted in some cases. How has science helped us to overcome pain?

In 1842 **Sir Humphry Davy** suggested the use of **nitrous oxide** (laughing gas) as an anaesthetic for the extraction of teeth; and about that time the volatile liquid **ether**, which also produces general insensibility or unconsciousness, was first employed. In 1847 **Sir James Simpson** devised safe methods of application, and its use became general. In any operation a separate physician, the anaesthetist, gives the anaesthetic, since its application is a matter requiring skill and experience, particularly when an operation takes a considerable time. The anaesthetic influence of **chloroform** upon animals was noted by a Frenchman named Flourens, but its application to human surgery in 1864 is also due to Simpson, whom we must regard as the originator of modern painless surgery. Another general anaesthetic is **ethyl chloride.** These substances are volatile liquids, and the patient inhales the vapour. In dentistry and some minor operations *local anaesthesia* is produced by the injection of a substance such as **cocaine** into the part to be operated upon. The part becomes insensible, but the patient does not lose consciousness. Since cocaine may produce unpleasant after effects, dental surgeons more commonly employ a substance called novocaine.

In order to understand the immense benefits of both antiseptic surgery and modern medical practice, we must consider briefly certain discoveries made during the last sixty years. Just as we owe wireless communication to the joint labours of men of science and inventors, so progress in bacteriology is the result of patient investigation by many workers, but the foundations of the science and its application have been laid chiefly by two very famous men. The great French biological chemist, **Pasteur,** and the equally famous British surgeon, **Lister,** have conferred upon the human race benefits so great that it is difficult to describe our indebtedness in words.

Louis Pasteur was the son of J. J. Pasteur, a French tanner, and was born on December 27, 1822, at the little town of Dôle in the Jura, though most of his boyhood was spent at the neighbouring town of Arbois. He had considerable artistic

ability, and inherited from his parents thoughtfulness and imagination, two characteristics of great value in scientific research. At the age of sixteen he went to Paris, where he studied at L'Ecole Normale. After some years of study and comparative poverty, he obtained a professorship at Strasbourg in 1849, later he was appointed at Lille, and then at L'Ecole Normale at Paris, where most of his bacteriological work was accomplished between 1857 and 1888.

Pasteur was a chemist and brought to bear upon medical practice a highly specialised knowledge of chemistry, which a physician with a smaller knowledge of the subject and occupied with medical practice could not do. At first, physicians were very much opposed to Pasteur, and regarded his work as being beyond his own province, but eventually truth triumphed, and his researches were eagerly extended by a band of devoted followers, many of them medical men. To-day there are numerous large institutions named *L'Institut Pasteur* in France, Tunis, Algiers, and other places where the work commenced by the great chemist is being extended. The mortal remains of Pasteur himself, who died in 1895, are buried in L'Institut Pasteur at Paris.

The existence of disease germs, or microbes as they are often termed, was known before Pasteur's time, but scientific workers had very confused ideas concerning them; it was left for Pasteur to crystallise these ideas, to establish the fact that many diseases were due to definite germs, to discover several species of germs responsible for certain diseases, and to find methods of treatment.

How did it come about that a chemist should throw such a flood of light upon **pathology** or the study of disease?

Some of Pasteur's earlier work included the microscopic study of the vegetable organism yeast (Chapter V) and its influence in causing alcoholic fermentation, that is, the conversion of sugar into alcohol (Chapter XLIII). Then he found that the conversion of alcoholic liquor to vinegar and the turning sour of milk are due to other distinct minute vegetable organisms.

If these bacteria produce changes like fermentation, is it possible for other minute organisms to produce alterations in the blood of animals? Pasteur answered this question by studying

a disease of silkworms, and found it was due to a distinct minute organism. Evidently a particular disease is caused by a particular microbe. Next he studied the deadly disease called anthrax, which was responsible for the destruction of great numbers of sheep. He proved what others had suspected, that anthrax was due to a definite bacterium, and he effected a means of prevention by **innoculation,** that is, by injecting into the blood a prepared substance or **vaccine,** which enabled the blood to resist the attack of anthrax germs.

The injection of vaccines and other substances called **antitoxins** is now much practised in connection with many diseases, including diphtheria, cholera, tetanus, plague, etc., and in order to understand the principle of the treatment we must go a little further back before the time of Pasteur and consider the work of **Edward Jenner,** a physician of Berkeley in Gloucestershire. It was known before the beginning of the nineteenth century that persons who had suffered from a milder but related disease called cowpox (vaccinia) were *immune* from smallpox, that is, their blood was in some way fortified against the attack of smallpox. About the year 1796, it occurred to Jenner that if persons were treated with an injection of vaccinia or cowpox virus, they would be prevented from having smallpox. Jenner was right, and this special innoculation against smallpox is called **vaccination.** At first Jenner was taken more seriously on the continent than at home, and Germany introduced compulsory vaccination some time before England did. For some years the death-rate or number of deaths per 1000 people from smallpox in Germany was extremely small compared with that in England and France.

Wherever there has been extensive vaccination, as in the armies during the Great War, there has been none or very little smallpox. Now, if that is true of smallpox, why should it not be true of anthrax, diphtheria, typhoid, and many other diseases? So thought Pasteur, and he endeavoured to find means suitable for the prevention of some of these diseases. He was particularly successful in dealing with anthrax, also with rabies (hydrophobia) the poisoning due to the bite of mad dogs. He discovered suitable vaccines capable, when injected into the blood of the patient, of dealing with these diseases. Vaccines

are generally substances containing either dead or much less virulent germs of the same disease, so that a person develops a mild form of the disease and his blood becomes experienced and capable of dealing with a virulent or more violent attack of the malady The germs for vaccines are cultivated and kept in suitable media.

Another famous man who must be mentioned in connection with this struggle against bacteria is **Metchnikoff**, a Russian zoologist who worked with Pasteur. He discovered the **phagocytes** or white amoeboid corpuscles of the blood which, by wrapping around the bacteria, consume them The phagocytes function as the police force of the blood, and once they have had experience of a particular bacterium, they know how to deal with it in future, and the person becomes immune or less likely to suffer another attack of that disease. It is now known that other bodies present in blood serum exert an influence upon the ability of the phagocytes to destroy bacteria, but the explanation of this influence is rather too difficult to be discussed here.

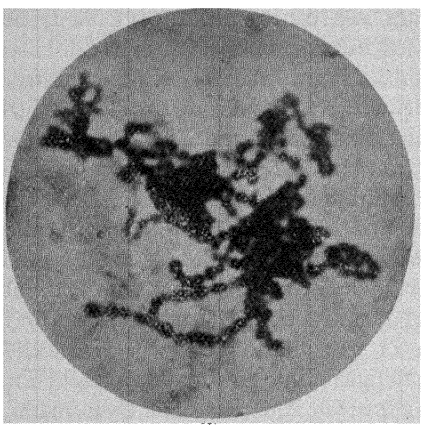


FIG 112 —CLUSTERS AND CHAINS OF MICROCOCCI, *Staphylococci pyogenes*, × 2000
(*Photomicro by P J H Turton, M D*)

The germs or microbes against which the phagocytes and antitoxins have to contend may be classified in three structural groups ·

Micrococci. or rounded more or less spherical organisms Examples are the *Pneumococcus*, responsible for the lung disease called pneumonia, and the germs of erysipelas and sepsis or poisoning (Fig. 112).

Bacilli, rod-like bodies. These include the organisms producing diphtheria, influenza, typhoid, leprosy, plague, anthrax,

and many other diseases (Figs. 113 and 114). Certain bacilli are also responsible for the fermentation of milk and cheese.

Spirilla, spiral, twisted, or wavy bacteria. The germs of cholera and relapsing fever are of this kind.

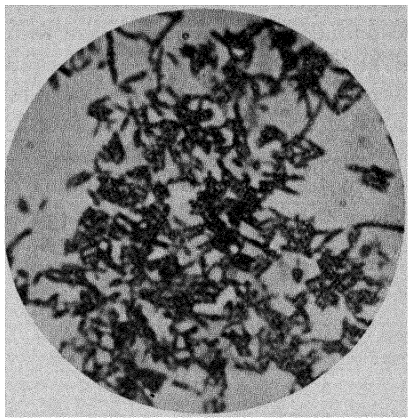


FIG. 113.—*Bacillus diphtheriæ* × 2000.
THE GERM WHICH ACCOMPANIES DIPHTHERIA.
(*Photomicro. by P. J. H. Turton, M.D.*)

The discovery of these various organisms is the result of investigations by many workers, among the more celebrated being the German bacteriologist, **Koch,** who discovered several germs, including that of tuberculosis or consumption in 1882, and that of cholera in 1883.

Though most disease-producing organisms are minute, unicellular plants (Chapter V), some of the most serious maladies are caused by animal organisms called **trypanosomes.** Thus *Trypanosoma gambiensi* is responsible for the dreaded disease commonly known as sleeping sickness, and in this case an insect, the African **tsetse fly,** acts as a carrier, taking it from one person to another (Fig. 110).

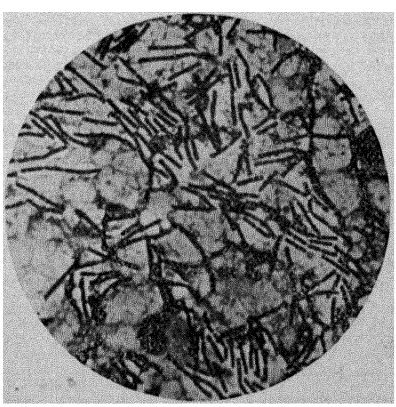


FIG. 114.—*Bacillus anthracis,* × 1000.
THE GERM OF ANTHRAX (WOOL SORTER'S DISEASE)
(*Photomicro. by P. J. H. Turton, M.D.*)

The relation of insects to disease has received a great amount of attention in recent years, and remarkable results have been obtained by **Sir Ronald Ross** and others. It is impossible to do the subject justice in a few words, but it must be

observed that the classic investigations of Ross have shown that mosquitoes carry malarial fever. These insects not only carry the disease germs from person to person but also the germ undergoes essential stages of development within the body of the mosquito. By the destruction of mosquitoes and their larvae, regions formerly scourged with malaria have been made fit for human habitation, a great example of this being the Isthmus of Panama.

Owing to the terrible ravages of yellow fever the earlier attempt to construct the Panama canal was a failure, but since the discoveries of Ross were applied by **Gorgas**, the fever has been

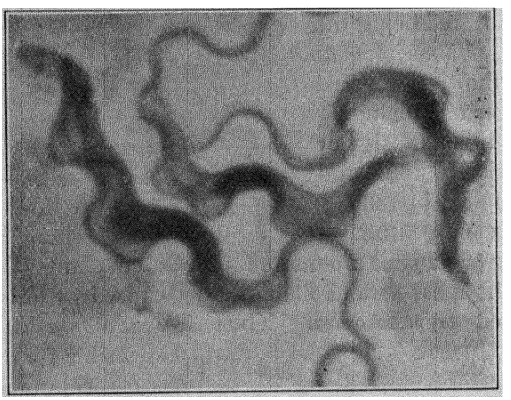


FIG 115.—TRYPANOSOMES
VERY HIGHLY MAGNIFIED

conquered and the canal finished. The chief means of removing the mosquito pest consist of draining swampy places and covering water with oil so that the larvae cannot reach the surface to breathe.

Now to return to disease germs in relation to surgery. Joseph Lister, the son of a celebrated optician, was born at Upton in Essex on April 5, 1827. Young Lister studied at University College, London, where he obtained degrees in both arts and medicine. After qualification he became house surgeon at University College Hospital, where he was greatly impressed by the terrible amount of poisoning which affected wounds, and caused death even after quite simple operations. In 1860 he was

appointed professor of surgery at Glasgow University, and here again he was appalled by the great toll of lives taken by sepsis (blood poisoning) among the patients of the Glasgow hospitals.

It was then generally believed that the oxygen of the air was responsible for sepsis, but Lister considered that germs gaining access to the wounds may have been the cause. Assuming this to be the case, the problem he had to solve was how to kill these malignant germs and yet not harm the bodily tissues of the patient. In searching for some suitable substance as a disinfectant or germ destroyer, he noticed that **carbolic acid** took away unpleasant odours from sewage material. He treated wounds with carbolic acid, which formed a crust preventing the entry of germs, and was gratified to find that the wounds so treated did not become septic, and the patients recovered. Eventually the solutions of carbolic were diluted and made less likely to cause injury to the tissues. In Glasgow and other cities, the hospitals, in which great numbers of patients formerly died of sepsis in spite of perfect cleanliness and ventilation, showed great changes in the amount of recoveries obtained.

Lister's work was not confined to antiseptic solutions and wound dressing; he also improved the means of tying up the arteries inside the body when they had to be cut in the process of operation. His methods have revolutionised surgery, and to-day every precaution is taken to prevent germs entering wounds, even the breath and hands of the operating surgeon being screened from the patient's body, and all instruments are *sterilised*, that is, rendered free from bacteria.

Though disease germs are among the most serious enemies of mankind, the practice of medicine is also concerned with many other vital matters. Within recent years a considerable amount of knowledge has been obtained concerning the importance of certain glands in relation to health. Glands are organs the function of which is to manufacture or secrete some fluid necessary for processes taking place within the body. Thus the gastric glands of the stomach prepare gastric juice, and the liver manufactures bile. The liver is a very large organ and secretes something else besides bile. It manufactures a starch-like material known as **glycogen,** and stores it for future use. If plenty of glycogen is

stored in the liver we can do our work well. During periods of excessive work the glycogen is used up. Bile is a secretion passed out from the liver into the intestine, but there are several glands which manufacture *internal secretions* which are passed directly into the blood inside vessels within the gland itself. These internal secretions or **hormones** are now known to exert a great influence upon health and development. A deficiency of the hormone manufactured by the pancreas produces the disease called diabetes, a condition in which sugar that ought to be assimilated is discharged from the body in the urine. Quite recently a Canadian physician, **F. Banting,** has found that if diabetic patients have injections of a preparation containing the hormone extracted from the pancreas of animals they are again enabled to assimilate sugar. This hormone is called **insulin.**

On the top of each kidney is a suprarenal gland secreting a hormone called **adrenalin,** which controls the blood pressure and exerts a beneficial influence upon the nerves of the sympathetic system.

In front of the neck, just below the projection known as Adam's apple, is situated the thyroid gland, which manufactures a hormone having great influence upon growth and development. A deficiency in this hormone produces a dwarf or undersized person called a *cretin.* By treatment with extract of thyroid such cases are greatly improved. But the thyroid gland may produce too much hormone, in which case certain nervous troubles are produced.

It is believed that deficiency in the hormones secreted by other small glands (the parathyroids) situated near the thyroid is the cause of twitching or muscular convulsions and of some kinds of paralysis, accompanied by shaking of the limbs. The influence of two other glands must be noted. The *pituitary* gland, situated at the base of the brain, manufactures a hormone that exerts a powerful influence upon the growth of skeletal structures. An excess of this hormone during the period of youth leads to unusual growth so that the person often becomes a giant, and in adult life an excess leads to unusual enlargement of the bones, particularly those of the hands, feet, and jaw. A smaller body.

the *pineal* gland, at the top of the brain and about the size of an orange pip, secretes a hormone which also has some influence upon the growth of bones.

While many workers have devoted their energies to the study of physical ills, others have made careful observations upon various mental disturbances. Some disorders of the mind accompany a diseased condition of the brain cells, but a great number of mental derangements are due to the action of the mind itself, and are not due to any diseased condition of the matter forming the brain. One of the most striking achievements of recent times is the discovery of an **unconscious mind,** which at times may exert an unpleasant influence upon our conscious minds. The great investigators **Freud, Jung,** and **Adler** have shown that many mental troubles in adult life are due to events which happened in childhood. These events have long been forgotten in the conscious mind, but the unconscious mind forgets nothing, and the events in question may produce an undesirable effect on our conscious mental states. An actual example may make this clear. A certain man experienced unaccountable terror on going into any dark place, such as a tunnel. On careful mental examination by a competent expert, who analysed his mind, or submitted him to **psychoanalysis,** it was found that when he was a small boy he was attacked by a dog in a dark alley. The incident was forgotten by his conscious mind, but unconsciously it exerted its influence and accounted for his apparently unreasonable terror. The cause being explained to him, his terror of the dark disappeared ; he was cured.

Some people shrink from climbing heights, others dread open places, still others dislike persons without any apparent cause, and so on, and these things are due to the influence of events registered in the unconscious. A great variety of cases of harmful unconscious mental activity occur, and a large number of cures have been effected; but it must be understood that the process of psychoanalysis is of considerable danger except in the hands of an experienced physician who has made a special study of the subject.

THE VALUE OF STATE HYGIENE

Individual persons are units in a more complex organism known as the community or society, and since the health of society is dependent upon that of its individuals, it is of the greatest importance that the State should introduce and enforce laws to maintain the general health of its individuals. Necessary laws are made to compel individuals and communities to observe and take advantage of the facts learned from scientific research.

In the earlier part of last century, young children were put to work in factories and mines; the conditions in factories and workshops were not conducive to good health, ventilation was often bad, rooms overcrowded, lighting was insufficient, hours of work too long, and sanitary arrangements were not as they should be. The **Factory and Workshops Act of 1878** did much to alter these conditions, but this Act was revised and improved by the Acts of 1901 and 1907. According to these laws it is not legal to employ in a factory any person under 14 years of age. Every worker must have at least 250 cubic feet of air space (in many occupations more than this). There must be thorough cleanliness and ventilation or renewal of fresh air, good lighting, a suitable temperature (which varies with the kind of work done), protection from dangerous machinery, proper sanitary accommodation, and a proper means of escape from fire. In order to see that the provisions of these Acts are observed, **inspectors of factories** are employed, and they are at liberty to enter and inspect any factory or workshop at any time. In a similar manner, mines, quarries, chemical works, etc., are controlled by Acts of Parliament and are subject to inspection, though they may be owned by private individuals or companies.

The **Shop Acts** make it illegal to overwork employees, particularly those under 18 years of age.

The young people of to-day are the adult citizens of the future, and very considerable care of the health of children is enforced. Schools are inspected not merely to test the mental progress of the scholars, but also to see that regulations concerning fresh air, ventilation, warmth, safety exits, etc., are properly observed. The personal health of all children attending public elementary

schools is in the charge of a **school medical officer,** a physician appointed by the local Education Authority. Each child is examined at least three times a year, his height, weight, the condition of his teeth, eyes, throat, etc., being noted. In this work a school nurse usually assists, and an attendance officer sees that all healthy children attend school until the age of 14 years. Of course, any suffering from infectious or contagious diseases are kept at home and not permitted to return to school unless certified by a physician that they are not liable to infect other people. Brothers and sisters of a child suffering from measles or other infectious disease must also be kept at home until sufficient time has elapsed to show that they have not contracted the disease. For the sake of public safety the child who is ill is isolated, and the others in the same house are placed **in quarantine**[1] or prevented from associating with others to whom they might carry infection.

The principles of isolation and quarantine also apply to adults in cases of smallpox, diphtheria, and other virulent diseases, the sufferer when possible being taken to an isolation hospital.

Persons disembarking from ships on which infectious disease has broken out and dogs or other animals coming from abroad are also placed in quarantine for a period, since they may be carriers of disease.

The conditions of general health in a district are under the supervision of a **Medical Officer of Health,** who is a physician appointed by the Urban District Council if the district consists of a town, or the Rural District Council if the area is made up of smaller places.

The medical officers for such districts are usually doctors also having private practices, but the County Council appoints a *county* medical officer of health who spends all his professional time in looking after the health conditions of the county as a whole.

The medical officer of a town or county district has many duties to perform. He must investigate the origin and distribution of diseases in his district. Any infectious disease *must*

[1] So called because the period enforced was formerly 40 days.

be notified to him by the doctor attending the case, and he must then visit the place where the disease is, and ascertain that all necessary precautions against its spreading are being taken. The local council looks to him for advice on all matters affecting the health of the district, and when necessary he must give his support to any legal action which may arise concerning such matters. If required he must examine and report upon the condition of milk, meat, and other perishable food-stuffs in shops, etc., and since food is a matter of vital importance, the medical officer

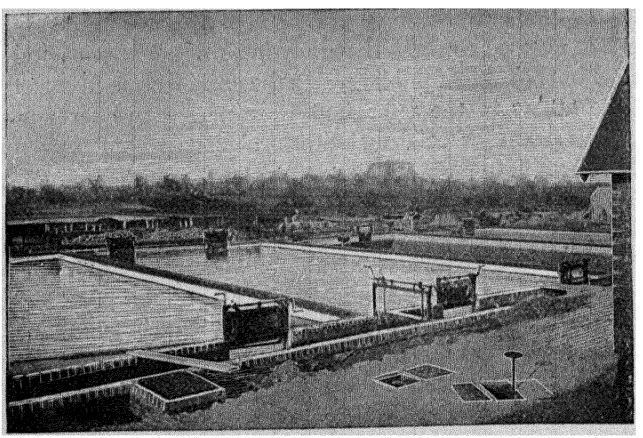


FIG 116.—A SEWAGE WORKS

may purchase samples of commodities from shops and forward them to be analysed by the public analyst to see if they contain impurities.

The condition of drinking water, the pollution of streams, and the disposal of sewage and household rubbish also come under his supervision, and in this he is assisted by a **sanitary inspector** who reports all cases of nuisance to him

The disposal of sewage is sometimes effected by means of a **sewage farm,** in which the liquid containing waste matter is allowed to be exposed to and oxidised by the air, the solution then being used to manure the land (Fig. 116) But often the material in sewers is conducted to some convenient stream or

to the sea. Household rubbish is burned in destructors or tipped on to waste land beyond the town.

In many other ways the State endeavours to promote good health among its citizens; for example, one of the duties of the local council is to approve plans of houses and to inspect every house several times during its construction in order to ascertain that the drains, etc., are properly constructed. There are so many ways in which State control is making for good public health that it has been impossible to give anything but a brief outline in this chapter. The results already obtained strikingly demonstrate the value of such control, and these results may be summarised in a single sentence—*the average length of life of the individual is now several years longer than it was fifty years ago.*

QUESTIONS AND EXERCISES

Questions marked C.S.C. *are taken from papers set at Civil Service Commission Examinations, with the permission of the Controller of H.M. Stationery Office ; and those marked* O. and C. *are from Examinations of the Oxford and Cambridge Schools Examination Board.*]

PART I.

ASTRONOMY.

1. Of what is the 'Milky Way' composed ? State what you know of the distribution of stars in the universe. [O. and C.]

2. What is meant by the 'magnitude' of a star ? What 'magnitude' would you estimate the Pole Star to be ?

3. What is a constellation ? Make sketches of any three constellations that you know.

4. What is a spectroscope, and what facts concerning the constitution of the stars have been learned by its use ?

5. Explain how the position of a star may be defined by Right Ascension and Declination.

6. Say what you know of different types of nebulae.

7. What is a variable star ? Give an explanation of one kind of variability.

8. Distinguish between the proper and apparent motions of stars.

9. What do you know of the physical and chemical constitution of the sun ?

10. Describe the appearance of the sun during a total eclipse. Make a drawing to illustrate your answer. [O. and C.]

11. What is a sunspot, and how are the spots distributed over the sun's disc ?

12. What peculiarities with regard to the rotation of the sun are brought out by observations of sunspots ?

13. Why does the moon wax and wane ? What effect does the moon have upon the sea ? [O. and C.]

14. Describe briefly the chief physical features of the lunar surface.

15. What is a planet, and why do the inferior planets exhibit phases similar to those of the moon ?

16. Describe Bode's Law, and state how it led to the discovery of the first asteroid.

17. Say what you know of the comparative sizes and distances from the sun, and the physical condition of Mars, Mercury, and Jupiter.

18. State briefly the history of the discovery of the planet Neptune.

19. Say what you know of comets and meteors.

20. Explain the terms 'latitude' and 'longitude,' and state how they are determined for any particular place. [O and C.

21. Explain the cause of the seasons experienced in temperate latitudes

22. What is the difference between solar and sidereal time, and why is solar time employed in everyday life ?

23. Explain the connection between longitude and local time.

24. State what you know of the earth's shape.

GEOLOGY.

1. What is shingle ? Where is it generally found and how is it formed ?

2. By what processes are materials deposited on the sea bottom converted into hard rock

3. What are limestones, and how are they formed ? Is anything like chalk in process of formation at the present day ? [O and C]

4. Give four examples of common stratified rocks, and explain the conditions under which each was formed

5. What is the origin of coal ? [O and C]

6. Compare the type of scenery found in a clay district with that of a hard sandstone area Give examples.

7. What are fossils, and what light do they throw on the past history of the place where they are found ? [O and C.]

8. Distinguish between metamorphic and igneous rocks Mention three examples of each, and explain how they were formed.

9. Define *anticline* and *syncline*. How have these geological features been produced ?

10. What is an *escarpment* ? Where do escarpments occur in England, and of what are they composed ?

11. Write a short essay on the formation of coral islands

12. What evidence is there to show that active volcanoes have existed in the British Isles in past times ? [O. and C.]

13. Draw a sketch illustrating a section through a typical volcano, and mention volcanic products that are of use to man

14. Say what you know of the distribution of active volcanoes at the present time

15. Explain the theory of isostasy, and show how it accounts for earthquake phenomena.

16. What are *consequent* and *subsequent* streams ? Illustrate your answer by reference to the Weald.

17. Outline the evidences of glaciation in the British Isles in past times.

18. In what ways may lakes be formed ?

19. What is the probable condition of the earth's interior ?

20. Describe the processes and results of marine erosion.

21. In what British rocks, and where, are salt, iron ore, coal, and lead ore found ?

22. What are *transverse* and *longitudinal* valleys ? Show the relation of such valleys to railway routes in the Alpine region.

23. What are *kaolin* and *bauxite*, and of what use are they ?

24. Describe rocks which have been formed by the agency of the wind.

BOTANY AND AGRICULTURE.

1. Describe the simple vegetable organism found as a green scum on water tubs.

2. Write a description of the common mushroom.

3. In what ways does a typical plant differ from a typical animal ? [O. and C.]

4. What is chlorophyll ? Explain what is meant by ' photo-synthesis.'

5. Describe briefly the main features of any plant with which you are familiar.

6. What are 'stomata' ? Where are they found and what purpose do they serve ?

7. What do you understand by 'vegetative reproduction' ? Give some examples.

8. Distinguish between the several methods of reproduction by plants. [C.S.C.]

9. What is meant by (*a*) an annual, (*b*) a biennial, (*c*) a perennial ? Give examples of each.

10. Describe and give sketches of the essential organs of any flower with which you are acquainted.

11. How do the following plants reproduce themselves : (*a*) potato, (*b*) dandelion, (*c*) strawberry, (*d*) fern, (*e*) mushroom ? [O. and C.]

12. In what parts of a plant, other than the seed, may food be stored ? Give as many examples as you can, and name the kind of food stored in each case. [C.S.C.]

13. By what various means is the dispersal of seeds accomplished ?

14. What are parasites and saprophytes ? Give examples.

15. Give an account of the part played by water in the life of a plant. By what mechanisms are plants able to avoid too great a loss of water ? [O. and C.]

16. By what agencies is soil formed from rocks ? [O. and C.]

17. Why is chemical analysis of a soil not a good indication of its fertility ?

18. What is meant by an 'artificial manure' ? Name three substances used as such, and point out what are their chief effects. [O. and C]

19. Why is dung an important manure ?

20. Say what you know of bacteria in soil and the work they perform.

21. Describe the principal changes that take place in the soil when ground is lying fallow, and explain to what they are due. Why is lime often applied to land to increase its fertility ? [C S.C]

22. What is meant by the rotation of crops, and what advantages are gained by adopting this system of agriculture ? [O. and C]

23. What are kainit, superphosphate, and ammonium sulphate, and why is each applied to soil ?

ZOOLOGY

1. What are corals, and under what conditions do reef builders thrive ?

2. Describe minute organisms the shells of which collect as a deposit on the sea floor

3. What is a sponge ? Which types of sponge are unsuitable for domestic purposes, and why ?

4. Describe the chief parts of a typical insect.

5. State what you know of the life-history of the common flea. [O and C]

6. What is meant by 'metamorphosis' ? Describe the metamorphosis of a typical insect.

7. Write a brief description of the life and habits of the honey-bee [O and C.]

8. In what ways are mosquitoes injurious to health, and what means can be employed to minimise the nuisance ?

9. Mention any three insects which are harmful to mankind or to agriculture What damage do they do, and how would you destroy them ? [O and C]

10. How is the cultivation of certain insects beneficial to agriculture ?

11. What is a crustacean ? Describe some crustacean which is used as an article of diet.

12. State what you know of the life history of the eel

13. What are 'sardines,' and how are they prepared for market ?

14. Describe the chief kinds of edible fish found around the British coasts.

15. State what you know of the migrations of the salmon.

16. Describe the structure of a frog's egg, and trace the changes that

are visible with the aid of a hand lens from the time when the spawn is laid until the little frog leaves the water. [C.S.C.]

17. Make a sketch of a dissection either of a frog or of a rabbit to show the parts of the alimentary canal and the adjacent structures. [O. and C.]

18. Describe the skeleton of the common fowl, and point out differences in its construction from that of a frog.

19. Give a description of a hen's egg. [C.S.C.]

20. Compare the structure of a bird's fore limb with that of a bat.

21. What do you know of bird migration and of the causes to which it is due ?

22. Give a brief description, with a sketch, of the digestive organs of a bird.

23. Give examples of birds which are (*a*) beneficial, (*b*) harmful to agriculture.

24. How are the mouths of birds adapted to different types of food ?

25. What is a mammal ? To which division of the mammalia would you refer each of the following : porpoise, bat, goat, wolf, sloth, cow ?

26. Compare briefly the skull and dentition of a rabbit with that of a dog.

27. Give a description, with sketch, of the heart and circulation of a mammal.

28. What animals supply the following clothing materials : wool, silk, fur, leather ? [O. and C.]

29. How is leather prepared ? Describe the chief varieties of leather and fur.

30. What is meant by respiration ? What is the importance of respiration to both animals and plants ? [C S.C.]

31. What functions are performed by the brain of a vertebrate animal ? [O. and C.]

32. What do you know of the Arctic whale and the sperm whale, and the useful products obtained from them ?

33. Mention animals which yield : ivory, porpoise leather, isinglass, sepia, pearls. Of what use is each of these materials ?

34. What is a ruminant ? Describe the ruminating process.

35. How does the digestive system of a mammal differ from that of a bird ?

36. What light have fossils thrown upon the ancestry of the horse and of the whale ?

HUMAN PHYSIOLOGY AND HYGIENE.

1. Give the chief parts of the human skeleton.

2. Write what you know concerning the ancestry of man.

3. Describe a movable joint, and explain how it works.

4. By what methods are the activities of the human body controlled ?

5. Draw a diagram of the nervous system to show the different parts of which it is made up.

6. Of what use is the sympathetic nervous system to the body ? Say what you know about it

7. What do you understand by a reflex action ? Give some examples.

8. What is known about local centres of control in the brain ?

9. Give an account of the human digestive system.

10. What are the chief constituents of human diet ? Why is an exclusive diet of tinned foods harmful ? [O and C]

11. What are the advantages and disadvantages of cooking food ?

12. Which classes of food are mainly responsible for (*a*) building new tissue, (*b*) maintaining energy ? Give examples of these classes

13. What are vitamins ? Mention the chief vitamins, name foodstuffs containing each, and state the result of a deficiency of each

14. Explain the part played by (*a*) saliva, (*b*) bile, (*c*) gastric juice in the processes of digestion

15. What are the chief uses of the different kinds of corpuscles of the blood ?

16. Draw a diagram of the circulation, and indicate with arrows the direction in which the blood is flowing

17. Define ' artery ' and ' vein,' and compare arterial blood with venous blood

18. Describe the structure of the lungs How does the oxygen of the external air reach the internal organs ?

19. Explain what is meant by excretion What organs in the body do the work of excretion ?

20. Write notes on the methods used to eliminate the following diseases . (*a*) smallpox, (*b*) malaria, (*c*) consumption, (*d*) diphtheria. [O. and C]

21. Say what you know of the life and work of Pasteur.

22. What are hormones, and what influence have they on growth and health ?

23. Give an account of important work in public health carried out by Jenner, Lister, and Ross.

24. Describe the duties of a Medical Officer of Health

25. Give some account of the means taken to prevent refuse and sewage becoming dangerous to public health.

26. In what ways has legislation improved the conditions in factories and workshops ?

27. What is meant by ' quarantine ' ? Why is it necessary ?

INDEX TO PART I

Alluvium, 72.
Alpine flora, 78; railways, 76; rivers, 76.
Alps, 66.
Ammonium sulphate, 112.
Amœba, 88.
Anaesthetics, 212.
Anthrax, 215.
Anticline, 54.
Antitoxin, 215.
Ants, 125.
Archaeopteryx, 153.
Artesian well, 54.
Asteroids, 21, 23, 24.
Asthenosphere, 67.
Astrology, 1.
Aurora, 19.

Bacilli, 216.
Bacteria, 89; in soil, 108.
Bacteriology, 211.
Basalt, 59, 69.
Bauxite, 61.
Bees, 122.
Beetles, 130.
Blood, 174; circulation of, 173; structure of human, 203.
Blubber, 182.
Bode's law, 23.
Brain, 174; human, 194.

Calorie, large, 201.
Canyon, 73.
Capillarity in plants, 94.
Carbohydrates, 95, 200.
Carbolic acid, 219.
Carbon dioxide, 95.
Carboniferous limestone, 51.
Carnivora, 171, 179.
Celestial sphere, 3.
Centrosphere, 67.
Cerebellum, 194.
Cerebral hemispheres, 194.
Cerebrum, 194.
Chalk, 50; escarpment, 53, 74.
Chloroform, 213.
Chlorophyll, 88.
Circulation of the blood, 173.
Clay, 47; London, 53; boulder, 97.
Coal, 49.
Coal measures, 48.
Cocoa, 93, 100.
Comets, 26, 28.
Conglomerate, 46.
Constellation, 3.
Continental shelf, 65.
Copernicus, 1.
Coral, 84, 134.
Cotton plant, 99.
Crops, rotation of, 113.
Crustacea, 137.

Darwin, Charles, 84, 86.
Date line, 32.
Davy, Sir Humphry, 223.
Declination, stellar, 7.
Diatoms, 133.
Digestion, 138.
Dinosaurs, 58.
Diphtheria, 210, 217.
Dykes, 61.

Earth, 29; crust of, 43; density of, 25; interior of, 67; rotation, 30; shape, 29.
Earthquakes, 66.
Eclipses, 42.
Ecliptic, 42.
Ecology, 115.
Eel, life history of, 144.
Egg, fowl's, 167.
Eider duck, 156.
Entomology, 117.

Enzymes, 90.
Equinox, 37.
Erosion, 73, by glaciers, 78, by rivers, 72, by sea, 82.
Escarpment, 53.
Evolution, 57, 86.

Factory and Workshops Act, 222.
Faults, 55.
Felspar, 43, 60.
Fertilisers, 110.
Fisheries, 146
Fish products, 147
Fissure eruptions, 59, 69
Flea, 129
Flint, 136
Fly, 126, Ichneumon, 126
Food, 196, kinds of, 200, storage in plants, 99
Foraminifera, 133.
Fossils, 45, 57, zone, 59
Fraunhofer lines, 11
Freud, S., 221
Frog, 147, metamorphosis of, 149.
Fumaroles, 70.
Fungi, 89
Fur industry, 170, 179.

Galileo, 2
Game birds, 166
Gastric juice, 161, 198
Geological record, 56
Geology, 44.
Geysers, 70.
Glaciers, 77.
Glands, 139, 161, ductless, 219, salivary, 171
Globigerina ooze, 50
Glycogen, 219
Gneiss, 62.
Granite, 43, 61
Gregory, Sir Richard, 24

Harvey, William, 205
Herschel, Sir William, 2, 21
Hormones, 220.
Horst, 56.
Housefly, 126.
Humus, 105.
Hydrosphere, 29.

Icebergs, 80.
Igneous rocks, 44, 59.
Insects, beneficial, 126, 132; metamorphosis, 120, structure, 118
Insulin, 220.
Isostasy, 66.

Jeans, Sir J. H., 14
Jenner, Sir E., 215.
Jung, 221

Kainit, 112
Kaolin, 62
Kepler, 2, laws of, 26.

Lakes, 80
Larderello, 70
Latitude, 7, celestial, 7.
Leather, 185
Leguminosae, 109.
Light year, 6
Lime, 112.
Limestone, 49, Carboniferous, 51.
Lister, Lord, 213, 218
Loess, 77.
Longitude, 7, and local time, 31.
Lymph, 206

Malaria, 129
Mammalia, 169, orders of, 170.
Man, 187, prehistoric, 191
Manures, 110
Medical Officers of Health, 223
Mendel, G., 86
Meridian, 30
Metamorphosis of frog, 149, of insects, 120.
Meteors, 26, 29.
Micrococci, 216.
Midnight sun, 36
Migration of birds, 163, of salmon, 143
Milky way, 3
Month, 38
Moon, 38, eclipse of, 42, librations, 39, orbit, 38, phases, 41.
Moraines, 97
Mosquito, 128, 218.
Mushroom, 90.

Nautical Almanac, 7
Nebulae, 12.
Nebular hypothesis, 14.

Neptune, 11.
Newton, Sir Isaac, 2.
Nitrates, 108.
Nitrogen, 107.
Nitrolime, 112.

Oolite, 53.
Orbits, 28; planetary, 26; of earth, 35; of moon, 38.
Osmosis, 94.
Overthrust, 56.
Oxygen, 107.

Panama Canal, 218.
Parallax of stars, 4.
Pasteur, Louis, 213.
Phagocytes, 216.
Phanerogams, 92.
Photosynthesis, 96.
Piltdown skull, 189.
Pithecanthropus erectus, 189.
Planet, 21, 25; distances of, 22; minor, 21; orbits, 26; physical condition of, 25; satellites, 25-28.
Plankton, 133
Polar ice cap, 80.
Proteins, 100, 200.
Protoplasm, 85.
Protozoa, 133.
Psychoanalysis, 221.
Pterodactyl, 58.
Ptolemy, 1.

Quarantine, 223.
Quartz, 43, 47, 61.

Reproduction, asexual, 88; parthenogenetic, 93; by seeds, 92; by spores, 90; vegetative, 91.
Rift valley, 56.
Right ascension, 7.
Rivers, 71; action of, 72; Alpine, 76; Wealden, 74.
Rocks, 43; metamorphic, 44, 62; plutonic, 44, 61; sedimentary, 44, etc.; volcanic, 44, 59.
Rock salt, 43, 48.
Ross, Sir Ronald, 217.
Rubber, 102.
Ruminants, 184.

Saliva, 161; function of, 197.
Salt, 43, 48.
Sand, 46.
Sandstone, 43, 46.
Sanitary Inspector, 224.
Saturn, 21-28; rings of, 27.
School Medical Officer, 223.
Sea, work of, 82.
Seasons, 35.
Seeds, 92; dispersal of, 99; germination, 98.
Shale, 49.
Sheep, types of, 185.
Sills, 61.
Silk, 121.
Simpson, Sir James, 213.
Slate, 62.
Snow line, 77.
Soil, 105.
Solstice, 37.
Specialisation in birds, 155; in mammals, 175.
Spectroheliograph, 19.
Spectroscope, 10.
Spectrum, 10, 12, 19.
Spermacetti, 182.
Sponges, 135.
Stalactites, 50.
Star, 3, motions of, 6; parallax, 4; Pole, 6, 8; variable, 12.
Strata, 45.
Subsoil, 105.
Sun, 15; chromosphere, 19; corona, 19; constitution of, 19; eclipse, 42; motions, 20; photosphere, 16; prominences, 19; spots, 16; temperature, 15; transit, 30.
Syncline, 55.

Teeth, 197.
Telescope, 2.
Tides, 42.
Time, 30; Greenwich, 31; local, 31; sidereal, 8, solar, 8.
Trade winds, 33.
Transpiration, 94, 96.
Tropics, 36.
Trout, 141.
Trypanosomes, 217.

Unconscious mind, 221.
Ungulates, 171, 183.
Uranus, 2, 21-27.

Vaccination, 215.
Vaccine, 215.

Valleys, 72; glacial, 77; river, 72-76
Venus, 21-26; phases of, 26.
Vitamins, 200.
Volcanoes, 59, 68-71.

Wallace, Alfred Russel, 86.
Wasps, 125.
Weald, geological history of, 74.
Whales, 181.
Wood, 102.
Wool, 185.

Xylem, 102.

Yeast, 89.

Zodiac, signs of, 3, apparent motion of sun through, 38
Zone fossils, 59
Zones of vegetation, 115.

PRINTED IN GREAT BRITAIN BY ROBERT MACLEHOSE AND CO LTD.
THE UNIVERSITY PRESS, GLASGOW

Class Books of Science

A CLASS BOOK OF PHYSICS. By SIR RICHARD GREGORY and H. E. HADLEY, B.Sc. Parts I. and II., Fundamental Measurements, Hydrostatics and Mechanics. 2s. 6d. Parts I., II., and III., Fundamental Measurements, Hydrostatics and Mechanics, Heat. 3s. Part III., Heat. 1s. 9d. Part IV., Light. 1s. 9d. Parts I., II., III. and IV., 4s. 6d. Parts III. and IV., Heat, Light. 2s. 9d. Parts III., IV., and V., Heat, Light, and Sound. 3s. Parts IV. and V., Light and Sound. 2s. 6d. Parts VI., VII., and VIII., Magnetism, Static Electricity, Voltaic Electricity. 3s. Complete, 6s. 6d.

A CLASS BOOK OF CHEMISTRY. By G. C. DONINGTON, M.A. Part I. 2s. 6d. Part II. 2s. 6d. Parts I. and II. 3s. 6d. Part III. 2s. 6d. Parts II. and III. 3s. 6d. Parts I. to III. 4s. 6d. Parts III. and IV. 3s. 6d. Part IV. The Metals. 2s. 6d. Parts I. to IV. 6s. 6d. Part V. Organic Chemistry. By Prof. T. M. Lowry, D.Sc., and P. C. Austin, D.Sc. 3s.

A CLASS BOOK OF BOTANY. By E. STENHOUSE, B.Sc. 7s. 6d.

A CLASS BOOK OF GEOLOGY. By SIR ARCHIBALD GEIKIE. 7s. 6d.

A CLASS BOOK OF PHYSICAL GEOGRAPHY. By A. T. SIMMONS, B.Sc., and ERNEST STENHOUSE, B.Sc. 5s. 6d.

A CLASS BOOK OF PHYSICAL CHEMISTRY. By Prof. T. M. LOWRY, D.Sc., F.R.S., and S. SUGDEN, D.Sc.

EVERYDAY PHYSICS. By H. E. HADLEY, B.Sc. Section I. Fundamental Principles. 2s. 6d. Sections II.-IV. Sound, Heat, and Light. 2s. 6d. Section V. Magnetism and Electricity. 2s. 6d. Complete, 6s. 6d.

EVERYDAY CHEMISTRY. By Prof. J. R. PARTINGTON, D.Sc.

LONDON: MACMILLAN AND CO., LTD.

FIRST BOOKS OF SCIENCE

Globe 8vo. 2s. 6d. each.

A First Book of Arithmetic. By S. LISTER, B.Sc. Without Answers. (Also Paper, 2s.) Answers separately Paper, 6d.

A First Book of Geometry. By J. V. H. COATES, B.Sc.

A First Book of Practical Mathematics. By T. S. USHERWOOD, B.Sc., and C. J. A. TRIMBLE, B.A.

A First Book of Physics. By L. LOWNDS, B.Sc. (Lond.), Ph.D.

A First Book of Experimental Science. By W. A. WHITTON, M.Sc.

A First Book of General Science. An Introduction to the Scientific Study of Animal and Plant Life. By A. T. SIMMONS, B.Sc, and A. J. V. GALE, M.A.

A First Book of Applied Electricity. By S. R. ROGET, M.A.

A First Book of Chemistry. By W. A. WHITTON, M.Sc.

A First Book of Botany. By ELIZABETH HEALEY, Associate of the Royal College of Science, London.

A First Book of Nature Study. By E. STENHOUSE, B.Sc.

LONDON: MACMILLAN AND CO, LTD.

FIRST BOOKS OF SCIENCE

Globe 8vo. 2s. 6d. each.

A First Book of Zoology. By T. H. BURLEND, M.A., B.Sc.

A First Book of Physiology and Hygiene. By GERTRUDE D. CATHCART, M.B., B.Sc.

A First Book of Home Science. By J. HART-SMITH, A.R.C.Sc., and E. M. HART-SMITH.

A First Book of Rural Science. By J. J. GREEN, B.Sc.

A First Book of School Gardening. By ALEX. LOGAN, Formerly of Gordon Schools, Huntly.

A First Book of Commercial Geography. By T. ALFORD SMITH, B.A., F.R.G.S., St. Dunstan's College, Catford, London.

A First Book of General Geography. By B. C. WALLIS, B.Sc., F.R.G.S.

A First Geography of the British Isles. By W. M. CAREY, M.A., B.Sc.

A First Book of Physical Geography. By W. M. CAREY, M.A., B.Sc.

A First Book of Geology. By ALBERT WILMORE, D.Sc., Headmaster, Secondary School, Colne.

LONDON: MACMILLAN AND CO., LTD.

READABLE BOOKS

IN

NATURAL KNOWLEDGE

Globe 8vo. Fully Illustrated. 2s. 6d. each.

THREADS IN THE WEB OF LIFE

(*ANIMAL LIFE*)

By MARGARET R. THOMSON, and
Professor J. ARTHUR THOMSON, M.A.

WONDERS OF PHYSICAL SCIENCE

(*PHYSICS*)

By E. E. FOURNIER, D.Sc.

TILLERS OF THE GROUND

(*PLANT LIFE*)

By MARION I. NEWBIGIN, D.Sc.

THE PAST AT OUR DOORS

OR, THE OLD IN THE NEW AROUND US

(*MANNERS AND CUSTOMS*)

By W. W. SKEAT, M.A.

ACHIEVEMENTS OF CHEMICAL SCIENCE

(*CHEMISTRY*)

By Professor J. C. PHILIP, M.A., D Sc.

THE CHANGEFUL EARTH

AN INTRODUCTION TO THE STUDY OF THE ROCKS

(*GEOLOGY*)

By Professor GRENVILLE A. J. COLE, F.R.S.

LONDON: MACMILLAN AND CO., LTD.