

UNIVERSAL
LIBRARY

OU_168743

UNIVERSAL
LIBRARY

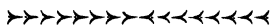
570
S67B

26366

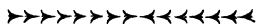
OSMANIA UNIVERSITY LIBRARY

Snyder Emily Eveleth
Biology in the
making, 1940.

BIOLOGY IN THE MAKING



EMILY EVELETH SNYDER
*Science Department, Junior-Senior High School
Little Falls, New York*



McGraw-Hill Book Company, Inc.

NEW YORK AND LONDON

Checked 1969

COPYRIGHT, 1940, BY THE
MCGRAW-HILL BOOK COMPANY, INC.

Checked 1975 PRINTED IN THE UNITED STATES OF AMERICA

*All rights reserved. This book, or
parts thereof, may not be reproduced
in any form without permission of
the publishers.*

To
my mother and father

ANNIE SIMMONS EVELETH

AND

GEORGE SIMMONDS EVELETH, M.D.

Foreword

DINOSAURS wander about in comic strips and loom up in advertisements. Are they creatures of the imagination like the winged horse of the Greeks? If not, how do we know so much about the structure and life habits of these prehistoric monsters?

In 1740 a small fleet sailed from England to capture Spanish ships in the Pacific. A year later 525 of the 960 men on board were dead, most of them struck down with the strange disease, scurvy. Today scurvy has ceased to be the "scourge of seamen." What discoveries cut down the scurvy death lists?

The Panama Canal could not be built until disease-carrying insects were conquered. How was the relationship between insects and diseases discovered?

For thousands of years plant and animal breeding was carried on. But until Mendel's laws of heredity were discovered, little scientific progress was made in improving plants and animals. How did Mendel, a Moravian monk, discover these laws?

Ninety per cent of the patients undergoing operations once died of blood poisoning. Today surgery is comparatively safe. How did this change come about?

The author further wishes to express appreciation to Grace S. Kern, Herkimer, and to Richard T. Jones, Little Falls, whose encouragement never failed and whose criticisms made it possible to clarify portions of the manuscript that otherwise would have been too technical for readers without a scientific background.

EMILY EVELETH SNYDER

Contents

FOREWORD	vii
ACKNOWLEDGMENTS.	ix
I. CLASSIFICATION	
<i>from Aristotle to Linnaeus.</i>	3
II. OBSERVATION AND EXPERIMENT	
<i>Vesalius and Harvey.</i>	32
III. THE CELL THEORY	
<i>Hooke, Brown, Schleiden, Schwann and Purkinje</i> .	46
IV. LEARNING FROM FOSSILS	
<i>Cuvier and Agassiz</i>	80
V. EXPLAINING THE ORIGIN OF SPECIES	
<i>Lamarck and Darwin</i>	105
VI. "DIVERSE RECIPES"	
<i>Galton, Mendel, Weismann, De Vries, and Morgan</i>	126
VII. MADE-TO-ORDER PLANTS	
<i>Grew, Kolreuter, and Burbank</i>	162
VIII. BEFORE AND AFTER THE GERM THEORY	
<i>Jenner, Pasteur, Koch, and Lister</i>	175
IX. MALARIA, YELLOW FEVER, AND VIRUSES	
<i>Ross, Gorgas, Reed, and Stanley</i>	207

X.	TICKS, WORMS, AND INSECTS <i>Smith, Stiles, and Howard</i>	238
XI.	ANTITOXINS, TOXIN-ANTITOXINS, AND SERUMS <i>Roux, Von Behring, Ehrlich, and Flexner</i>	260
XII.	BLOOD WILL TELL. <i>Mechnikov and Landsteiner</i>	272
XIII.	CONQUERORS OF PAIN <i>Long, Morton, and Simpson</i>	283
XIV.	EVERY GREEN LEAF IS A CHEMICAL FACTORY <i>Ingenhousz, Sachs, Willstatter, and Conant</i>	299
XV.	CALORIES AND VITAMINS <i>Rubner, Benedict, McCollum, and Evans</i>	325
XVI.	TROPISMS AND REGENERATION <i>Loeb, Jennings, and Spemann</i>	349
XVII.	CHEMICAL MESSENGERS <i>Kendall, Bayliss, Starling, and Banting</i>	368
XVIII.	NERVES AND MUSCLES IN REACTIONS <i>Pavlov, Hill, Sherrington, and Adrian</i>	393
XIX.	PROTOZOA AND TISSUE CULTURES <i>Calkins and Carrel</i>	411
XX.	MODERN EXPLORERS <i>Beebe, Andrews, Byrd, and Lindbergh</i>	420
XXI.	BIOLOGY IN THE MAKING	441
	CHRONOLOGICAL LIST.	451
	GLOSSARY.	471
	GENERAL BIBLIOGRAPHY	495
	INDEX	519

BIOLOGY IN THE MAKING

Classification

FROM ARISTOTLE TO LINNAEUS

WHY is it not sufficient to call a cat a cat, and a man a man without bothering with such long Latin names as *Felis domestica* and *Homo sapiens*? What advantages are to be gained from the use of scientific classifications? These questions and others like them are frequently asked. Some people who ask these questions seem to think that classification was invented to make the study of botany and zoology difficult. They do not realize that by classification knowledge may be increased and put into a usable form.

The history of naming and classifying plants and animals extends far back into the past. When primitive man first gave names to animals or represented them in crude pictures on the walls of his caves, he began to classify them.

The earliest and simplest divisions of plant and animal life were probably strictly on the basis of usefulness: those which furnished food or could be used to make clothing and shelters, and those which were unfit for use, poisonous, or troublesome. However, the idea of sacred and taboo objects became important long

before written records were made. The walls of the caves of the paleolithic man had many pictures of animals, but few, if any, of plants. It is believed that the animals were drawn in a religious spirit or for the purpose of magic. Plants did not require prayers or sacrifices, for, with the exception of large trees, they were within man's power to collect and use.

The two ideas, that of use and that of religious significance, therefore, might be considered as the first bases for classification. But such a classification would include comparatively few kinds of plants and animals, because a much greater number of both would seem to be of no importance whatever—not even worth naming.

As civilization progressed, there was a desire to make an orderly arrangement of knowledge. Added to this was an interest, still common today, in seeing and talking about unusual things. Travelers, then as now, brought back the unusual to show their friends. However, they could not tell them about the unusual things they had seen and were unable to bring back unless they had names for them. A very early record of plant life, showing the interest in the unusual, is a group of carvings which have been found in Egypt. These carvings represent plants collected by an expedition on its return to Egypt from Syria in 1500 B.C. Because these plants were so different from those in Egypt, the ruler, believed to have been Thothmes III, had an inscription made in which he affirmed their actual existence.

In the story of the flood and in several other places in the Bible, the animals are classified into more or less natural groups according to their habits. Thus we find them listed as aquatic animals, birds, and land animals.

The land animals are further divided into wild beasts, domestic animals, and creeping things. Classification was carried further when certain animals, such as sheep, goats, and bullocks were mentioned as acceptable animals for sacrifices; while the pig, on the other hand, was taboo either for sacrifice or for human consumption.

Commerce and conquests gradually brought the peoples of the countries around the Mediterranean and in the valleys of the Nile and the Tigris-Euphrates in contact with one another. Since these countries differed in physical features and climate, the numbers of known animals and plants were greatly increased. By the time Grecian civilization was in the ascendancy, both plants and animals were being classified in writings. The extensive use of plants as medicines made the classification of them most important. Modern investigators have found descriptions of between four and five hundred plants used in the treatment of diseases during the fifth and fourth centuries before Christ.

Aristotle (384-322 B.C.) is often spoken of as the "Father of Biology." His work on the classification of animals is cited as a great advance in scientific thought. In one of his writings he classified 520 species of animals. As some of the animals common in Greece are not mentioned by him, it is reasonable to suppose that he was familiar with a few more than this number. But when it is remembered that in 1899 William Beebe (see page 421) had 900 species of living birds in the New York Zoological Gardens, Aristotle's number seems rather insignificant.

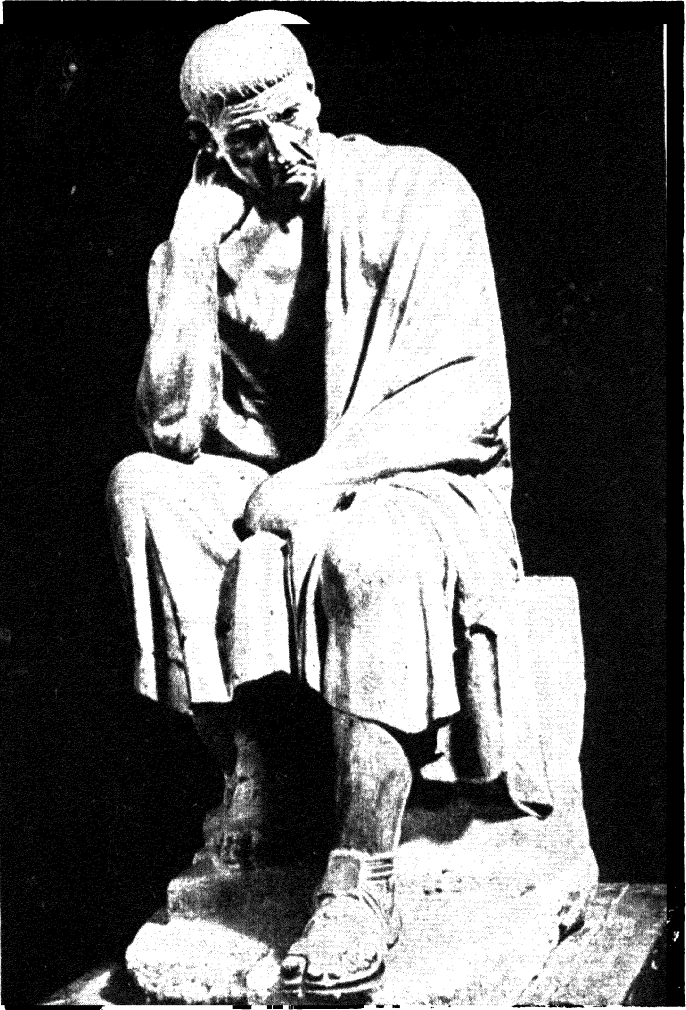
Modern knowledge is based on such different conditions that before it is possible to appreciate Aristotle's contributions to biology, it is necessary to understand

something of the civilization existing in this fourth century before the Christian era. In spite of the fact that the known world was greater in extent than it had ever been before, it was very small in comparison with the known world today. At the time Aristotle was a young man the Greeks knew well the Grecian peninsula, Macedonia, the southern part of Italy, Sicily, and Asia Minor. They knew something about the coastline of most of the Mediterranean Sea and the Black Sea. They had little really accurate knowledge of Asia or northern Europe. Beyond the limits of the territory they had explored and colonized, the world existed only in folk tales and myths and was populated with a variety of mythical monsters. When we consider what a small amount of territory was actually known, we can understand one reason why it was possible for an individual in Aristotle's time to have a comprehensive knowledge of the known world in a way that has never been possible since.

Further than that, since there were no intricate machines, no telescopes nor microscopes, the intellectual pursuits of an educated man were limited. The possibility of knowing more and doing more in the branches of science such as astronomy, biology, physics, and chemistry was definitely restricted by lack of tools.

Aristotle was by no means the first Greek to make an attempt at classifying animals. However, his mental ability and the circumstances under which his writings spread throughout Europe in later centuries have made him an outstanding figure.

Aristotle was born in the Greek town of Stagira in 384 B.C. His father, Nicomachus, was an Asclepiad. The



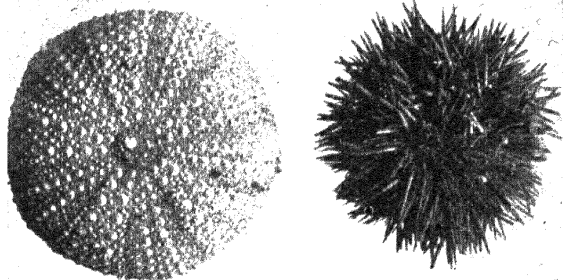
ARISTOTLE

Although better known as a philosopher, Aristotle is often called the "Father of Biology." His writings about animals influenced the development of biology for many centuries (*The Bettmann Archive.*)

Asclepiads were the physicians in Greece, who effected their cures in the name of Aesculapius, the god of healing. Their treatments were undertaken with a great deal of mystery and ritual, such as the sacrifice of white cocks and the use of large harmless snakes. On the other hand, they kept records of the patients who came to the shrines. They listed their symptoms and made notes of the way they responded to treatments. These records were passed on from generation to generation, and gradually effective methods of curing or helping some of the patients were accepted.

Nicomachus was a physician in the court of the ruler of Macedonia. As a child Aristotle played with Philip who later became a powerful ruler and the father of a more famous son, Alexander the Great. Nicomachus died when Aristotle was still a youth. One of the vows taken by the Asclepiads was that they would give their services in educating the children of their colleagues; accordingly, Aristotle received his training in biological and medical subjects from the friends of his father. This early training influenced his thought throughout his whole life. It is apparent in his philosophy, for which he is more widely known than for his studies of living things.

When he was seventeen or eighteen, Aristotle went to Athens to study under Plato, the greatest teacher then living. He remained at Athens until the death of Plato twenty years later. Since he was not named Plato's successor as head of the Academy, he went to Asia Minor. There he was attached to the court of Hermeias, who was a Persian vassal-prince. Aristotle married the niece of the prince. A political revolution robbed Herme-



SEA URCHINS

The eggs and embryos of these invertebrates are excellent laboratory material for the study of fertilization and segmentation. Biologists often refer to the converging jaws of the sea urchin as "Aristotle's lantern" (*Courtesy G. P. Weldon, from "Economic Biology"*)

ias of his power and forced Aristotle to flee to Macedonia, where by this time, his former playmate, Philip, was the ruler. Philip put him in charge of the education of his son, Alexander.

What Aristotle taught to young Alexander is not definitely known, but it is probable that he taught him many biological facts, for at all times Aristotle was greatly interested in living things. Some of his best observations were made on marine animals. Even today we find that his name has been preserved in the label "Aristotle's Lantern" which was given to the converging jaws of the sea urchin.

After the assassination of Philip, Alexander, then about twenty years old, became the ruler of Macedonia. Aristotle's sympathies were quite naturally with the Macedonians, and for this reason he was not in favor with the influential party at Athens. Also he approved of a monarchic form of government instead of the simple democratic form that was the ideal of many of the

Athenians. In spite of the strong feeling against Aristotle, the power of Alexander was so great that under his protection it was safe for the philosopher to return to Athens and found a school.

Here he was allowed to use a temple dedicated to Apollo Lykeios for his school. This became known as the Lyceum. The word "Lyceum" is used today as a term for an association or institution for literary study, debates, and popular lectures.

Aristotle attracted great numbers of pupils to his lectures. His former teacher, Plato, had called him "the brains" of his school. Now, as a teacher himself, Aristotle had the opportunity to show his remarkable mental powers. His days at Athens were fully occupied. Mornings, he gave lectures to his chosen pupils among whom were many men well known throughout Athens for their own accomplishments. In the evenings, he lectured to younger men who came to the Lyceum. He must have devoted a great deal of his time to writing, for his manuscripts covered a wide field. Some of the subjects he wrote about were art, biology, logic, metaphysics, politics, and psychology.

Aristotle continued his school until the death of Alexander, when a rebellion in Athens against the Macedonian government made his life unsafe there. He fled to the island of Euboea where he died in 322 B.C.

Aristotle's classification of animals was a standard for hundreds of years because the groupings were based on structural differences rather than on the uses of animals. In a general way he considered two factors: how the animals reproduced or from what they were formed, and whether or not blood was present in the animals.

According to Aristotle, the highest group of animals brought forth their young alive and had blood. In this group he included man and the land and sea mammals that he knew. The second group reproduced by eggs. In this group were the birds, reptiles, amphibians, and fish. These he considered to have blood. However, in this division he placed the cuttlefish, octopus, and crustaceans that he considered bloodless. The third group contained the insects. Over and over again, Aristotle showed the keenness of his powers of observation. However, in his discussion of insects he made a surprising statement. He thought that all insects began life as worms. He must have seen the eggs of insects, but he evidently did not know what they were. In the fourth group, he placed the lower forms of mollusks. These, he thought, were formed from slime and mud that in some unknown manner had become alive, or that new animals grew on the old ones and then became free from the parents. In the last group he was shrewd enough to include the coral and other marine animals in spite of the fact that they resemble plants because they are attached to some base. These he thought were produced by spontaneous generation. The idea of spontaneous generation—that organisms come into being without parent organisms—is a very old and persistent one.

Aristotle's influence on his contemporaries was great. His influence many centuries later was so powerful that it shaped the development of biological thought for generations. In time his works acquired a sort of sanctity: that is, what Aristotle had written was considered the truth even if a person could see with his own eyes that Aristotle had been mistaken.

The principal treatises about animals that have been preserved are—to translate the titles—*The History of Animals*, *The Parts of Animals*, and *The Generation of Animals*.

One of Aristotle's pupils and contemporaries carried on his work of classification. This man was Theophrastus (372–288 B.C.). To him Aristotle passed over the management of the Lyceum when political troubles drove him from Greece. He also gave him his personal library and manuscripts. Theophrastus was particularly interested in botany. As companion works to those of Aristotle, he wrote *The History of Plants* and *The Study of Plants*.

Competent investigators have concluded that Theophrastus is justly deserving of the title of "Founder of Scientific Botany." As late as the eighteenth century he was recognized as a scientific botanist. Some of the reasons for his importance are: he divided plants into flowering and flowerless groups; and he first used the term *fruit* in the botanical sense in which it is used today—a ripened ovary with any parts of the flower that may be attached.

The story of classification begun by Aristotle and his pupil was interrupted by the course of history. Greece was in time absorbed in the expanding Roman Empire. The civilization of the Romans differed greatly from that of the Greeks. They expended their energies in politics, warfare, colonization, and the construction of roads and aqueducts. Practical agriculture appealed to them more than the study of plants and animals as an intellectual pursuit. Even the practice of medicine, until recent times the foster parent of so much that is now included in biology, did not make great advances.

One Roman, nevertheless, occupies a unique place in the literature of the natural sciences. He was Pliny the Elder (A.D. 23-79). His vast work, divided into thirty-seven books, influenced students for fifteen hundred years. The title of this work *Naturalis Historia*, translated *Natural History*, does not give a correct idea of the vast number of subjects it contained. It was more like an encyclopedia than any other type of book.

In the section about zoology, Pliny described both real and imaginary animals. With complete sincerity he wrote about unicorns; dragons breathing fire hot enough to wither anything it touched; elephants that would not board a ship until the master had sworn to return them to their native land. Pliny listed the animals without regard to likenesses in structure, but usually with the largest and most remarkable coming first. Each animal was considered in its relation to man, whether it was beneficial or harmful. In many instances the importance of an animal was based on its use as a medicine. Two of the hundreds of remarkable cures from the book are:

“A tooth stops aching when worms are taken from a certain prickly plant, put with some bread in a pill-box and bound to the arm on the same side of the body as the aching tooth.”

“Two bed-bugs bound to the left arm in wool stolen from shepherds are a charm against nocturnal fevers; against diurnal fevers if wrapped in russet cloth instead.”*

Bed-bugs are also listed as a cure for snake bites.

* THORNDIKE, LYNN, *History of Magic and Experimental Science*. New York: The Macmillan Co., 1923. Vol. I, p. 89.

Pliny gave the uses of medicinal plants in great detail. He believed that all plants were of medicinal value; only in some cases their exact uses were not as yet known.

There are two reasons for mentioning Pliny in a chapter on classification. First, in his *Natural History* he made an attempt to summarize all the information known about plants and animals. This summarization took the place of and delayed classification on more scientific lines. Second, his writings were so popular in the fifteenth century that between 1469 and 1499 seven editions were brought out in Italy alone. Not until 1492 was there a book written which called attention to the errors to be found in Pliny. No wonder that, with such popularity, all sorts of romantic and unusual ideas about plants and animals continued to be believed by the educated for centuries, and are still more than half-believed by the ignorant. Charles Singer in *From Magic to Science* says that the spells recited even now by gypsy fortune tellers are inaccurate formulas taken from Pliny's works and handed down by word of mouth through the centuries.

During that period of history known as the Middle Ages, changes took place which influenced intellectual activities in every field. The monasteries were the seats of learning. In them the monks spent long hours writing, copying, and illuminating manuscripts. However, their activities were not entirely confined within the monastery walls. They considered that taking care of the sick was a form of charity they should practice. For this purpose they carefully cultivated many kinds of herbs. The value of some of these plants was real; of some, imaginary. As

a natural result of circumstances a new kind of book appeared, the *herbal*. As the title suggests, the herbals were written about medicinal plants.

The plants in the herbals were listed according to their specific uses. Some of these herbals were beautifully illustrated with drawings by which plants could be recognized. In others, the drawings were so conventionalized that they resembled no particular plants. In a few of these books an even more bewildering situation occurred. The plants of one locality were described while the drawings were of plants found in an entirely different locality. For example, in a manuscript prepared in England about 1050, the illustration accompanying a plant called "henbane" is not of the English form, but of one growing near the Mediterranean. Naturally, such inaccuracies led to confusion in the minds of people who were anxious to learn about plants.

Before taking up the modern idea of classification, we must note with particular interest a book written by Konrad von Gesner. Gesner was born in Zürich, Switzerland, in 1516. Friends who had been attracted by Konrad's ability and earnestness in his school work contributed enough money to make it possible for him to study in Basle, Paris, and Montpellier. After the completion of his education he was for a time professor of Greek in Lausanne and was then appointed town-physician of Zurich. He died in 1565 while fighting an epidemic of the plague in that city.

During his life Gesner wrote an immense work called *Historia Animalium*. It was about thirty-five hundred pages in length and was published in four volumes. It is difficult to translate the Latin titles of many books



GESNER IN HIS MUSEUM

This picture gives an idea of the specimens to be found in a museum in the sixteenth century. The few and simple tools used in preparing specimens indicate that no very delicate work was undertaken. (*The Bettmann Archive*)

into concise English. The contents of Gesner's book can be more clearly indicated by calling it a description rather than a history of animals.

In classifying animals he followed the same grouping that had been established by Aristotle in the fourth century before Christ. However, to make the book easier to use, he arranged the animals in alphabetical order within the groups. Each animal was discussed from eight points of view. First, all the known names of the animal were given, including names in different languages. Second, a description of the animal, including its habits and origin, was given. Third, "the natural function of the body" was discussed. The fourth point would be a surprise if found in a modern textbook, for

it concerned the qualities of the soul of the animal. The next item gave the general uses of the animal to man, and the sixth its use as food. The seventh section contained the medicinal uses of the animal, many of which were based on the uses found in Pliny's *Natural History*. The last item cannot help but amuse the modern student of biology. It consisted of "poetical and philosophical speculations" about the animal, together with stories to be found about it in other books.

Gesner's book was interesting and it was widely read. The author reported many accurate observations of his own. At the same time, he relied so much on Aristotle and Pliny for information that his book preserved old inaccuracies. Furthermore, he included descriptions and drawings of animals that he had been told existed in America. Actually, these strange creatures existed only in somebody's vivid imagination. Nevertheless, the book was valuable in many ways and it marks a dividing line between the medieval and modern points of view in biology.

Since Gesner's book was the best of its kind when it was published, it is easy to see that classification was not carried on in a very scientific way. During the next two centuries a new impetus was given to the study of plants and animals. Expeditions of conquest and exploration took Europeans to countries hitherto unknown to them. New animals and plants were found. For example, the opossum in North America and the kangaroo in Australia greatly surprised the first Europeans who saw them. Ship captains brought back large collections of living and preserved specimens of plants and animals to exhibit to their friends. Some of them were mere curiosi-

ties, but others, such as the white potato, proved to be of economic importance.

Many educated people who were interested in plants and animals did not have opportunities to travel to new countries. They amused and instructed themselves by making collections and by growing unusual plants. Amateur and professional gardeners induced their friends who traveled to bring back any strange plants they might find. They exchanged the bulbs and seeds from their gardens with as much enthusiasm as boys show when trading stamps. The wealthier gardeners paid high prices for exotic plants.

It can be easily understood that the influx of new kinds of plants and animals made apparent the need of a reasonable method of classification. Many disputes also arose about the factors which determined a species. How different must two plants or animals be in order that they should be considered examples of two species?

Unless one is aware of this interest in nature manifested by many educated people in the eighteenth century, it will be impossible to appreciate the importance of Linnaeus to his contemporaries and to his followers.

Carolus Linnaeus was born in Råshult, Sweden, in 1707. How his father, Nils, happened to have the name Linnaeus is told by a Swedish writer. Nils was a peasant lad from Sunnerbo, in the province of Småland in Sweden. As was the case with country people in general in Sweden, he had no family name. When he was at school preparing for the ministry, he adopted the name of Linnaeus after a mighty linden tree growing near his home, which was regarded by the country folk as a sort

of sacred tree. Nils Linnaeus loved plants and in the parishes where he lived he was known for the unusual collection of herbs he raised in his garden. Carolus, when he was old enough, had his own garden in which he took great delight.

In 1717 young Linnæus was sent to Växjö to school. His progress was far below the standard of the school, especially in Latin. Therefore, the authorities sent word to his father that he would be wise to apprentice his son to a cobbler and give up the idea of making him a priest. Fortunately Dr. Johann S. Rothman, the boy's teacher in physics, had observed his interest in natural science. He did not agree with the other teachers that Linnaeus was wasting his time when he spent the hours on collecting trips that they thought he should have spent on books. Dr. Rothman persuaded the father to let the boy continue his schooling. Not only that, but he took a personal interest in him. He gave him Pliny's *Natural History* and books by Joseph de Tournefort and Hermann Boerhaave to study. Tournefort was a French botanist who had advanced a theory that the higher plants could be classified according to peculiarities of the flowers. Boerhaave, many years later, became very much interested in Linnaeus and recommended him for a position that influenced his life from that time.

When Carolus was twenty he went to Lund, where he studied at the University. He lived in the home of Dr. Kilian Stobæus, professor of medicine. Here the boy had many advantages, such as the use of the professor's large library, but unfortunately he incurred the jealousy of another student named Nicholas Rosen. The unpleasantness which arose made matters very difficult for

Linnaeus. During the succeeding years the paths of these two crossed several times to the disadvantage of Linnaeus.

The following year Dr. Rothman, his former teacher, advised the young man to go to Upsala where there was a superior school of medicine and botany. Linnaeus had no money, but his family hoped that a relative connected with the university would be able to find him employment. He arrived in Upsala on the day of the funeral of the relative. His other hope for aid was that he might find favor with Olof Celsius, the dean of the college. Celsius was away when Linnaeus arrived. Before long, Carolus and a fellow student, Peter Artedi, with whom he had formed a firm friendship, were reduced to abject poverty. Linnaeus was eventually forced to mend his shoes with birch bark and paper. When he was on the point of giving up all hope, Celsius returned. He was at once impressed by Linnaeus's knowledge of botany. He gave him employment as tutor to his children and as assistant in helping him prepare a dissertation on the flowers mentioned in the Bible. While aiding in this work, Linnaeus was allowed to use the library of Celsius. Here he found a small treatise on the sex of plants. This with the previously mentioned work by Tournefort made him think more and more about the problems of classification.

At Upsala, Linnaeus came to the attention of Olaus R. Rudbeck, Jr., an elderly professor of botany. The old professor talked for hours about a trip which his father had taken through Lapland. He himself had always intended to take such a trip but had never found the time. Linnaeus was intrigued by the descriptions he



LINNAEUS IN HIS GARDEN

Botanical gardens filled with rare and unusual plants, such as the one represented in this picture, were popular during the time of Linnæus. The naturalist is shown here using a magnifying glass. There is no evidence that he used a microscope in his work. (*The Bettmann Archive*)

heard. Therefore when the Academy of Sciences at Upsala decided to have another survey of plant life made in this little-known region, Linnaeus was appointed to make it. In 1732, he set out on a journey through Lapland as an observer and collector.

He made the journey of approximately 3,798 miles alone or with an occasional guide. He traveled on foot, by horseback, and in a few places, in crude boats. Great stretches of the country were desolate. Several times he was so short of food that his strength nearly gave out. He carried only such extra clothing and equipment as he could get into a knapsack. For days he walked through swamplands where he frequently sank to his knees in the mud. While he lived among the Laplanders, his bed was made of two layers of moss, one for a mattress and the other for a blanket.

At one place Linnaeus did the natives a great service. Their reindeer were dying of some strange poison. Linnaeus discovered that the poisonous water hemlock grew there in abundance. He pointed out this noxious plant to the Laplanders and advised them to keep their herds away from the places where it grew. On his way back to Upsala, he spent ten days in the mining region near the head of the Gulf of Bothnia, where he studied the art of assaying metals.

In 1733 Linnaeus returned to the mining district to make a further study of the minerals of his native land. During this trip he met Baron Nils Esbjörnson Reuterholm, governor at Falun and director of mines in Sweden, who had heard of Linnaeus's journey into Lapland. Linnaeus proposed a trip through Dalecarlia, which Reuterholm agreed to finance. The plans were left in an indefinite state when Linnaeus returned to Upsala.

Fortunately later, at a time when Linnaeus was again reduced to want, the Baron remembered the proposed trip and sent for Linnaeus. On this trip he was accompanied by nine young men, each of whom had some particular interest in natural science. They covered about 533 miles, for the most part on horseback.

Linnaeus returned to Falun, the home of the Baron. On his previous visit there he had met Sara Elizabeth Moraeus, the daughter of a well-to-do physician. He had fallen in love with her and wanted to marry her. Her father would not consent to the marriage until Linnaeus had a definite means of earning a living. The best plan seemed for him to go to Harderwijk in Holland and get a degree in medicine. This would have been impossible except for the fact that Sara Elizabeth gave him her savings, which amounted to about a hundred dollars (Swedish).

The year 1735 was an eventful one for Linnaeus in spite of his poverty. In Holland he received his doctor's degree and with the financial aid of a friend published his *Systema Naturae*. This was the first of his books in which he presented the scheme of classification now known as binomial nomenclature. Immediately botanists in Europe and England took notice of it.

After several years in Holland, Linnaeus became so homesick for Sweden that he returned. He settled in Stockholm and subsequently married Sara Elizabeth. At first his practice was small; but before long he came to the attention of the court, and his practice increased rapidly.

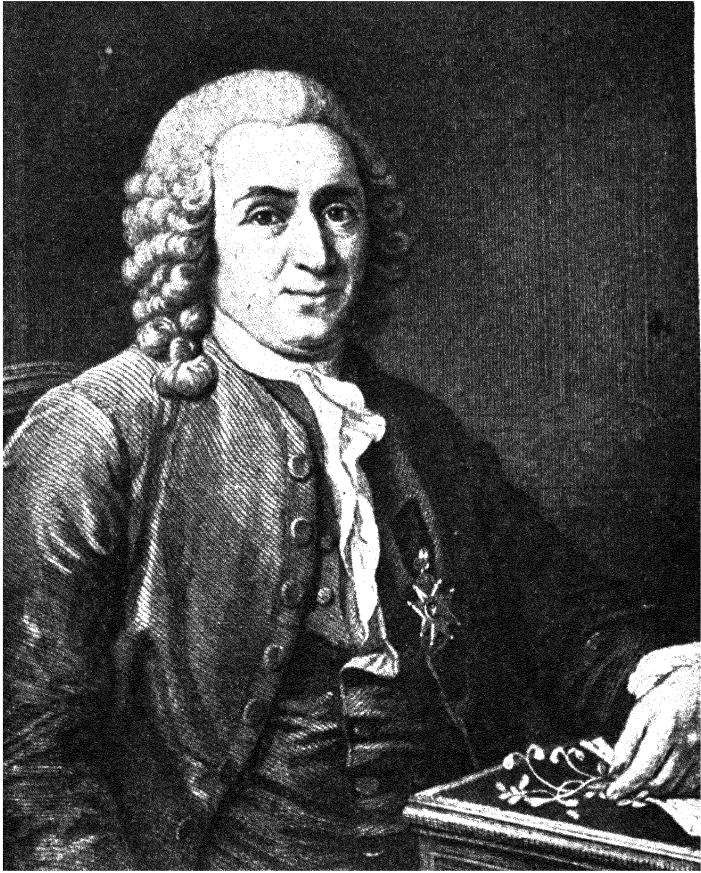
In 1739 Linnaeus was appointed physician to the Swedish Navy. He gave considerable attention to the dietary, or allotment of food for the sailors. Later it was brought to his attention that large amounts of lumber in

the shipyards were being destroyed by the borings of the larvae of an insect. At his direction the wood was kept under water during the short time when the female insects were laying their eggs. The carrying out of his instructions saved the government many thousands of dollars.

For years Linnaeus had hoped that some day he might return to Upsala as a professor. An opportunity came in 1741 when he was asked to lecture on anatomy. The subject was not what he most wanted; nevertheless, he accepted the post. Curiously enough, the lectures on botany, materia medica, and natural history, the subjects in which he was most interested, were being given by his old rival, Rosen. But Rosen was dissatisfied. He wanted to lecture on anatomy. In spite of the bitterness between them caused by earlier differences, the two men came to terms and exchanged professorships during the following year. Linnaeus held his professorship until 1763, when he had his son appointed to succeed him.

In the later years of his life, Linnaeus received many honors. He was awarded the Order of the Polar Star in 1753. Eight years later he was ennobled and took the name of von Linné. At that time he designed his own coat of arms which bore the motto that translated means "To spread fame by deeds." Carl von Linné, the son, who had few of the father's talents, died without heirs, so according to custom, this coat of arms was broken over his grave.

After Linnaeus's death in 1778, a quarrel in the family resulted over his collections. In an indirect way this was the reason why the collection, library, and correspondence of Linnaeus left Sweden and were taken to England



CAROLUS LINNAEUS

In this engraving the Swedish naturalist holds a spray of his favorite flower. It is commonly called twin flower, but in Latin it perpetuates his name as *Linnaea borealis*. He wears the insignia of the Order of the Polar Star (*The Bettmann Archive*)

where they became cherished possessions of the Linnaean Society. This society has exerted a wide influence on scientific thought in England since its founding.

Linnaeus was an excellent teacher. His courses in botany were conducted largely by means of field trips and were very popular. He believed that a botanist should know the plants in his own country first, but he encouraged a wider experience, if possible. Daniel Charles Solander, who was a botanist with one of Captain James Cook's expeditions in the South Pacific, was a pupil of Linnaeus.

The writings which brought Linnaeus to the attention of all botanists were *Systema Naturae*, published in the same year that he received his degree in medicine; *Fundamenta Botanica*, *Genera Plantarum*, and *Critica Botanica*. They were published in Latin, as were all scientific books at the time. In these four books he fully expounded his famous system of classification.

In the attempt to make names of plants signify characteristics, botanists prior to Linnaeus often used so many words that the name was really a description of the plant. For example, the name of one kind of grass contained fifteen Latin words. Written in a line, the name is as long as a blade of grass. Linnaeus felt that such terminology was absurd.

In a letter to Albrecht von Haller, dated June 8, 1737, Linnaeus asked this question: "Why should we retain the ell-long names of *Monolasiocallenomenphyllorum*, *Hypophyllocarpodendium*, etc., and other barbarian jargon?"

His solution to the problem was to give each species a generic and a specific name. The generic name indicates

its relationship to allied species. The specific name distinguishes it from allied species. As an example of the economy resulting from this method, we find that the name of the grass mentioned above was changed to *Poa bulbosa*.

It must always be kept in mind that classification is an invention of man's brain by which he tries to show the similarities and differences between things. No method of classification is perfect, because an organism may be like another organism in some characteristics and different from it in other characteristics. The question then arises: on what basis shall it be classified? By his schemes of classification, Linnaeus brought a large measure of order to the task of classification. He pointed out what characteristics should be used as standards in distinguishing species.

Although many of the terms have been changed or modified and plants and animals have been shifted around, yet the whole modern scheme of classification has a foundation in Linnaeus's work. It is not necessary to describe exactly what Linnaeus meant by his terms; it is more important to outline briefly what is meant by classification today.

The house cat can be classified as follows:

Kingdom	<i>Animal</i>
Phylum	<i>Chordata</i>
Subphylum	<i>Vertebrata</i>
Class	<i>Mammalia</i>
Order	<i>Carnivora</i>
Family	<i>Felidae</i>
Genus	<i>Felis</i>
Species	<i>domestica</i>

To explain classification it may be more simple to begin at the bottom of the scheme and go to the top. *Species* is a term applied to a group of individuals which closely resemble each other. In the case of the cat, the word *domestica* means household or domestic. (Subspecies, varieties, and so on may also be included.) At the time Linnaeus published *Systema Naturae* he believed in the fixity of species. By this term students of natural history expressed their belief that a species had bred true since its first appearance on the earth and would continue to do so. Before his death Linnaeus somewhat modified his views on this point, but not sufficiently to cause any great change in his methods of classification. In later chapters the modern conception of the changing of species by mutations will be discussed (see page 157).

A *Genus* is a group of related *Species*. A lion and a tiger have many characteristics in common with a house cat. The names *Felis leo* and *Felis tigris* express that relationship. A *Family* is a group of *Genera* which have common characteristics. In the same way an *Order* is made up of *Families*. In the classification of the cat, *Carnivora* means flesh eating. Related *Orders* are grouped in a *Class*. The word *Mammalia* refers to animals that nourish their young by milk secreted from the mammary glands. A consideration of the four-legged domestic animals will at once show that these belong to the *Class Mammalia*. A *Subphylum* is made up of *Classes*. *Vertebrata* refers to the fact that the animals have backbones. The *Phylum Chordata* includes animals which have a more or less well developed nervous system, dorsally situated. The *Phyla* make up the *Kingdom*. There are two *Kingdoms* of living things—*Animal* and *Plant*. Recently, some of the very

simple organisms having the characteristics of both have been placed in a group called the *Protista*.

Having worked from the bottom of the system up, we will now work down, as would be natural in using a table of classification. Taking man as an organism to be classified, we first find that he belongs to the *Animal Kingdom*. A well-developed dorsal nervous system places him in the *Phylum Chordata*; a backbone, in the *Sub-phylum Vertebrata*. As a baby he is fed by milk from the mammary glands of the mother, so he belongs in the *Class Mammalia*. So far, the man and the house cat, the lion and the tiger, the cow, the pig, and the horse are members of the same groups. Now comes a great difference. Normally, man stands in an erect position on two legs. For this reason, he belongs to the *Order Primates*, animals which stand erect or nearly so. The *Family* to which he belongs is *Hominidae*; the *Genus*, *Homo*; and the *Species*, *sapiens*. *Sapiens* refers to the ability of man to know—to think.

When one considers the rapidity with which a new craze like that of crossword puzzles can spread, it is easy to understand how classification of everything became a vogue. To many people classification of all sorts of things became a kind of game. Even scientists put altogether too much importance on mere cataloguing. Many more useful and practical types of research were neglected. As with everything else, enthusiasm waned after a time. Now classification has reached a more normal level of importance and is recognized as the means to an end and not as the end itself.

In an indirect way classification had an interesting effect on the English language. When the naturalists classified and described species, it was necessary to

distinguish between shades of color. There were very few color words in the language. For this reason some words were borrowed from different languages, suffixes were added to others and they were used in new combinations. The descriptive language of literature was thereby greatly enriched. For example, in the eighteenth century an English naturalist attempted to describe 133 varieties of parrots. The scarcity of color words in the English language was a great handicap to him. Before he was able to accomplish much, he was forced to enlarge his color vocabulary to a great extent. He used such Latin words as *rufous* and added the suffix *ish* to the already existing color words. He also introduced pea-green, peach-blossom and other compound words as names of colors. Linnaeus in Sweden and Buffon in France (see page 108) are given credit for increasing the color vocabularies in their native languages.

In looking back over the development of classification from earliest times to the present, we must not forget that it was a natural development. Increasing knowledge could be put in a manageable form only by inventing some scheme in which facts could be related.

Aristotle's name will always be important in the history of classification because he accomplished more in that line than any of his predecessors. Furthermore, after his writings became popular in European countries, they exerted a tremendous influence on naturalists.

The binomial nomenclature developed by Linnaeus gave later naturalists and biologists a workable scheme for classification. Although classification received too much emphasis for a time in the natural sciences, it is, nevertheless, a necessary tool in many lines of research.

It is estimated that there are more than fifty times as many species of plants and animals known to biologists today as there were when Linnaeus lived. Classifying himself as *Homo sapiens*, man has classified millions of other species of living things and continues to find new forms to classify.

Hints for Further Reading

CADDY, FLORENCE, *Through the Fields with Linnaeus*.

OSBORN, HENRY FAIRFIELD, *From the Greeks to Darwin*.

Observation and Experiment

VESALIUS AND HARVEY

A HIGH school pupil, after he finishes a course in biology, knows more about the anatomy and physiology of the human body than a university professor did at the beginning of the seventeenth century. However, he knows very little in comparison with the total amount that is known about the body. How has all this knowledge been accumulated? Men have learned to observe accurately and to experiment with purpose and skill.

We read and hear a great deal about the modern scientific attitude. To people born in this century, much of this emphasis seems unnecessary. To them the scientific attitude toward experimentation and the application of scientific knowledge seems like nothing more than common sense. Strangely enough, what is considered common sense in one century may have been hardly suspected or, perhaps, entirely unknown a century earlier. The so-called common sense changes and grows year by year.

A list including the names of all the men who have contributed information helpful in understanding the human

body would be very, very long. In time it would begin with early written records. There would be several well-known names in the periods when Greece and Rome controlled the world. Here and there in the first sixteen centuries A.D. would appear the names of a few outstanding men. After the sixteenth century the numbers of names would increase rather rapidly until by the time the last half of the nineteenth century was reached, there would be so many names, we should not know what to do with them.

Mental attitudes restricted the acquisition of knowledge for many centuries. Three of these attitudes should be mentioned. One was veneration for famous ancient authorities, such as Aristotle and Galen (see pages 11 and 179). Another was superstition. A vast amount of superstition grew up about all kinds of living things. The third attitude was connected with religion. By many people it was considered wrong to try to understand living things and natural phenomena.

Among the men in the first eighteen centuries A.D., who freed themselves from mental restrictions and carried on remarkable pieces of research work, were Andreas Vesalius, William Harvey, and Marcello Malpighi.

Andreas Vesalius was born in Brussels about 1515. From an early age Vesalius was interested in anatomy. He read books on this subject belonging to his father and other relatives. His father was an apothecary to Charles V.

Vesalius added to his knowledge by dissecting all the animals he could get. When he was eighteen, he went to Paris, where Jacob Sylvius was teaching Galen's doctrines. Claudius Galen had lived in the second century. He was the most famous physician of his time, and for

centuries his writings on anatomical subjects were regarded as almost sacred (see page 179). While in Paris, Vesalius continued his dissections. Before long his skill was recognized, and he was asked to take the place of the barber-surgeon in making dissections on human bodies. He studied for three years in Paris. Then after working a short time in Brussels, he went to Venice. Immediately after his graduation there, he became a professor of anatomy at Padua where his lectures became popular at once.

Vesalius was not satisfied to lecture while some barber-surgeon made the dissections. With the help of his students he made his own dissections. This procedure was frowned upon by some of his colleagues who thought it beneath them to replace the barber-surgeons who were more or less despised by the professors. The results of Vesalius's personal entry into the field of dissection were twofold. He was forced to believe and to teach what he saw, in spite of the fact that his findings were often contrary to the accepted statements of Galen. Furthermore, while performing dissections he felt the need of more adequate tools. As a result, he modified instruments in existence and invented new ones.

In 1543, when he was twenty-eight years old, Vesalius published *De Humani Corporis Fabrica* (*Structure of the Human Body*). In it he corrected about two hundred mistakes that Galen had made. The subject matter in the book was arranged in the same order in which he presented it to his classes: the bones, the muscles, blood vessels, and nerves; the internal organs, and the brain. Besides containing the most important written matter on anatomy, *Fabrica* was illustrated with remarkable plates.



ANDREAS VESALIUS

Anatomical drawings in the sixteenth century were usually made by artists and contained a detailed background. Often, as in this picture, the anatomist was shown (*The Bettmann Archive.*)

Most of these were done by an artist, John Stephen de Calcar, a pupil of the great Titian.

Of course, the followers of Galen were angry when they found Vesalius was bold enough to call attention to Galen's mistakes, and they made life very uncomfortable for Vesalius. The opposition stirred up against him was one reason why he left Padua in 1543 and became a physician to Emperor Charles V, whom his father had served as an apothecary. After an absence of nineteen years, he returned. There was a vacancy at the University of Padua, and he was anxious to be appointed to it. While he was waiting for the matter to be settled, he made a pilgrimage to Jerusalem. Unfortunately, he died on the return trip, in 1564.

Vesalius was not fifty years old when he died. He had taught comparatively few years, yet many modern practices in surgery and the study of anatomy are directly traceable to him. Dissection followed a new direction. Surgical instruments became more efficient. Even methods of mounting skeletons show his influence.

Other men whose influence was felt in anatomical studies in Italy during the sixteenth century were Gabriello Fallopio (1523-1562), Bartolommeo Eustachio (?-1574), and Girolamo Fabrizio (1537-1619). The latter is known as Fabricius ab Aquapendente. Fallopio's name is perpetuated in the Fallopian tubes in higher animals through which the egg cell passes from the ovaries to the uterus. Fallopio was a pupil of Vesalius and became a professor at Padua.

Eustachio was a physician in Rome and taught in the papal medical school. The date of his birth is not known, but he died in 1574. The Eustachian tube, connecting the

middle ear and pharynx, bears his name because of the researches he conducted on this part of the ear.

Fabricius, one of Fallopio's pupils, did some excellent work in embryology. He is better known today, however, as the teacher of William Harvey than for his own research work.

William Harvey, whose name is the one most commonly associated with the discovery of the circulation of the blood and the functioning of the heart, was born in Folkestone, on the south coast of England, in 1578. His parents had sufficient means to give their children a good education. Harvey received his first degree from Cambridge and then went to Padua in Italy where the famous Fabricius ab Aquapendente was lecturing.

The anatomical theater of Padua was the most famous place of its kind in the sixteenth century. Today it seems like a crude affair. Around the center where the dissecting was done, tiers of circular galleries were built. There were no seats. The students leaned on the railings as they took notes. The light for dissection was furnished by candles.

It was not long after Harvey's arrival at Padua that he attracted the attention of his teacher. In spite of the great difference in their ages, they became such intimate friends that Harvey knew the details of the research work his teacher was carrying on. At this time Fabricius was investigating the valves of the veins. The arteries, through which the blood passes away from the heart, have smooth inner surfaces. The veins, on the other hand, through which the blood returns to the heart have valves that retard backward flow. Fabricius, who still believed much that Galen had written in the second century, was

puzzled. If the blood flowed first in one direction and then in the other as Galen had said it did, what could be the function of these valves? That he could not answer. But later the purpose of these valves became apparent to William Harvey.

In 1602 Harvey returned to England with a degree from Padua. Since this degree would not give him the prestige he desired in London, he took the Cambridge examinations and received his doctor's degree. His large practice among the wealthier class proved that his ability was recognized in a short time. By 1615 he was a lecturer at the Royal College of Physicians.

The date at which Harvey made known what he discovered about the circulation of the blood is usually given as 1628. In that year he published his famous book, *De motu cordis et sanguinis*. However, examination of the notes prepared for lectures in 1616 shows that he knew much about the circulation then.

While trying to solve some of the problems connected with the circulatory system, Harvey made use of very practical methods. He used common sense.

College professors had taught him that the blood was made in the liver and went to the muscles by way of the heart. That it returned to the heart from the muscles was not generally considered true. In some unknown way, blood was supposed to be deposited to form the tissues around the bone. At this point Harvey used mathematics. He killed a sheep and found that a ventricle would contain about two ounces of blood. Figuring that the sheep's heart was about the same size as that of a man's, he calculated how much blood would be forced out in a minute while the heart was beating normally.



HARVEY DEMONSTRATING THE CIRCULATION OF THE BLOOD

King Charles I and his young son are interested spectators at the demonstration. Harvey is indicating the chambers of a heart with his dissecting knife (*Brown Brothers*)

The result was astonishing. About ten pounds of blood a minute would leave the heart. From what could that amount of blood be made? No one could possibly consume enough food, if he ate constantly, to produce such a quantity. Was the blood returned to the heart from the muscles and used over and over again?

By tying blood vessels in a living serpent he found part of the answer to his problem. A tied artery swelled between the ligature and the heart. A tied vein swelled beyond the ligature. The valves discovered by Fabricius also swelled beyond the ligature. Fabricius had noticed this swelling when he tied the arm of a patient in prepara-

tion for the process of bleeding, then considered a necessary treatment in most cases of illness. Harvey continued to experiment. He cut an artery and a vein and saw that in the artery the blood flowed from the cut end nearest the heart. In a vein, the reverse situation was observed. Before he was through experimenting, Harvey had determined the functions of the auricles and ventricles of each side of the heart. The right side received blood from different parts of the body and sent it to the lungs. The left side received the blood from the lungs and sent it back to the muscles.

To his own satisfaction he proved that the circulation of the blood is continuous. He had no microscope; he could only surmise a connection between the ends of the smallest arteries and veins. He never saw the capillaries, those minute vessels about $\frac{1}{2500}$ of an inch in diameter, that connect the larger vessels. He assumed that there must be a connection and his assumption proved correct.

Was this reasonable explanation accepted without controversy? It was not. Harvey's private practice suffered as a result of the publication of his book. Opposition reached its height in England in a book written by a young Dr. James Primrose. He did not do any dissecting to prove that Harvey was wrong. Primrose merely quoted old authorities, in particular, Galen. Harvey's book was based on years of research. Primrose spent a few weeks writing his, but it naturally appealed to those people who dreaded to part with an old false idea for a new true one. In France, the teaching of Harvey's ideas was forbidden for some years.

Besides his work on the heart and blood vessels, Harvey spent much time studying the development of the embryos

of animals. He had a passion for dissecting. During the years he was in royal favor, he was allowed to have deer from the king's hunting preserves for this purpose. Birds interested him, but the writings of Aristotle about them had made such an impression that he continued to misunderstand them. To one bird, his wife's parrot, he paid a great deal of attention while it was alive and dissected it after its death, hoping to find out what had ailed it.

In addition to his private practice, Harvey was the physician to two kings, James I and Charles I. During the Civil War, Charles I was forced to flee for his life, and the faithful Harvey went with him. While he was away from London, soldiers plundered his house. To the loss of science, his collections and many of his manuscripts were destroyed.

Many scientists who have made important discoveries have died long before their work received recognition. Harvey was fortunate to live long enough to see his explanation of the circulation accepted by most of the leading teachers and students. He died in 1657. As he had no children, he willed his estate to the Royal College of Physicians with the provision that the proceeds should be used "to search out and study the secrets of nature."

Harvey's place in the biological sciences is comparable to that of Galileo's in the physical sciences (see page 82). Each marks a definite if not complete breaking point with the authority of the ancients. Each contributed much to the solid beginning of the modern scientific point of view based on accurate observations.

In the year that Harvey published his book on the circulation, 1628, Marcello Malpighi was born near Bologna, in Italy. His father was a well-to-do farmer and

Marcello was given a good education. At the university in Bologna, he became a student of philosophy, that of



MARCELLO MALPIGHI

Through his lenses Malpighi saw the capillaries in the tissues of the lungs which Harvey had thought must exist (*Ewing Galloway*)

Aristotle (see page 8) in particular. Misfortune interrupted his studies when he was twenty-one, before he had decided on a definite profession. Both his father and mother died. Left with seven younger brothers and sisters to care for, Malpighi was forced to give up study for two years and to devote his time to them. However, in 1651, he returned to the university and two years later he received his degree in medicine.

Malpighi was a successful practitioner and a popular lecturer in the different universities to which he was called. In addition he carried on a vast amount of research work. A glance at the adjective "Malpighian" in the dictionary will show that nearly a dozen structures in plants and animals were named for him. For example, the Malpighian tubes, part of the excretory system in the bee, and the Malpighian layer of the human skin perpetuate his name.

Malpighi was a pioneer in the use of lenses for examining plant and animal tissues. Like Antony van Leeuwenhoek (see page 54), his contemporary, he used both a single lens and combinations of lenses. There is also a

likeness between the two men in their curiosity about the structure of living things, but Malpighi's training made him direct his curiosity in more definite channels. What takes place during breathing was one of the questions he determined to answer.

When Malpighi was a student of anatomy, the lungs were considered a special kind of flesh into which the ends of the small arteries, veins, and air tubes opened. Here, the blood was supposed to mix with air before returning to the heart in the pulmonary veins. How this mixture took place no one knew.

On the tissues of the lungs, Malpighi directed his lenses. He soon discovered they contained quantities of minute air sacs. Further than that, he saw that even the very small arteries divided into smaller and smaller tubes. He selected one of these tiny tubes and followed its wandering course. It did not end. Instead it was joined by another tube like itself, then another and another, finally becoming large enough to be recognized as a small vein. The arteries and veins did not open into the tissue of the lung! They were connected by an intricate network of almost invisible vessels. Malpighi had discovered the capillaries Harvey thought must exist, but which he never saw.

Malpighi described these capillaries to a friend in letters during 1660. A few years later Leeuwenhoek (see page 57), using an ingenious arrangement, a combination of a test tube and lenses, saw the capillary circulation in the tails of living tadpoles and fish. Thus, much of the mystery of circulation was removed, and the study of respiration and the importance of the capillaries to living tissues took on a new meaning.

Eventually it was discovered that through the walls of these minute vessels, a constant exchange of substances occurs. Food and oxygen are brought to the cells and waste materials removed. Nutrition of individual cells is therefore dependent on the capillaries. Their combined length is almost unbelievable. It is estimated that if all the capillaries in the muscles of an average man were connected in one continuous tube, this tube would be long enough to go around the world two and a half times.

Malpighi was always conscious that both living and nonliving things are exceedingly complicated. In writing about his research work, he said that in his student days he was greatly attracted to human anatomy. The more he studied, the more complicated the problems he attempted to solve seemed to be. Hoping to simplify matters, he turned to animals a little lower in the scale than man. These were also too complicated. He began to study insects. His work on the silkworm, published in 1669 by the Royal Society in London, is still famous. Not finding simplicity in insects, he turned to plants. His observations on the structure of plants, as shown by his drawings, were remarkably accurate, although his interpretations of the uses of different tissues were often wrong. Even in plants, he did not find the simplicity he sought. He said that the whole mineral kingdom should be investigated, but he was growing old and did not have time to begin that.

After thirty-eight years of great activity as a doctor, a teacher, and a research worker, Malpighi was made the personal physician to Pope Innocent XII. Three years later, in 1694, he died of apoplexy.

Malpighi's writings were in the form of short papers, a large number of which were published by the Royal Society. He was very proud of his membership in that body and kept up an active correspondence with it about his work.

Pioneers in scientific research, such as Vesalius and Harvey, built the foundation for the present knowledge of the human body. Without this knowledge the practice of preventive and curative medicine, and of surgery could never have developed.

Hints for Further Reading

HERRINGHAM, WILMOT, "The Life and Times of Dr. William Harvey," *Annals of Medical History*, IV (July, 1932), 347-363.

MACLEOD, J. J. R., "Harvey's Experiments on Circulation," *Annals of Medical History*, X (Dec., 1928), 338-348.

The Cell Theory

HOOKE, BROWN, SCHLEIDEN, SCHWANN, AND PURKINJE

SINCE the earliest time when men began to think about their environment and of what it consists, they have been puzzled by these two questions. Of what is matter composed? What are the differences between living and nonliving matter? Answers have been given that were only half-answers or evasions. Some of these answers were accepted temporarily. However, as the sciences of chemistry and physics developed, new findings made the old answers seem absurd. Even now when the atom has been carefully studied, matter is still a mystery. Although the colloid chemist and the biochemist have made many important discoveries, living protoplasm cannot be made to order in a chemical plant.

Before a knowledge of chemistry existed, the Greeks made attempts to explain the composition of living and non-living matter. Pythagoras, who lived in the sixth century B.C., had a theory that all matter was composed of combinations of earth, water, air, and fire. Hippocrates in the next century described the body as containing four liquids, or humors: blood, phlegm, black bile, and yellow bile. These two ideas were combined in the

minds of later writers who considered blood to be related to fire; phlegm to water; yellow bile to the air; and black bile to the earth. The idea that matter consisted of the four so-called elements, earth, air, fire, and water persisted until the seventeenth century. The word "element" was not used in the sense of a chemical element as it is most commonly used today.

Before the seventeenth century many people had guessed that living organisms were made up of minute structures. That these structures actually existed was not proved until lenses were ground. The date at which lenses were first made is uncertain. There is reliable evidence that glass was used in the early part of the thirteenth century for making spectacles. Two Hollanders, Johann and Zacharias Janssen, seem to have used lenses in combinations between 1591 and 1608. The use of the compound microscope was not general for some time, but magnifying glasses were common when Harvey (see page 38) published his work on the circulation of the blood in 1628.

The early microscopes were very different from the sensitive ones used today in research work. One type consisted of two lenses mounted in a short round tube. The object to be examined was fastened at one end of the tube which was then pointed toward the light. Because of their abundance and the ease with which they could be caught, insects were among the first things to be closely examined through these crude microscopes. For this reason, the instruments were often called "flea-glasses" or "fly-glasses."

During the period when lenses were coming into use, light was being studied intensively. It is not strange,

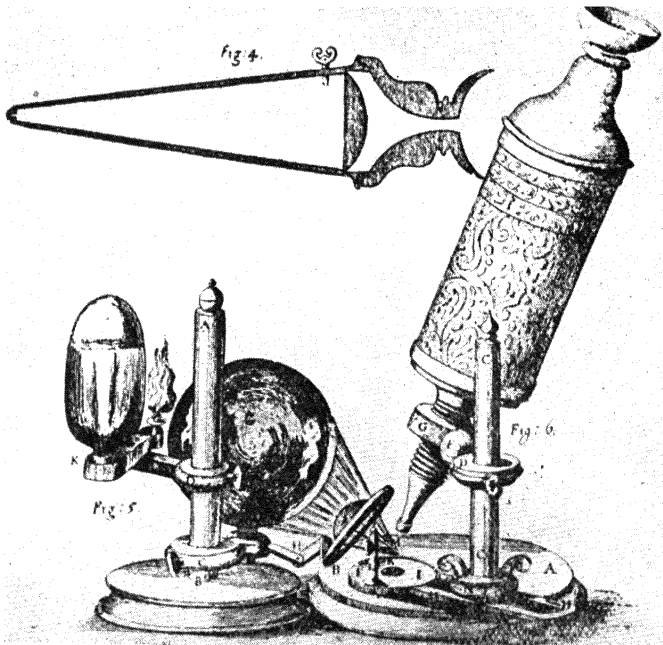
therefore, that a physicist made observations that resulted in the naming of the cell. Robert Hooke, to whom the honor of naming the cell is given, was primarily a physicist, but his originality led him into many bypaths. He was born on the Isle of Wight, in 1635. As a child he was not well enough to have the usual schooling. To amuse himself, he made all sorts of mechanical toys. He had musical as well as mechanical ability, for in 1653 he went to Oxford as a chorister at Christ Church. A description written about him at this time portrays him as frail, stooped, and sharp-featured. He was a solitary, restless person, quick-tempered and melancholy. His ill-health was at least partly the cause of the disagreeable disposition that brought himself and his associates much unhappiness.

Not long after his arrival at Oxford, he became an assistant to Robert Boyle, one of England's best-known physicists. In Boyle's laboratory, Hooke constructed all sorts of apparatus, such as air pumps and diving bells and gauges to measure the velocity of the wind and the amount of rainfall. While assisting Boyle, Hooke built up a reputation for himself as an experimenter. In November, 1662, it was proposed that Hooke should be asked to serve as the curator of the Royal Society. The journal-book of the society reads that Hooke be asked "to furnish the society every day they meet with three or four considerable experiments, expecting no recompense till the society gets a stock enabling them to give it." In a further entry, Mr. Boyle is thanked for allowing Mr. Hooke to leave his employ to become the curator and experimenter of the society.

Again and again in reading the history of science, one finds the Royal Society mentioned. The influence of this society upon scientific thought during the past three centuries is immeasurable. No one can fully appreciate the importance of the Royal Society without knowing a little of its history.

For several years before 1660, a small group of men had been meeting for the purpose of discussing philosophical questions and of performing experiments to prove or disprove popular beliefs. Early in his reign, Charles II granted a charter to this group and they were incorporated as the Royal Society. One of the avowed purposes of these serious-minded men was to try all things in order that they might be able to separate truth from superstition. For example, in July, 1660, the society met to test the alleged supernatural power of powdered unicorn's horn. The following observation was recorded in the minutes of the meeting: "A circle was made of powder of unicorn's horn, and a spider set in the middle of it, but it immediately ran out several times repeated. The spider once made some stay upon the powder."

It is difficult to imagine how men whose names now rank among those of the greatest scientists and thinkers could have watched a spider surrounded by a circle of powder. Of course, the powder was presented to them in good faith, as the existence of unicorns was not doubted then. Many of the experiments listed seem so obvious to the twentieth century reader as to be absurd. On the other hand, they were not all of this caliber. All the experiments, however, show the scientific attitude of the men.



HOOKI'S MICROSCOPE

Figure 4 is a cross section of the tube showing two lenses. Figure 5 shows how the light from a flickering flame could be focused on the object being studied (*The Bettmann Archive*)

It was not long before the Royal Society became a clearing house for scientific ideas and theories. The approval of the society carried great weight, not only in England, but on the Continent and later in America. Many of the papers that are now landmarks in the advancement of scientific thought were sent to the Royal Society before they were published. Many expeditions sent out all over the world for purposes of exploration and observation were backed by the Royal Society.

Robert Hooke was an exceptionally good experimenter. He was regarded by other members as a mathematical and mechanical genius, in spite of the fact that his violent temper antagonized many of them, including Sir Isaac Newton.

Hooke's interest in optics resulted in an advance in the science of biology because Hooke spent much effort in making microscopes. He felt he was unequalled in the field of making lenses. His confidence in himself is expressed in a communication to the society. In it he stated that he had an unfailing method for improving optical instruments so that "whatever almost hath been in notion and imagination or desired in optics, may be performed with great facility and truth." He never divulged his method of making and using lenses except in an anagram, a kind of puzzle, and this he never explained.

Like a boy today with a toy microscope, Hooke looked at everything that was near at hand. One day he cut a very thin slice of cork and looked at it. Immediately he saw a more or less regular pattern. He was reminded of little boxes or cells packed close together. Thus the word "cell" entered the scientific vocabulary and became so firmly rooted that all attempts to substitute a more adequate term have failed. What Hooke actually saw was the dead cellulose walls of the cells and not the living contents, the essential part. Other people, both in writings and drawings, had hinted at the structure of plant tissue, but no one had given the units a name. Hooke's discussion of the cell spurred on to further study other botanists, among them Nehemiah Grew (see page 164).

In 1665 Hooke published a book, *Micrographia*, dedicated to the Royal Society. It was the first book to be published dealing almost exclusively with microscopical observations. In it are descriptions of a great variety of things: the edge of a razor, crystals of snow, parts of flies and bees, the fine hairs of a nettle. The drawings were made by Hooke himself.

In his book on the mosquitoes of North America, Leland Ossian Howard, the entomologist (see page 257), mentions the interesting description of the development of mosquitoes which Hooke gave in *Micrographia*.

The action of the larvae attracted Hooke's attention. He remarked that they hang, suspended from the surface of the water with their heads downward. They reminded him of an animal he had "seen in London that was brought out of America, which would very firmly suspend itself by the tail—and was said to sleep in that position, with her young ones in her false belly (pouch)." Evidently, Hooke had seen a captive opossum. Hooke also described the pupal and adult stages of the mosquito and said himself that he had never read any account of the changes the insect undergoes. He discussed the origin of mosquitoes and wondered if they were really formed from decaying matter in the water, as many people thought, or if they might not develop from eggs that had been laid in the air where they might float until washed down by drops of rain.

Hooke died in February, 1703. He was an active member of the Royal Society until a few months before his death. His quarrels with Newton prejudiced many scientists against him. His actual contributions to scientific thought were many but, except for his indirect

contribution through the development of the microscope and his naming of the cell, he was a much greater physicist than biologist.

Born three years before Hooke and living ten years longer, Antony van Leeuwenhoek, also a maker of lenses, made many and careful observations of minute organisms and parts of organisms.

Antony van Leeuwenhoek was born at Delft, Holland, in 1632. His father, a basketmaker, died when Antony was six years old. His schooling seems to have been limited. When he was sixteen years old, he went into a clothing establishment belonging to a relative. His lack of education is shown by the fact that he did not know Latin, then considered a fundamental study.

Records show that in 1654 he opened a store for himself in Delft, where he sold cloth, ribbons, buttons, and the usual dry goods. When Leeuwenhoek was about twenty-eight, he received an appointment as "chamberlain of the Council Chamber of the Worshipful Sheriffs of Delft." A document has been found in which his duties were listed. They were not difficult, and some of them were probably performed by people he hired, for they included the cleaning of the room where the meetings were held and the building of fires when necessary.

Some time later he became an alderman, and in 1669 he was appointed a surveyor. Leeuwenhoek must have been a competent mathematician to have received this appointment. His careful calculations of minute objects also show his ability in mathematics.

All his combined duties seem to have been so light that he had sufficient time to indulge in his hobby of lens making. His lack of formal training was counterbalanced



LEEUFNHOEK DISCOVERS SOMETHING NEW

The artist has caught the spirit of Leeuwenhoek's enthusiasm when he saw something unusual. Leeuwenhoek's microscopes were more simple than Hooke's and were held toward the source of light. (Courtesy *The Seal-test System of Laboratory Protection*)

by unusual skill with his hands, by his very keen eyesight, and by an unbounded curiosity. He made lenses of quartz, glass, and diamonds which he tried in different combinations. One single lens made by him and still in existence is said to magnify an object two hundred and seventy times.

Leeuwenhoek's observations were brought to the attention of the scientific world in 1673, when Regnier

de Graaf wrote about them to the Royal Society of which he was a member. In this letter, de Graaf gave great praise to the lenses his friend ground. In a note accompanying de Graaf's letter was one from Leeuwenhoek in which he described the microscopic structure of a bee and of a louse. This was the beginning of a correspondence with the Royal Society that lasted until near the close of Leeuwenhoek's life. His communications were in Dutch. He frankly admitted that he knew no Latin. In the archives of the society at the time of his death were 375 papers and letters from him. This figure would not seem large, if the observations recorded had been made in a haphazard fashion. But Leeuwenhoek was very proud of his observations and made very sure of what he saw before telling anyone. He examined everything: crystals, pepper, rain water, the water from the canal, the deposits from people's teeth, and the pigmented layers from the eye of an ox.

Standards of measurement are developed only when there is a new need. The modern microscopist measures minute objects in terms of microns, a micron being the thousandth part of a millimeter. Leeuwenhoek had no such scale. He could only compare what he saw with something known, such as a fraction of the diameter of a hair, or a spider's web, or a grain of sand. After a standard of measurement was set, these dimensions were checked, and it was found that Leeuwenhoek was very accurate.

Always searching for something different, examining everything he could find, Leeuwenhoek was the first person to describe with accuracy the blood corpuscles in man, in frogs, and in other animals. In 1675 he wrote



ANTONY VAN LEEUWENHOEK

Leeuwenhoek's skill in grinding lenses and his keen eyesight enabled him to see through his microscopes things that no one had ever seen before (*The Bettmann Archive*)

to the society that he had discovered very tiny living animals in water. He described these animalcules so clearly that they are now known to have been specimens of *Vorticella*. From his letters and sketches in 1683, it is evident that Leeuwenhoek saw the three forms of bacteria—rod, spiral, and round. He obtained his first specimens in scrapings from his own teeth. He confirmed his observations by examining the saliva and scrapings from the mouths of a child, two women, and two old men.

The fact that Leeuwenhoek ground lenses for different purposes and arranged them in different ways was one reason for his success as an observer. He did not confine

himself entirely to observations of minute organisms. By an ingenious arrangement he was able to see the capillary circulation in the tail of a very young tadpole. A few years earlier Malpighi (see page 43) had seen capillaries; now Leeuwenhoek saw the blood coursing through them.

Leeuwenhoek would not tell the secrets of his success in grinding, nor would he sell his lenses. Dr. William Albert Locy writes: "The number of microscopes accredited to him is rather overwhelming; it is said that he possessed not less than 247 complete microscopes. In addition he had 172 lenses set between plates of metal. . . ." People from England and the Continent came to Delft to look through his microscopes. When Peter the Great of Russia came to Holland to watch shipbuilders at work, he sent for Leeuwenhoek. For two hours Peter looked through lenses at various things, including the circulation of the blood in the tail of an eel.

Leeuwenhoek could have made a fortune if he had been willing to sell his lenses. This was not the case. He took great pride in the fact that no one else could equal them and that he saw many things through them no one had ever seen before.

He did, however, feel gratitude toward the Royal Society for publishing his communications. In 1721, about two years before his death, he wrote the society that he had directed his daughter upon his death to send a "small black, lacker'd and gilded" cabinet to the society. It contained twenty-six microscopes. In this letter he goes on to say that he ground each lens himself and that he extracted the silver in the mountings from minerals. His daughter, Maria, carried out his wishes and

the microscopes were sent to England. After the microscopes had been received, the Royal Society sent Maria a handsome silver bowl engraved with the arms of the society. Strangely, this collection of microscopes, so much valued at the time, disappeared about twenty years later. There is no record of what happened to them.

Antony van Leeuwenhoek died in 1723. He was an unusual person, and he holds an unusual place in the history of biology. He described more different microscopic specimens than anyone had up to that time. Unlike many discoverers he seems to have been satisfied with recording observations, without building up many speculations and theories about the things he saw.

Hooke had seen the cell walls in cork; Leeuwenhoek had seen living one-celled plants and animals. The next observation to stimulate the study of the structure of the cell came in 1831 when Robert Brown, an English botanist, discovered the nucleus in plant cells.

Robert Brown was born in 1773, in Montrose, Scotland. His father was a clergyman. Brown was educated at Aberdeen and Edinburgh. In 1795, after completing his education, he obtained a commission as ensign and assistant surgeon to a regiment in the north of Ireland. Three years later, when in England as a recruiting officer, he met the famous botanist, Sir Joseph Banks, then president of the Royal Society. Banks had been a botanist on one of the voyages of Captain James Cook in the southern Pacific, and through his influence Brown sailed as a naturalist on a scientific expedition to Australia and New Zealand in 1801. The expedition was under the command of Captain Matthew Flinders. After some months of exploration the ship, called the "Investi-

gator," was declared unseaworthy. The captain started for England to procure a new boat, but he was first shipwrecked and then captured by the French. Brown and the artist of the expedition were left in Australia. Their enforced stay lengthened into months, then into more than a year. During this time Brown collected plants; he had about four thousand when he returned to England in 1805. Most of these were new to English botanists.

The profession of botanist would not give Brown an income unless he were connected with a society or university. Therefore, from 1805 to 1822 he earned his living as secretary to the Linnaean Society. It will be remembered that Linnæus's collections, library, and correspondence were brought to England not long after his death (see page 24). In 1810, Brown also became a librarian for Sir Joseph Banks. He held this position until the latter's death. Banks willed Brown his home, collection, and library. In 1827, the Banks collection was transferred to the British Museum. In the terms of the transfer, Brown arranged that he be given a life position as keeper of the botanical collections at the museum.

Brown was well qualified for the title of "plant geographer," in use at this period. He had worked on the collections made by Banks and had gathered a large collection of his own from Australia and New Zealand. Such work naturally presupposes considerable knowledge of classification. Dissatisfied with the systems then in existence, he worked out a system of his own based on those of Bernard de Jussieu and Linnaeus. Many of the changes were important, such as the distinction he made in 1827 between the *gymnosperms*, a group containing the

cone-bearing trees, and the *angiosperms*, a group containing the flowering plants and such trees as maple, elm, and oak. The separation of these two groups is based on a fact that Brown discovered. The angiosperms have seeds that are covered. The seeds of the gymnosperms are naked; that is, they develop no covering.

The accuracies of Brown's observations are clearly shown in his writings. In his work on classifications he became aware of many minute details of plant structure. Some of the facts which appear more or less as digressions in his writings exerted more influence on scientific thought than did his main thesis. In 1831 he read a paper before the Linnaean Society on the reproduction of certain orchids and related plants. In this paper he gave the first description of the nucleus of a cell. He described it as a "single circular areola generally somewhat more opaque than the membrane of the cell." He saw it first in the epidermal cells of the leaves, but on further study found that other cells in the same plant contained this areola, or nucleus. Brown did not think that he was the first person to have seen this structure, as he was sure that it was indicated in the recent works of Purkinje (see page 70) and other scientists. These men had paid so little attention to it that the structure was not described definitely or labeled in the accompanying drawings. Brown proved his ability as a research worker when he attached importance to this "circular areola."

Another discovery by Brown left its mark in the study of plants. Many botanists were confident of a relation between pollination and the production of seeds in plants. Fragments of the story of fertilization were known. Joseph Kolreuter (see page 166) some years before had



ROBERT BROWN

Robert Brown, a "plant geographer," collected about four thousand plants in New Zealand and Australia. The magnifying glass and herbarium sheets in the portrait indicate his interest in botany. (Courtesy *The Linnean Society of London*)

conducted experiments in which he tried to determine the real function of the pollen. Other investigators had seen the tube formed by a pollen grain after it reached the pistil of a flower. Brown traced the continuance of the pollen tube to the nucleus of the ovule in the base of the pistil.

Neither the terminology of the nuclei of cells nor the processes of fertilization perpetuated his name. However, in another connection his name appears in many textbooks. While studying pollen grains placed in water under a lens, Brown's attention was attracted to their constant and irregular motion. This motion of small particles in a liquid was later called the "Brownian movement." This movement is now believed to be due to the bombardment of neighboring particles. This phenomenon may seem to be far removed from biology. On the contrary, now that the study of colloid substances is so important in biochemistry, the Brownian movement receives a great deal of attention.

Robert Brown died in 1858. He was very highly regarded by his contemporaries both for his fine character and for his ability as a research worker. Baron Alexander von Humboldt, the famous German explorer and naturalist, dedicated one of his books to Brown. Asa Grey, the great American botanist, wrote of Brown that he never suggested a theory until he had thought over all the possible objections to it.

The discovery and description of the nucleus in the cell was an important step in a series of investigations that resulted in the so-called cell theory. Six men who are notable in this connection are: Felix Dujardin (1801-1862); Matthias Jakob Schleiden (1804-1881); Theodor

Schwann (1810–1882); Johannes Evangelista Purkinje (1787–1869); Hugo von Mohl (1805–1872); Max Schultze (1825–1874). It will be noted that these men were contemporaries.

For the sake of clarity in the discussion of the development of the cell theory, their lives will not be taken up in the chronological order of their births but in the order in which they are listed above.

Felix Dujardin was born in Tours, France. His father was a watchmaker, and the boy received early training as his assistant. The skill he developed in the use of his hands was of great advantage to him later in his work with the microscope. Sketching and painting interested him so much that when he was seventeen he went to Paris to study art. Unable to earn a living with his brush, he took a position as an engineer on a piece of hydraulic construction. From engineering he turned to library work and from that to teaching. He was a professor at Toulouse and then at Rennes. At first his greatest interests in the field of natural science were in botany and geology. About 1834 he turned his attention to microscopic one-celled animals. He found that they were composed of a homogeneous mass that carried on the life functions, such as absorbing food and reacting to stimuli, by contracting and moving. In 1835 he called this jelly-like appearing substance of which they were made "sarcodé." The word was derived from the Greek words meaning flesh-like. He described this substance as "a living jelly endowed with all the functions of life." He studied its reactions to acids and alkalies, and its solubility in water and other liquids. He proved to his own satisfaction that it was different from mucus or

gelatin. Oddly, he first used the word "sarcode" when he was working on fossil shells along the Mediterranean coast. Hitherto, the very tiny shells found in certain deposits had been considered to be those of mollusks. Dujardin proved that they had been formed by minute one-celled animals. The word "sarcode" was used in France and to some extent in other countries, until it was replaced by "protoplasm."

One of Dujardin's outstanding characteristics was his modesty. Several works were published based on his findings in which no acknowledgement was given to him. He made no charges against the authors. Dujardin's modesty, therefore, kept him from receiving the recognition that was certainly due him.

Of an entirely different disposition was Matthias Schleiden, who was born in Hamburg in 1804. His father was an eminent physician. Schleiden studied law and began to practice in his native city. His lack of success brought on a period of despondency. When he recovered from his mental upset, he went to the universities in Göttingen, Berlin, and Jena and took a degree in medicine and botany. In 1839 he became an associate professor of botany at Jena.

Before some of the concepts that Schleiden brought to the field of botany can be made clear, it is necessary to mention his acquaintance, Theodor Schwann. Schwann was six years younger than Schleiden and had been born in a small town in Rhenish Prussia. His father was the owner of a bookshop. Schwann had studied under Johannes Peter Müller, who is recognized as one of the greatest teachers of anatomy and physiology in the nineteenth century. So keen was Müller's interest in Theodor



MATTHIAS SCHLEIDEN

Schleiden, as a botanist, contributed important evidence on the cellular structure of plants (*The Bettmann Archive*)



THEODOR SCHWANN

Schwann's work on nerve tissue made him conclude that animals were composed of cells. His statement about the cellular structure of plants and animals has become known as the cell theory (*The Bettmann Archive*)

Schwann that he had him made his assistant when the former was called to the University of Berlin. There Schwann worked on animal tissues, in which Muller was interested.

In October, 1838, Schleiden happened to have dinner with this other worker on cells. During this dinner Schleiden mentioned his work on plant tissues and especially his observations on the nuclei of cells. (Brown, the discoverer of these structures, had hinted that no one had paid sufficient attention to them. He did not go further himself than to describe them and give instances of different types of cells in which he had seen nuclei.) Schleiden was interested in the observations that Schwann had made on animal cells. After dinner they went to

Schwann's laboratory where they examined some nerve tissue. From the results of their observations and discussions, both men came to the conclusion that the cell was the unit of structure in both plant and animal tissues.

Schleiden published an article on cells in 1838. His work on the nuclei led him to ask the question: "How does the cell arise?" His answer to that was not in itself correct, but it stimulated other students to work on the same subject, and gradually the right answer was found.

In 1842, Schleiden published *The Principles of Scientific Botany*. In this he treated plants in respect to cellular structure, the structure of the organs of which they are built up, and the chemistry (so far as it was known) of the composition of plants. This was a great innovation, as texts before this had dealt almost entirely with the classification and uses of plants. Julius von Sachs, the great botanist, wrote of Schleiden's book " . . . its appearance at once put botany on the footing of a natural science in the modern sense of the word. . . ." Later Schleiden published *The Plant and Its Life*. A translation of this was brought out in the United States in 1853. The popularity of botany was greatly increased by this book.

To one of Schleiden's students, Carl Zeiss, belongs credit for many improvements in the microscope. Zeiss was so dissatisfied with his own microscope that he gave up the study of botany and applied his skill to the making of better instruments.

Schleiden left the University of Jena in 1863. He was connected with a university in Russia for about a year. From that time until his death in 1881, he confined him-

self to private teaching and the study of history, anthropology, and philosophy. At the time of his death he was working on the third and last of a series of articles in which he was showing the influence of natural agents on the development of civilization. In the first article he showed the importance of salt, as a representative of a mineral substance. The second article was based on the importance of the rose, as an example of a plant. He had chosen the horse, as an animal, for the subject of the third article.

Schleiden was a restless, irritable man, quick to take sides in any controversy and very sharp tongued against his opponents. With Schwann, however, he seems to have kept on friendly terms. But this may have been more than half due to Schwann's calmer temperament.

The year after Schleiden published his article on cells, Schwann wrote *Microscopical Researches into the Accordance in the Structure and Growth of Plants and Animals*. His conclusions about the structure of organic things were supported by his microscopical examination of many tissues. It was much harder to demonstrate the cellular structure of animals than of plants, since cell walls in plants make the boundaries more visible. Besides the difficulties encountered in examining cells in animal tissue, there was an old belief which had to be broken down. For a long time flesh had been considered as a deposit built up by materials from the blood vessels. However, when the cellular nature of many tissues could be demonstrated, the cell was accepted as the unit of structure. In his treatise, *Microscopical Researches*, Schwann makes the statement that has become known as the cell theory.

Schwann's conclusions about the structure of organic things were based on his microscopical examination of many tissues and upon the observations of other biologists, notably those of Purkinje and his pupils (see page 72).

Recent investigations have shown that, although Schwann has been given the credit for the fundamental idea of the cell theory, the Czech scientist, Purkinje, had already demonstrated both the likenesses and differences in the cellular structures of plants and animals. He also had a more nearly correct idea than Schwann of the origin and development of these units.

Both Schleiden and Schwann continued to work for many years. Schleiden's great work on botany appeared after the cell theory had been made public. Schwann's work, on the other hand, was climaxed by his treatise on cellular structure. In 1839, the same year in which this was published, he went to the Catholic University of Louvain as a professor of anatomy. A few years later he went to Liège in Belgium. Although Schwann was an exceptionally fine experimenter and demonstrator, the amount of his original work became less from the time he was no longer under the stimulating direction of J. P. Müller. It is evident that he needed the inspiration of a strong-willed person to keep up his own enthusiasm for research work.

While working as Müller's assistant, Schwann did some very original work. He discovered the ferment in the gastric juice which he called "pepsin." The delicate covering of a nerve fiber perpetuates his name as the "sheath of Schwann." In the important handbook of physiology prepared by Müller at this time, Schwann's

name appears many times in connection with microscopical discoveries.

Some authorities claim that the germ theory of disease and the antiseptic methods of Lister (see page 200) are traceable to Schwann's influence. His interest in spontaneous generation led him to experiment with Infusoria, and he proved that these minute organisms do not arise spontaneously. Furthermore, he believed that putrefaction and fermentation were caused by something in the air that could be destroyed by heating.

Schwann seems to have led an uneventful life at Liége. The only important paper he published there was on the bile. He died in 1882.

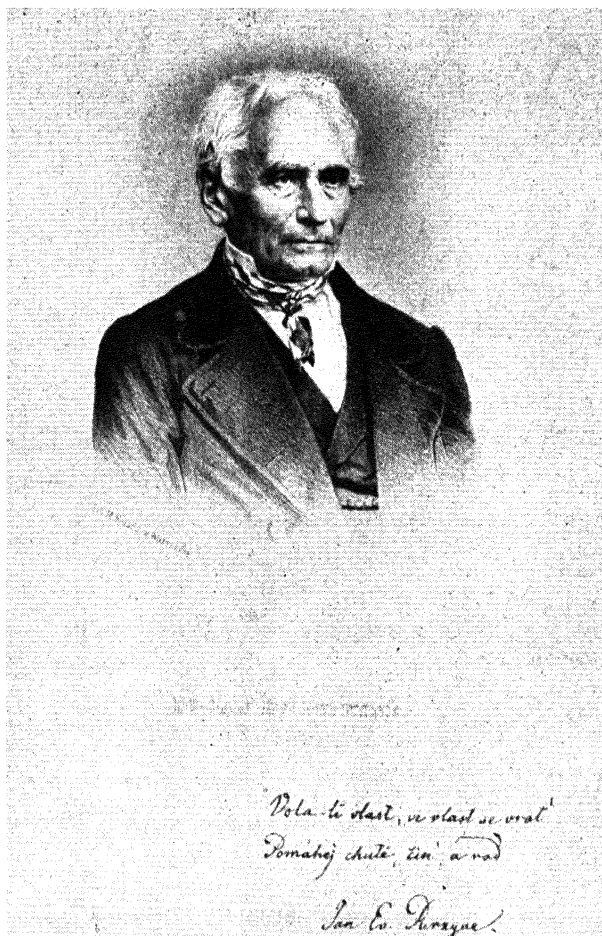
In its first usage the word "cell" was a misnomer. As the structure of the cell was further studied, more confusion of terms arose. Some of this confusion is still evident today in texts, to the annoyance of the reader. As already mentioned, Dujardin called the living substance in one-celled animals "sarcodc." In 1840, Purkinje (see page 72), while working on developing embryos, employed the word "protoplasm," derived from the Greek words meaning "first to form." The fitness of the use in this instance is plain, since all embryos begin as one cell and develop by the growth and reproduction of that cell.

In 1846 Hugo von Mohl used the same word to apply to the contents of plant cells with the exception of the material in the nucleus. Also he recognized that this jellylike material was fundamentally alike in both plants and animals. In 1861 Max Schultze helped to clarify matters to some extent. As Schleiden had asked, "How does the cell arise?" so Schultze asked, "What is the most

essential thing in a cell?" His conclusion was that the protoplasm and the nucleus of a cell were necessary for life. Upon this conclusion, the modern conception of the cell as the unit of structure and function in plants and animals arose. But the word "cell" no longer referred to the cellulose wall that Hooke saw, but to the living contents. The confusion of terminology did not end here because protoplasm was used by some to indicate the entire living material and by others to indicate the living material exclusive of the nucleus. William Seifriz makes this apt statement in regard to the present terminology in texts: "When speaking of protoplasm, it is customary to include the nucleus and to use the word 'cytoplasm,' when the nucleus is to be excluded, though actually few biologists bother always to make the distinction."

As mentioned before, the word "protoplasm" was first used by Johannes Evangelista Purkinje, a Czech born in Libochowitz. His father was at this time manager of the estate of Prince Dietrichstein. A large part of his early education was received in monasteries, and as a novice he taught in one of them. His desire for more education led him to leave the monastery and go to Prague. Since it was necessary for him to earn his living, he later became a tutor in the family of a baron in Blatná. The encouragement and help which this man gave him made it possible for Purkinje to study medicine.

At the time of receiving his degree, Purkinje's thesis was on vision. Later, when he applied for membership in the faculty of the University of Breslau, Goethe is said to have exerted his influence in favor of the Czech. Johann Wolfgang von Goethe was a strange combination of scientist and poet. While much of his scientific work



JOHANNES EVANGELISTA PURKINJE

Purkinje was the first to use the word "protoplasm" This was in 1840 while he was working on developing embryos The great Czech naturalist lived up to the ideal of patriotism expressed in the lines inscribed on the picture "If the nation calls, return to your country Help with a will Work gladly" (Courtesy Prof Dr. F. K. Studnička)

was based on incorrect suppositions, nevertheless, there was something in his philosophy and his manner of writing that stimulated more accurate men in their own work. In this way Goethe's influence was apparent in the dissertation written by Purkinje while at Prague.

When Purkinje became a member of the faculty at Breslau in 1823, physiology was taught entirely by lectures. During the following year Purkinje introduced experiments and laboratory work, and about eight years later he asked permission from the Ministry of Education to establish an independent institute of physiology. He did not succeed at the time, but in 1832 he was given a Ploessel microscope which was the best instrument of its kind at the time. With this he immediately began an intensive study of animal tissues.

Most of his early work in histology was done in a makeshift laboratory in his own home. However, by 1839 the work of Purkinje and his pupils had become so well known that he was given the use of a small building. Here he established the first physiological institute of its kind.

During the time Purkinje was at Breslau, 1823 to 1850, he not only carried on extensive investigations himself, but directed the investigations of his pupils along many lines. One reason why the scientific world has been so tardy in recognizing Purkinje's worth is that he did not publish a great deal himself. Besides that, what articles he wrote appeared in periodicals which had a limited circulation. It was only when the writings of his pupils were carefully analyzed, together with his own works, that an adequate summary of his knowledge could be made.

In 1837 Purkinje, in a communication to the Congress of German Naturalists and Physicians held in Prague, made the statements which, according to some authorities, should give him priority over Schwann in the matter of the cell theory, for it was not until 1839 that Schwann published his theory (see page 68).

When another Congress was held in Prague in 1937, Prof. Dr. F. K. Studnička gave an address in memory of the Czech scientist. In his closing paragraph he said: “. . . . in the month of September, 1937, it will be just one hundred years since Jan Evangelista Purkyně [Purkinje] expounded for the first time the fundamental idea—which was also the true idea—of the celebrated cell theory.” The Purkinje memorial seal shown on page 74 was issued during this year also, as a way of commemorating the one hundred and fiftieth anniversary of the scientist's birth.

During the recent revival of interest in Purkinje two of his champions, Studnička and O. V. Hykeš, have made available much material that shows what an exceptional person Purkinje must have been. In one article Studnička lists the activities of Purkinje under forty-eight headings. Some of his discoveries have been well known for many years because cells in the brain and heart bear his name. However, besides his work on individual cells, glands, and organs he carried on experiments to show the effects of such substances as opium, camphor, digitalis, and belladonna. He used himself as the experimental animal in this work. In his study of vision he worked out the fundamental idea upon which Herman Ludwig Ferdinand von Helmholtz constructed the ophthalmoscope, an instrument of importance today for examining the eyes.

In 1850, Purkinje left Breslau and returned to Prague. About this time he adopted the Czech spelling of his



IN MEMORY

name so that it became Jan Purkyně. In Prague, he continued his work in physiology and at the same time was very active in behalf of the cultural interests of the Czech people. He organized the Czech society of physicians and was editor of a medical journal and a natural history magazine.

Purkinje had always been interested in the arts. During his stay at Breslau he had translated the poems of Goethe and

Friedrich von Schiller into his native tongue. After his return to Prague, he took an active part in the formation of cultural societies. Also, he entered politics and was a deputy in the Bohemian Diet. His great interest in the causes of the Czech people made him unpopular with the Austrian scientific workers. No event could bring out more clearly the mixed sentiments toward Purkinje at the close of his life than the fact that none of the staff of the university attended his funeral in 1869, on the other hand, crowds of Czech people of all classes came to mourn for him.

Hugo von Mohl, a contemporary of Purkinje, independently used the word "protoplasm" in 1846. He was born in Stuttgart in 1805. Relatives on both his maternal and paternal sides held high state positions. Hugo was the youngest of four brothers, each of whom gained distinc-

tion in some important field of activity. To satisfy his father's wishes, von Mohl studied medicine at Munich, but his greatest interest was in the study of plants. In 1832 he was appointed professor of physiology at Berne. This appointment kept him from accepting an offer to become assistant director at the imperial botanical gardens in St. Petersburg. After three years at Berne, he went to Tübingen as a professor of botany.

Von Mohl was a painstaking and critical worker. He acquired unusual skill in the manipulation of a microscope and made improvements on the type then in use. Other workers, among them Robert Brown, had observed the streaming movement of protoplasm in cells; von Mohl made an extensive study of this phenomenon. Schleiden had formulated a theory about cell division based on incorrect observations or interpretations of what he saw. Von Mohl, in 1835, accurately described cell division in one of the algae. These studies opened up new fields in the interpretation of the development and growth of plant tissues.

As a "vegetable anatomist," Hugo von Mohl was unsurpassed in his generation. The conclusions he drew have been verified time and time again. Much of his writing consisted of short papers, which numbered about ninety. His two longest works were a textbook on the use of the microscope and a book on the anatomy and physiology of plant cells.

In 1843 he was one of the founders of a botanical journal which he edited until the time of his death in 1872. In the same year that this journal was begun, the King of Wurttemberg, then an independent kingdom, raised him to the rank of nobility.

In tracing the growth of the cell theory, we see that the development of the microscope was responsible for a great



HUGO VON MOHL

Hugo von Mohl popularized the word "protoplasm" (*The Bettmann Archive*)

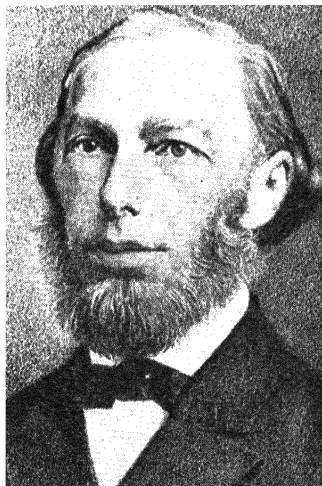
broadening of the subject matter of biology. The study of cells became as much a part of the training of a student as the gathering and classifying of plants and animals had previously been. Students everywhere were making observations on types of cells, their growth and peculiarities. Eventually, many of the observations were related. One of the men who made the cell theory more understandable was Max Schultze.

In spite of his comparatively short life—he was born at Freiburg in 1825 and died in 1874—Schultze left a rich legacy to biology. He grew up in a scientific atmosphere, for his father was professor of anatomy at Greifswald where Max later became a student. Like Schwann, he also came under the influence of Muller in Berlin. From 1859 to 1874, Schultze was a professor at Bonn.

Dujardin had described the sarcode in the one-celled animals. Schultze, an excellent microscopist, did considerable work on the same forms and on the nervous tissue of the vertebrates. It will be remembered that Theodor Schwann was working on nervous tissue at the

time he and Schleiden came to the conclusion that both plants and animals are made up of cells. Schultze, by experimentation, proved that the living substance in both forms of life is fundamentally the same. Hugo von Mohl seems to have come to this conclusion, but Schultze, in an essay published in 1861, so clearly expressed his findings on the subject that the essay is one of the outstanding writings in biology.

During the years that he was professor of anatomy and director of the Anatomical Institute at Bonn, Schultze made many important observations on the structures of worms and mollusks. He also studied



MAX SCHULTZE

Schultze's essay which explains that the living substance in both plant and animal cells is fundamentally alike is a classic in biological writings (*The Bettmann Archive*).

the organs in some animals, such as fish and eels, that are capable of producing enough electricity to give a shock to their would-be captors.

It is interesting to note that three of the men whose names are so definitely connected with the cell theory had strong artistic leanings. Dujardin wanted to be a painter of miniatures. Purkinje was enough of a poet to translate the poems of German writers into his own tongue. Schultze from childhood was a musician. His violin shared his affections with his microscope.

The achievement of developing the microscope and working out a technique in staining and mounting material so that cellular structure could be seen is remarkable in itself. But the realization that protoplasm is the foundation, or, as Huxley worded it, "the physical basis of life," has resulted in immeasurable benefit to the human race. Since every organism, whether unicellular or multicellular, is composed of one or more cells, there is unity in all living things. This implies that the living substance must have certain elements within itself and certain external conditions in its environment in order to keep alive. How important this understanding is to man's welfare may be realized in considering the strides made in the prevention and cure of diseases caused by micro-organisms.

In spite of the vast amount of research work done in recent years, scientists are still asking: Of what is matter composed? What are the differences between living and nonliving matter? New branches of science, such as biochemistry, have grown up through the efforts of students to answer these questions. The chemical composition of protoplasm has been thoroughly investigated. The colloid substances that seem to form the link between living and nonliving matter have been and are the focus of much work. From the physicist, the biologist has gained new concepts to apply to his investigations. Improved microscopes and new techniques have brought within sight the chromosomes in the nuclei, the centrosomes, and other infinitesimal structures within the cell. Bit by bit, partial answers are being found; theories are being advanced. But as yet there are no completely satisfactory answers to those two age-old questions.

Hints for Further Reading

- BAST, THEODORE H., "Max Johann Sigismund Schultze," *Annals of Medical History*, III (March, 1931), 166-178.
- BROWN, ROBERT, *The Miscellaneous Botanical Works of Robert Brown*.
- DOBELL, CLIFFORD (editor), *Anthony van Leeuwenhoek and His Little Animals*.
- HYKEŠ, O. V., and F. K. STUDNÍČKA, "Jan Evangelista Purkyně (Purkinje)," *Osiris*, II, Part 10 (Oct., 1936), 464-483.
- OPITZ, RUSSELL B., "Purkinje," *Journal of the American Medical Association*, XXXII (April, 1899), 812-814.
- PARKER, G. H., "Anthony van Leeuwenhoek and His Microscopes," *Scientific Monthly*, XXXVII (Nov., 1933), 434-441.
- SEIFRIZ, WILLIAM E., *Protoplasm*.

Learning from Fossils

CUVIER AND AGASSIZ

ABOUT the year 1710, a very large tooth was found near Albany, New York. It was taken to New York City where it aroused a great deal of curiosity and speculation. The man who finally gained possession of it was so curious about it that he had workmen dig in the ground near the place where it was found. A large fossilized bone was discovered. The tooth and the bone were sent to the Royal Society (see page 49) as evidence that giants had once lived along the banks of the Hudson River.

Suppose you were fortunate enough to find a large fossilized bone when you were rambling in the country. You would not think it belonged to a giant. Immediately you would wonder what prehistoric animal had lived where you were walking. You would ask yourself how old the bone was and how it happened to be where you found it. You might take it to some person who had studied such things and ask him your questions. The person would answer as best he could on the basis of his scientific knowledge about fossil formations.

The science of fossils is called "palaeontology"; it is the study of former life remains; it is the biology of the

past. Paleontology is a subdivision of a broader science, geology, which treats of the earth and its history. These sciences have given us museums where we can study exhibits of sections of fossil beds, of dinosaurs, and other prehistoric animals. These sciences have grown out of man's effort to find the answers to challenging questions about man and the universe in which he lives. The story of their development is a part of the story of biology, for there are no hard and fast lines between the different sciences. The knowledge gained in one field supplements that in many other fields.

To desire definite answers to questions and problems seems to be a very common characteristic of the human mind. The study of fossils is only one of man's attempts to unravel the mysteries of the universe. In the folklore and mythology of different tribes and peoples, we find many stories of the creation of the earth. Some of these stories are very beautiful in spite of the fact that they are fantastic. They indicate some of mankind's earliest attempts to explain the origin of the earth.

By the time the Greeks had reached a high point in their civilization, we find that thinkers had developed several different theories about the creation, the position, and the shape of the earth. Unfortunately one of the false theories was championed by a man who dominated thought for centuries. This was Ptolemy, an Alexandrian astronomer and mathematician, who lived in the second century A.D. He believed that the earth was a fixed center about which the sun and stars revolved.

Men accepted this belief until the sixteenth century, when Nikolaus Copernicus (1473-1543) startled the world with a different theory of planetary motion. He

declared that the earth rotated once in every twenty-four hours and that the earth moved around the sun once every year. Every child studying geography learns this today, but these were daring ideas at the time of Copernicus.

A generation later the Copernican theory was supported by the great Italian astronomer, Galileo (1564-1642), who explored the heavens with an amazing new instrument, a telescope. As the telescope was made more and more powerful, new chapters were added to the story of astronomy. But the old question about the origin of the earth and the solar system still baffled the scientists.

In 1796 Pierre de Laplace, a French astronomer, brought forth the nebular hypothesis. It expressed the idea that the earth had been formed by the condensation of matter in a nebula. Laplace thought that this condensation could be explained by the laws of physics. This explanation, however, did not stand the test of later astronomers, and another answer to the riddle was suggested early in the twentieth century by Thomas C. Chamberlin, an American geologist, and Forest Ray Moulton, a mathematician. In 1903-1904, their planetesimal hypothesis was published. According to this hypothesis, the creation of the solar system was the result of an accident. Two stars traveling at tremendous speeds through space passed too near each other. The gravitational pull of one passing star was strong enough to cause matter to leave the surface of the other star, our sun. This matter in cold space formed small bodies. The largest of these solids by their gravitational effects caused smaller ones to fall toward them. Thus the earth and planets grew larger as the material accumulated.

At the moment, this hypothesis is the best explanation that has been offered of the creation of the solar system. What more powerful telescopes will reveal cannot be predicted. Into what realm of mathematics some imaginative mind may extend itself in the future is unknown.

While astronomers were studying the skies, other men were turning their attentions to the earth, wondering how old it was and how the fossils were formed in the rocks. An observing man frequently found things that stirred his imagination. Excavations for buildings and roads showed different strata of rocks, one above the other. Some of these strata were rich in fossils.

In the vicinity of Paris, people had often noticed that the limestone quarried for buildings contained many fossils. A few scientists had studied them to some extent. but Georges Cuvier, who lived about the same time as Laplace, was the first man to investigate them thoroughly. The work he did on these fossils earned for him the title of "Father of Vertebrate Paleontology." Cuvier did his best work on fossils after he had made a name for himself as an anatomist.

Georges Cuvier and Napoleon Bonaparte were born in the same year, 1769. Cuvier's father was a retired French army officer. His mother, although uneducated herself, did everything possible to help Georges with his education, even to spending hours listening to him recite Latin. His interest in natural history was aroused at an early age. Finding books by Buffon (see page 108), he colored the pictures with paints and pieces of silk, not as most children would do to suit their own fancies, but according to descriptions in the text.

A wealthy neighbor sent Cuvier to a school in Stuttgart in Germany where military and civil service officers were trained. He spoke no German when he entered the school, but in four months he had mastered the language and was one of the leaders of his class. Anatomy was his favorite study.

At eighteen when there was no means for him to stay in school longer, he became tutor in the family of Count d'Héricy, then living in Normandy. There the sea washed up a multitude of specimens for him to examine and dissect. He had no books and few instruments, yet during the six years he lived there he untiringly made drawings of what he observed.

Occasionally, people interested in science in near-by villages met for discussions. This group developed into a small scientific society of which Cuvier was made the secretary. There was one man whose name meant nothing to the young naturalist. Perhaps it was curiosity that made him so attentive to the older man's talk. At length, Cuvier recognized him, from the knowledge he displayed, as the author of articles on agriculture in an encyclopedia. The man was Alexandre-Henri Tessier, the agriculturist, living under a false name as a military doctor at a near-by hospital. Since he had been in charge of an experimental farm in which Louis XVI was interested, Tessier was in danger from the enemies of the King.

At one of the meetings Cuvier approached the man and called him by name. Tessier exclaimed, "I am lost!" Cuvier assured him that on the contrary, since he was known, he would receive more protection from the scientific group than before.



GEORGES CUVIER

Cuvier is holding a fossil fish. His researches in fossil remains earned for him the name of the "Father of Vertebrate Paleontology." His earlier work placed the study of comparative anatomy on a scientific basis. In working out the correlation theory, he saw that there is a close relationship between the internal as well as the external structure of an animal and its habits of life. This correlation theory he applied to his work on fossils. (*The Bettmann Archive*)

Cuvier showed Tessier his drawings illustrating the structures of starfish, mollusks, marine worms, and other animals he had gathered along the shore. Tessier was so much impressed that he sent some of them to influential friends in Paris. He also wrote letters full of praise of the tutor. Étienne Geoffroy Saint-Hilaire (see page 109) became interested in Cuvier, and he was summoned to Paris.

It was an honor for this largely self-taught man to be called to Paris. He went, but fearful that he might not succeed, he retained his position as a tutor to the son of Count d'Héricy and took the boy with him. His fears were groundless. In a short time he was appointed a professor of comparative anatomy. The appointment was all the more remarkable since, up to that time, Cuvier had never dissected a human body. Nevertheless, the minute dissections he had made on the lower forms of animals had given him skill. Before long he was recognized as the greatest anatomist in France.

Between the years 1799 and 1805, Cuvier published works that put the study of comparative anatomy on a scientific basis. Among other important points, he developed the so-called correlation theory. This theory had already been suggested in its broader aspects by at least one other person. Cuvier worked out and presented the details of the theory. He saw a close relationship between the internal as well as the external structure of an animal and its habits of life. For example, a flesh-eating animal usually has claws adapted for catching and holding its prey. Its teeth are sharp and so placed in the jaws that they can tear flesh. On the other hand, a plant-eating animal lacks claws and has a different type of teeth.

Such differences are apparent, but Cuvier went further and showed that the digestive systems and other parts in the internal structure of flesh-eating and plant-eating animals are different.

Cuvier applied this correlation theory to his work on fossils. Thus his thorough knowledge of comparative anatomy made it possible for him to sort out the bones of different kinds of animals when they were found together in a fossil bed. His work on skeletal remains began the modern science of vertebrate paleontology and makes it possible to construct models of prehistoric animals, even when some of the bones of the fossilized skeletons are lacking. In 1812, Cuvier published a book about fossils.

In spite of his great contributions to comparative anatomy and paleontology, Cuvier expressed many ideas that retarded scientific thought. For one thing, Cuvier believed that the world had gone through a series of catastrophes: earthquakes, floods, and volcanic eruptions. He thought that at these times all living things were destroyed, but after each catastrophe new organisms were created. This would account for the differences in the species found in the lower and upper strata of rocks. In 1802 a discovery was made in Siberia which fitted in very nicely with his theory. A mammoth was found frozen in the ice. The flesh of the animal was so well preserved that it was devoured by the dogs of the fishermen who cut the ice away. To Cuvier, the finding of this mammoth in such an excellent condition proved that a catastrophe had happened. Otherwise the flesh would have rotted before the ice formed around it. The bones of animals found in caves he believed were swept there by some tremendous flood. Bones of prehistoric men found with

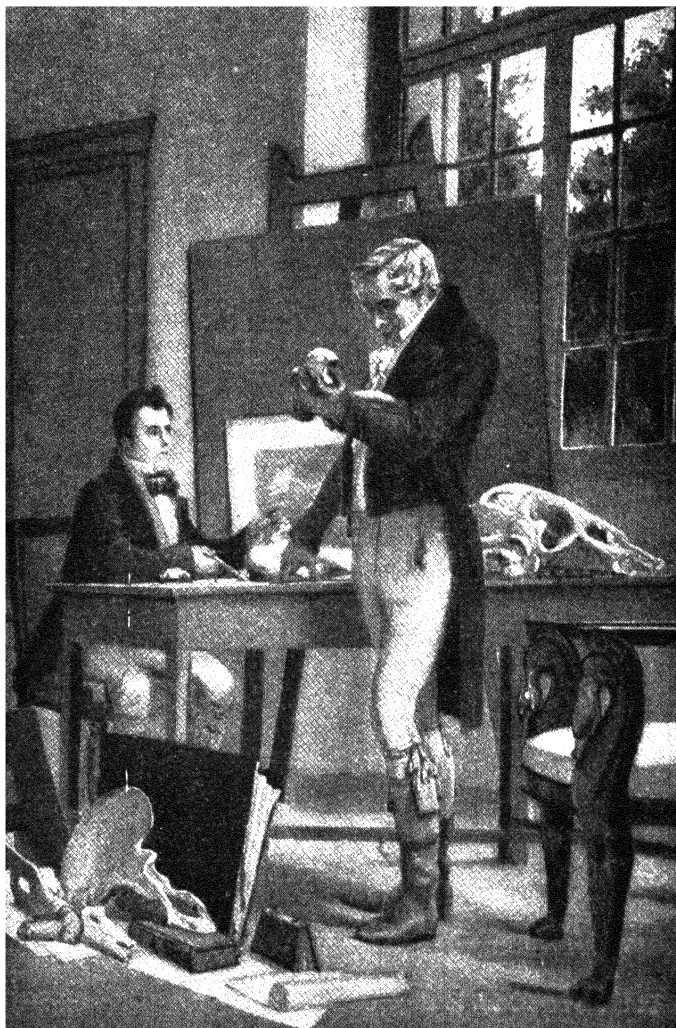
the animal remains he would have nothing to do with; he claimed they were not very old and merely happened to be found with those of the animals.

Since Cuvier believed that new species were created after each catastrophe, we can understand why he took such a positive stand on the question of the fixity of species. Was each species distinct from every other species? Had every undomesticated species of plant and animal been created as it appeared in his lifetime? Yes, said Cuvier with emphasis. This attitude caused a bitter battle in scientific thought when Cuvier and his friends lined themselves against Lamarck and his less powerful allies (see page 110). Cuvier's strength was not dependent entirely on his reputation as an anatomist. He was in favor with Napoleon, who made him a director of the higher educational institutions.

While Cuvier was at the height of his influence in the scientific world, an English geologist was writing a book that was to influence all future thought on the age of fossils and the fixity of species. Charles Lyell recognized that earthquakes, volcanoes, and floods wrought great changes in limited areas, but he did not believe they had caused all the geological changes he observed.

Sir Charles Lyell was born of well-to-do parents at his father's estate in Scotland, in 1797. When Charles was a small boy, a severe case of measles affected his eyes so that he was handicapped by poor vision all his life.

After completing his work at Oxford, Lyell was admitted to the bar as a lawyer in 1825. He practiced only two years. The lectures on geology at Oxford, given by Dr. William Buckland, had made more of an impression on him than anything else. The study of geology



CUVIER AND A FRIEND EXAMINING FOSSIL BONES

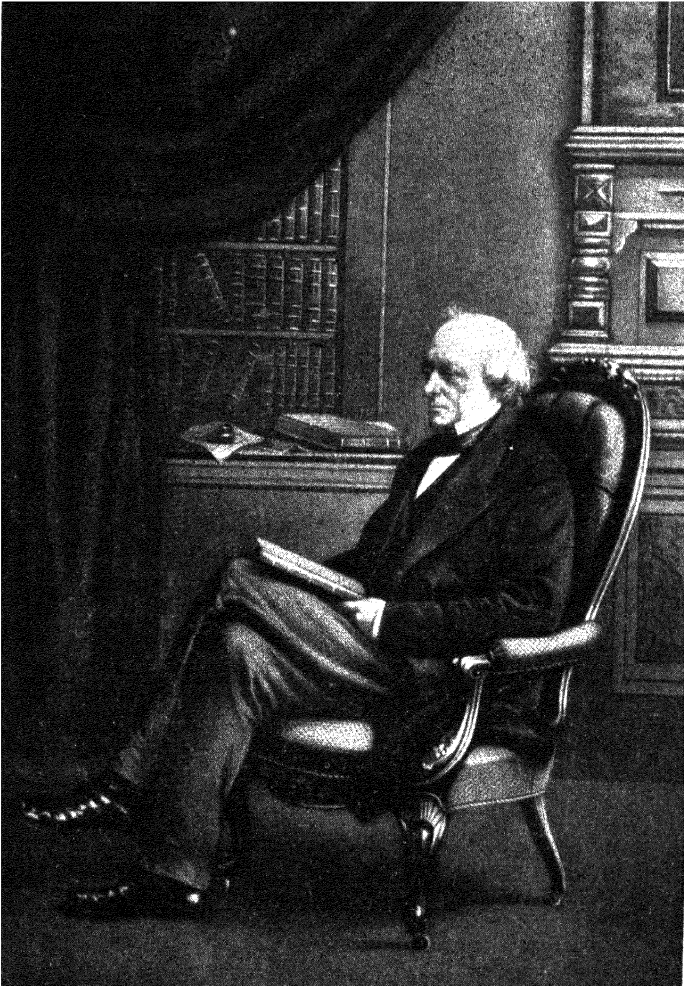
Cuvier was able to reconstruct the skeletons of prehistoric animals from fossilized bones (*Culver Service*)

became a lifework to him. He once said, "We must preach up traveling as the first, second, and third requisites for a modern geologist." Here was a man who practiced what he preached. He visited the famous fossil beds in Paris. Hammer in hand, he wandered through the Swiss Alps. He climbed Vesuvius to the edge of the hot lava streams. He slept in shepherds' huts in the Pyrenees. At Ischia, in the Mediterranean, he was elated to find at the height of two thousand feet fossils which belonged to the same class of animals as those still living at the shore line.

In 1829, Lyell was asked to be a candidate for a professorship in a London university. He did not accept the invitation because he was completely occupied in writing a book. In 1830, the first edition appeared of this now famous book: *Principles of Geology: Being an Attempt to Explain the Former Changes of the Earth's Surface by Reference to Causes Now in Operation*. The title was long, but it plainly indicated the subject matter. According to Lyell's explanation, the age of the earth must be much, much greater than anyone had supposed. As a matter of fact, Lyell made no attempt to reconcile his ideas with the popular beliefs of that time.

His book had a surprisingly large sale. It was clearly written and the style was lively. Furthermore, the author was considered to be something of a heretic—and heretics were different from other people and therefore interesting. Before 1875, *The Principles* had passed through twelve English editions.

In 1841 and again in 1845, Lyell and his wife visited America. Lyell was a keen observer of many things besides rocks. To read his *Travels in North America* and



SIR CHARLES LYELL

Lyell's contributions in the field of geology greatly influenced biological thought (*Brown Brothers*)

Second Visit to America is to gain an intimate knowledge of the points of geological interest and of the customs, beliefs, political situations, and educational systems then existing in the United States.

Lyell's first trip through the United States was thorough. He came up the Hudson to see the Palisades. He stopped in Little Falls, New York, to see the rock formation in a cut that had been blasted out of the rocks for a railroad. This same formation is shown every year to the geology students from half a dozen colleges. Niagara Falls interested Lyell greatly. In 1841, the Falls could be seen from a distance of three miles, with no houses to spoil the view. In Pennsylvania he made an extensive study of the coal formations. The Great Dismal Swamp presented some unsolved problems; so he went there.

On a beach in one of the Southern states he saw footprints of raccoons and opossums on the shore. They had been made since the ebbing of the tide. He wrote of this, "Already some of them were half-filled with fine blown sand, showing the process by which distinct casts may be formed of the footsteps of animals in a stratum of quartzose sandstone."

During his second trip to America, Lyell visited the country near New Madrid, Missouri. Earthquakes in 1811 and 1812 had left very visible effects; there was a fissure more than a mile long; acres of trees had been killed. Where a lake had existed there was now only a sunken depression in which none of the trees dated back farther than 1811, a fact ascertained by counting the rings in some of the larger trees.

Lyell's trip to America in 1845 was his last extended one, but he continued to make short excursions to the

Continent of Europe. In 1860 he went to Prussia to see the skull of the Neanderthal man, which had been recently dug up there.

Two of Lyell's works besides the *Principles of Geology* became well known. In 1838, he published *Elements of Geology*. This became a standard reference book. In 1863, *The Antiquity of Man* became what might be called a "best seller," for it ran through three editions in one year.

During the last few years of his life, Lyell's eyesight, never normal, failed him completely. He died in 1875 and was buried in Westminster Abbey. He had been given the honor of knighthood in 1848, and in 1864 he had been created a baronet.

Another pioneer in paleontology was Louis Agassiz. The span of his life nearly coincided with that of Lyell. He was born in 1807, ten years later than Lyell, and died two years before him, in 1873. In many ways Agassiz's life illustrates the difficulties of a person living at a time when ideas are changing rapidly. Although he was progressive and open-minded toward much that was new in scientific thought, he refused to accept some of the logical conclusions of his own research work.

Louis Agassiz was born at Môtiers, Switzerland, in 1807. His father was a clergyman and his mother was the daughter of a highly respected physician, Dr. Mayor. Louis and his brother, Auguste, were busy and adventurous boys. They kept a variety of pets: birds, field mice, rabbits, and other small animals. Their greatest interest, however, was in fish, which they caught usually with their hands.

At the beginning of the nineteenth century, it was common for tradespeople to go from house to house to

work. The shoemaker, the tailor, the barrelmaker were among those who visited the Agassiz home at different times of the year. They came with their materials and made and repaired shoes, clothes, and barrels enough to last until their next visit. Louis watched and imitated these workers until he could make shoes for his sister's dolls, do some tailoring, and make miniature barrels that were water tight. In later years he said that these early pastimes had developed the unusual skill with which he used his hands.

Louis's parents had decided that when he was fifteen he should leave school and work in the business establishment of an uncle. Louis had not had enough schooling to suit himself, and several teachers, who saw his possibilities, persuaded the parents to let him go to Lausanne. Here his enthusiasm for all subjects connected with the study of nature showed immediately. At seventeen, the idea of his becoming a business man was given up, and he was sent to a medical school at Zürich.

At Zürich, Professor Johann Caspar Schinz took so much interest in Louis that he allowed him to have a key to his private library. Knowing that money for any extra books was out of the question, Louis copied some of these books page by page. He was able to persuade his brother, Auguste, also a student at Zürich, to help him at his task. Copying books and going to lectures did not absorb him completely, for about one period of his life at Zürich he wrote: "I spent all my time in dissecting animals and in studying human anatomy, not forgetting my favorite amusements of fishing and collecting. I was always surrounded with pets, and had at one time forty birds flying about my study, with no other home than a

large pine tree in the corner. I still remember my grief when a visitor, entering suddenly, caught one of my favorites between the floor and the door, and he was killed before I could extricate him.”*

The reputation of some of the professors at the University of Heidelberg attracted Agassiz's attention about this time. In the spring of 1826 he went there as a student. The professors proved to be as stimulating as he had expected, and the friendship formed with a fellow student, Alexander Braun, did a great deal to shape his life from that time on. Braun was especially interested in botany; Agassiz, in zoology. Their collecting trips, the specimens hoarded in their rooms, and their discussions made each thoroughly acquainted with the other's particular field.

Braun's father owned a large house at Karlsruhe. Here Agassiz spent his vacations, as the distance from Switzerland made it impossible for him to go home. The Braun family was science-minded. Part of their house was given up to scientific purposes. The elder Braun had an excellent collection of minerals and a library of reference books. Alexander and Louis were given rooms to serve them as laboratories and as storage space for their growing collections. Alexander's sister, Cecile, had great artistic talent. She drew illustrations for her brother, and several years later, after her marriage to Agassiz, she made some of the best drawings of fish to appear in his works.

During an epidemic of typhus fever in 1827, Agassiz was taken critically ill. When he was able to travel, Braun took him to Karlsruhe. He did not recover completely;

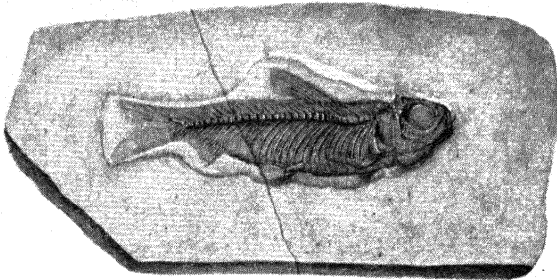
* AGASSIZ, ELIZABETH CARY (editor), *Louis Agassiz; His Life and Correspondence*. Boston: Houghton Mifflin Co., 1895. P. 147.

so he returned to Switzerland. While Agassiz was recuperating, Braun decided to transfer to the University of Munich and persuaded Agassiz to join him there.

At Munich, Agassiz and Braun had a room in the home of Professor Johann Joseph Ignaz von Döllinger whom they loved and respected. This room was soon nicknamed "The Little Academy," for it was a meeting place for students, teachers, and visitors to the university. Robert Brown made it a point to attend some of these meetings during a visit to Munich (see page 58). The students took turns lecturing to the group and in this way gained a skill in expressing themselves not to be equaled by any other means.

Voyages for scientific exploration were popular at this time. Humboldt's explorations in South America (see page 113) had stimulated other naturalists. In 1817, the King of Bavaria had sent Karl von Martius and John Spix on an expedition in Brazil. The trip lasted four years. During this time Martius collected plants and Spix collected animals. Upon their return, each began to work on the classification and description of his own specimens. Spix died in 1826, before finishing his work on the Brazilian fish. Martius, who attended the meetings in "The Little Academy," asked Agassiz to complete the work begun by his fellow explorer. This work developed into Agassiz's first book, which was of tremendous importance because it gained the notice of Cuvier.

Fish, which had interested Agassiz as a boy, claimed his attention more than ever. At the same time, he was studying the courses required for the doctor's degree which he received on April 3, 1830. The study of fish



ONE OF AGASSIZ'S FOSSIL FISH

This hitherto unpublished drawing was made by the draftsman Burkhardt, who was a member of Agassiz's household for many years. The handwriting in the lower right corner is Agassiz's own. (Courtesy Harvard Museum of Comparative Zoology)

kept him from returning to Switzerland immediately after he had been given his degree. Financial matters finally made it impossible for him to live without earning some money. He returned home and began to practice medicine. But his interest in fish persisted; in fact it was so strong that he took an artist back to Switzerland with him to draw fish.

By the time Agassiz was twenty-six, he was well known among the European scientists, but he had no definite income from any source. At last he was offered an opportunity he had long desired—that of teaching natural science in Neuchâtel, Switzerland. During his ten years there as a professor, he completed his five-volume work, published under the title of *Researches on*

Fossil Fishes. Agassiz identified more than 1,500 species of fossil fish. The number of fossil fish he could recognize was about three times as great as the number of living animals Aristotle had classified (see page 5).

Many incidents bear witness to the indefatigable amount of work that Agassiz expended on these fossils. Among these incidents is one that indicates a great deal about his character. For a time his eyesight was so seriously affected that he was forced to live in a dark room for weeks. Finding that his fingers were not sensitive enough to trace the tiny parts of his fossil fish, he continued to make observations using the tip of his tongue to gain his impressions.

To many people, Agassiz is better known for his work in the broader fields of geology than in the specialized one of paleontology. Much of his fame rests on his development of the glacial theory advanced by his friend, Jean de Charpentier. During the summer vacations while he was teaching at Neuchâtel, he made extended trips into the Alps to study the glaciers. Using the knowledge he had gained by firsthand observation, he was later able to identify in England many glacial formations which hitherto had been unexplained features of the landscape. The tremendous importance of Agassiz's writings on glaciers cannot be disregarded, for they opened new lines of thought about prehistoric conditions and life.

The year 1846 marks the end of one period and the beginning of another in the life of Agassiz. In October of that year he came to Boston to deliver a series of lectures. At the time he had no idea of remaining permanently in America. A chain of circumstances changed his whole



LOUIS AGASSIZ IN HIS YOUTH

This portrait of Agassiz as a young man hangs in the Harvard Museum of Comparative Zoology. The Alps in the background suggest his great interest in the study of glaciation, which he began there. He looks rather more like a young man on a holiday than a person whose unbounded energies built a foundation for much of the biological and geological thought of the present. (*Courtesy Harvard Museum of Comparative Zoology*)

life. His lectures were such a success that Harvard University asked him to become a member of the faculty. He accepted the offer. The decided foreign accent with which he spoke and his inability to think of the right English word at the right time did not lessen the interest he aroused in audiences whenever he spoke. With a piece of chalk and a blackboard always at his command, he could illustrate what he wanted to explain when words failed him.

At the time of her husband's departure for America, Mrs. Agassiz and the children had gone to Karlsruhe to visit at the home of her father. Mrs. Agassiz, who had never been very strong, died there before plans were completed for her to join her husband. A few years later Agassiz married Elizabeth Cabot Cary of Boston and had his children come to this country. Agassiz's attachment for the United States became so great that later in life he refused very important offers from universities in Europe.

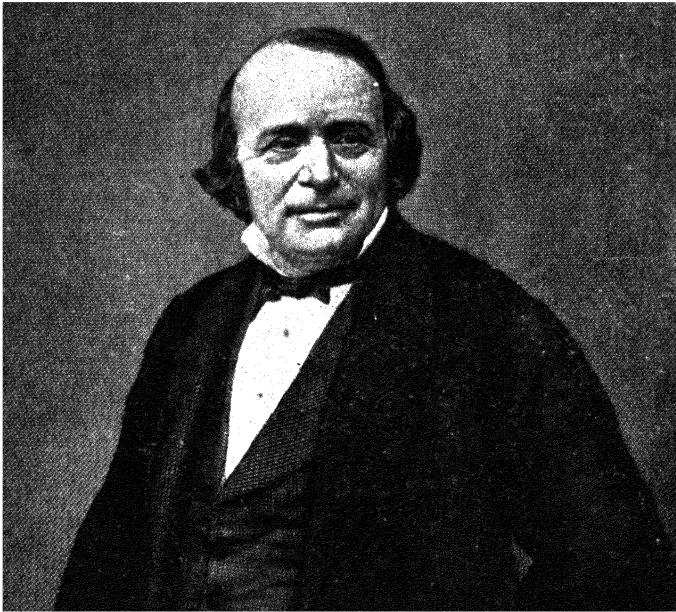
As a teacher Agassiz had unusual ability, but classroom instruction was not enough. Ever since the days when he had visited every museum he could reach, he had dreamed that some day he might plan a museum so arranged that students seeking information might find specimens grouped in accordance with some definite plan. Probably Agassiz himself would not have believed that an old boathouse on the Charles River, given to him as a place to store his collections, would be the forerunner of one of the most famous natural history museums in the United States. Agassiz talked about his ideal museum with anyone who manifested the least interest. The nucleus for it came in a legacy from Mr. Francis

Gray, who left \$50,000 to be spent for the scientific needs of such an institution. Harvard University gave the land for the building. Now there were land and money to maintain a museum but no building. Agassiz appealed to the Legislature of Massachusetts. It agreed to furnish the equivalent of \$100,000, if a specified additional sum could be raised by individual contributions. The tremendous amount of interest in natural history and, more especially, in Agassiz himself is shown by the fact that citizens in and near Boston gave \$71,125. Agassiz's dream was to become a reality.

Agassiz's activities were extremely varied after he came to the United States. In 1847, he made the first of several trips on the Coast Survey boats in the interests of the government. One of the results of these trips was the advancing of his theory of the formation of coral reefs. He continued the study of glacial formations he had begun in Switzerland. This work caused him to make extensive surveys in the Lake Superior region and in the New England states.

It will be remembered that Agassiz's first publication was about the Brazilian fish brought back by Spix. To his great joy, in 1865, he was invited by the Emperor of Brazil to head an expedition into that country. Spix had brought back fifty species of fish; Agassiz returned with many times that number.

At the same time his interest in teaching never diminished. A unique example of his desire to have people understand nature was shown in his founding a summer school for teachers. The school was located on an island in Buzzard's Bay. The first lectures were held in a barn while swallows darted in and out of the open



LOUIS AGASSIZ

This great naturalist, born in Switzerland, became an American and contributed immeasurably to the study of biology in this country (*Brown Brothers*)

doorway Louis Agassiz died in 1873, soon after the founding of the school

In his later years Agassiz had spent an inestimable amount of time and energy supervising the building and development of the museum. When examining the fossil fish in this now famous Harvard Museum of Comparative Zoology, one is immediately impressed with the infinite amount of patience and skill Agassiz must have used in chipping the stone from the skeletons. In a large hall that serves as an entrance to the fossil fish exhibit, there is the portrait of Agassiz as a young man, which is

reproduced on page 99. Although the Harvard Museum does not officially bear his name, it is spoken of on the campus as the "Agassiz Museum," and every year it fulfills the purposes of instruction that he dreamed it would.

Agassiz's son, Alexander, who enthusiastically assisted his father during the latter's life, carried on the exploration of coral reefs and made a study of the life to be found on them. One of the newer rooms in the museum is dedicated to Alexander Agassiz.

Comparative anatomy, palaeontology, and modern geology may trace their beginnings to the work of Cuvier, Agassiz, and Lyell. Of the three men, Lyell was the most willing to accept whole-heartedly the results of his own investigations and those of other scientists. For example, before Agassiz did his work on glaciers, Lyell attributed some of the unusual distribution of stones he had seen in England to melting icebergs. When he was convinced that Agassiz was right in believing that stones had been left by melting glaciers, he rewrote parts of his book. When he published *The Antiquity of Man*, he supported Darwin's theory of the origin of species (see page 119).

Cuvier and Agassiz could not reconcile with their religious convictions the idea that species underwent changes. Nevertheless, Cuvier, by study of comparative anatomy and fossils, gave much help to those who did not believe in the fixity of species. When Agassiz's work on fossil fish was completed, it was found that from the lowest, and therefore oldest, rocks in which fossil fish are found, to the topmost, and therefore the most recent, there was a progressive development in the structures of these animals. Agassiz did not believe that a simple

species had developed into a more complex one. To him, the rocks showed a series of special creations. He believed that there were differences in the successive layers because there was a change of plan in the mind of the Creator before each special creation. To his contemporaries, Lyell and Darwin, (see page 115) this change from simple to complex organisms furnished complete evidence of a natural progression of species in past geological periods.

Suppose, then, you do find a fossil while rambling in the country. If the person to whom you show it can tell you what animal it was and in what geological period it lived, he pays an indirect tribute to the pioneers of vertebrate or invertebrate paleontology and of modern geology.

Hints for Further Reading

- AGASSIZ, ELIZABETH C. (editor), *Louis Agassiz; His Life and Correspondence*.
- CHAMBERLIN, R. T., *Biographical Memoir of Thomas Chrowder Chamberlin* (pamphlet). Washington: National Academy of Sciences, XV (1934), 307-407.
- PEATIE, DONALD C., "Louis Agassiz: Inspired Scientist," *Nature Magazine*, XXII (Dec., 1933), 265-266.
- ROBINSON, MABLE L., *Runner of the Mountain Tops: The Life of Louis Agassiz*.
- ST. MICHALSKI, "Kopernik," *Science*, LXXIII (June 5, 1931), 616.

Explaining the Origin of Species

LAMARCK AND DARWIN

BASEBALL games, football games, and prize fights are not the only things that cause people to take sides and support their choices with great enthusiasm. Ideas may arouse people and divide them into opposing parties. At physical contests, people work off some of their enthusiasm or disgust by the activities of shouting, cheering, and snakedancing. In a conflict over an idea, people are more apt to express themselves in letters to the press, by writing pamphlets and books, by lectures, or by arguments in meetings. Often these are not sufficient outlets, and bitterness develops between individuals and between groups. If the idea can be submitted to rigid and conclusive experimentation one side is forced, grudgingly perhaps, to admit defeat.

The idea that species are not fixed, that they undergo gradual changes through centuries, caused a bitter battle in the intellectual world which reached its most violent stage in the last half of the nineteenth century. Unfortunately, this idea can only be put to limited tests within the lifetime of an individual. Time, long periods of time, would be necessary to carry on all the

phases of experimentation necessary for an absolute conclusion on all details. However, there are so many details that have been worked out that the majority of thinking people today are willing to accept the idea that plants and animals, in general, have developed from lower to higher forms.

The names of Lamarck and Darwin are inseparably connected with the idea of a progressive development of species. Each advanced his own theory to explain the origin of species. The idea that species could change was not entirely new in scientific thought. Even some Greek thinkers had held opinions very much like those that caused the turmoil during the nineteenth century. However, prejudices had hindered men from openly championing ideas which they themselves might believe, but which were not yet generally accepted. In this respect Lamarck and Darwin were exceptions.

Linnaeus, until the last part of his life, and Cuvier, during all his life, believed in the fixity of species. Even when Linnacus began to question it, he did not make positive statements, but tried to avoid the subject. Both Linnaeus and Cuvier had large and influential followings among the naturalists. Lamarck, on the other hand, had neither the position nor the powerful friends to aid him when he stated his theory of evolution. Nevertheless, his idea found favor with a few brilliant men of his time and had a definite effect in directing biological thought into broader fields.

Jean de Lamarck was born in Picardy, in 1744. He was one of a large family of children. His father, a poor nobleman, was determined that Jean should become a priest. This calling did not appeal to the boy, but until

his father's death, when Jean was seventeen, he was kept in a Jesuit school. As soon as his father died, he took the small amount of money he inherited, bought an old horse, and rode off to join the French Army then engaged in the Seven Years' War.

Few boys have had an opportunity to become a hero on such short notice. The day after his enlistment a battle took place. All the officers were killed. All the non-commissioned officers were killed. Young Lamarck gathered the survivors of the company together and held the post until reinforcements came. For this act he received a lieutenant's commission.



JEAN DE LAMARCK

Lamarck is known for his conception of the origin of species and his work on invertebrates (*The Bettmann Archive*)

During the remainder of the war he was on garrison duty in Toulon. His army career was brief, for when peace came he resigned because of ill health.

With a small pension as his only income, he went to Paris and studied medicine. One authority writes that he spent four years studying medicine and then became a student of botany under the well-known Bernard de Jussieu. His interest in plants dated back to the days when he was on garrison duty on the shore of the Mediterranean. He was particularly interested in the plants native to France. In 1778 he published *Flore*

Française. Lamarck himself could not have afforded the expense of publication. Fortunately, some articles of his had come to the attention of Buffon.

Comte Georges Louis Leclerc de Buffon, the French naturalist, was born in 1707, at Montbard, his father being councillor of the Bergundian parliament. Having inherited considerable property upon his mother's death, Buffon studied mathematics, physics, and agriculture. When he was appointed keeper of the Jardin du Roi and of the Royal Museum, in 1739, he began to collect materials for his *Natural History*.

This monumental work, entitled *Histoire naturelle, générale et particulière*, was the first French publication to present the isolated and disconnected facts of natural history in a popular form. The work consisted of forty-four volumes, with the publication extending over fifty years.

In addition to his own writings, Buffon frequently aided other scientists in getting their works published. Among those he helped was Lamarck. Buffon died at Paris in 1788 at the age of eighty-one.

In *Flore Française*, Lamarck developed a system of classification somewhat different from that employed by Linnaeus. This pleased Buffon who used his influence to have the book published at the expense of the government. This *Flore Française* was revised a number of years later and was for many years a standard reference work.

Buffon's interest in Lamarck was shown in another way. Buffon wanted to have his son, who had just finished his schooling, visit the museums and gardens in other European countries. As a guide and teacher, Lamarck was hired to accompany the boy. To add

dignity to this position, Buffon had him appointed a Royal Botanist. Serving in this capacity, he visited the botanical gardens in several European countries and procured specimens for the Jardin du Roi in Paris. After his return to Paris in 1782, Lamarck became connected with the Jardin. For a time he served as the keeper of the herbarium.

In June 1793, the Jardin du Roi was reorganized and became officially known as the *Museum d'Histoire Naturelle* (Museum of Natural History). Several new professorships were created during the reorganization. Two of these were in zoology. Candidates were considered. Absurd as it may seem, Geoffroy Saint-Hilaire, who had spent the greater part of his time studying minerals, was chosen as the professor of vertebrate zoology. Lamarck, an ex-soldier and botanist, was chosen as the professor of invertebrate zoology. The invertebrates include all those animals without backbones, and at that time were roughly divided into the *Insects* and *Vermes*. This appointment marks a turning point in Lamarck's life. His work in botany had earned for him the name of the "French Linnaeus." Now, forced to teach invertebrate zoology, he applied himself to this field as rigorously as he had to botany.

As a systematist, he produced order in the classification of the invertebrates. He divided the *Insects* and *Vermes* into the groups now known as *Infusoria*, *Annelida*, *Archnida* and *Crustacea*. His interest was not confined to living forms. He made a study of fossilized invertebrates, and in 1806 he published a book on fossil shells that was the first scientific book in paleontology. For this reason he should be regarded as the founder of invertebrate paleontology.

As his knowledge about different kinds of animals increased, Lamarck recognized relationships between them and also between animals and plants. It is significant that he coined the word "biology" in 1802, to cover the study of both plants and animals.

In the spring of 1800, Lamarck delivered a lecture in which he first stated his theory of evolution. The following year he published this as a preface to his *Système des Animaux sans Vertèbres*. This book gave a scheme of the classes, orders, and genera of invertebrate animals. *Philosophie Zoologique*, published in 1809, contained a full explanation of his theory of descent. The great German biologist, Ernst Heinrich Haeckel, made the following statement about Lamarck's theory of evolution: "To him will always belong the immortal glory of having for the first time worked out the theory of descent. . . ." Cuvier (see page 89) did not see anything to be praised in Lamarck's theory of the origin and development of species. The theory annoyed him, and he exerted his influence to have Lamarck's work disregarded or branded as false.

What was this theory of the origin of species? Lamarck believed that individuals become changed so that they are better able to live in a particular environment. For example, he explained the webbed feet of birds by the fact that when food became scarce on dry land, birds without webbed feet went to the swamps. Here they made the effort to swim and in so doing stretched the skin between their toes. Then he believed this beginning of a web was inherited by the offspring who, in turn, stretched their toes farther; and so on through successive generations until a useful webbed foot had become a

normal characteristic. Thus, in Lamarck's mind, the need or want of a new structure might result in its development.

Another part of his theory of the origin of species was that the development and force of organs was in direct relation to the amount that were used or not used. This part of the theory is often spoken of as the "Law of Use and Disuse." He explained the long neck of the giraffe by saying that in the past these animals had continually stretched their necks for food.

It will be seen from the preceding paragraphs that Lamarck, like Lyell (see page 90), believed that the earth was tremendously old. Also like the geologist, he believed that forces operating in the present had operated in the past.

One of the greatest objections to Lamarck's theory is that he believed that characteristics acquired by an individual during its lifetime could be passed on to its offspring. From Lamarck's time until the present, hundreds of experiments have been carried on with plants and animals to prove whether or not acquired characteristics can be inherited. The burden of proof is against this. Some of these experiments will be mentioned in a later chapter on heredity (see page 146).

Another criticism of Lamarck's theory was directed toward his choice of examples to prove his points. Wallace (see page 121) and Darwin, who later attacked the problem of the origin of species, had the advantage of years of travel over large areas of the earth. They had, therefore, much more material from which to choose their illustrations.

In his writings after he turned to invertebrate zoology, Lamarck showed three qualities necessary to a great scientific worker. His understanding of the anatomy of the entire range of living organisms was as great as, if not greater than, that of any of his contemporaries. He possessed the type of mind that makes it possible to see relationships which are not obvious at a first glance. Also, he was able to describe species with great precision. The many years he spent working with plants undoubtedly developed this ability.

During his entire life Lamarck was poorly paid for his work. His theories and work were unappreciated by his contemporaries, especially in France. Eventually, the strain of examining minute things caused him to become nearly blind. However, none of these obstacles could divert him from his work. Between 1815 and 1822, he published his great work on invertebrate animals, *Natural History of Invertebrate Animals*. This was in seven volumes. Before finishing the sixth volume, he had become totally blind so that the remainder of the work had to be dictated to his daughter. Lamarck died in 1829.

As has been said, Lamarck received altogether too little recognition during his life for his scientific inquiry. About fifty years after Lamarck first expressed his ideas on evolution, Darwin published his *Origin of Species*. The scientific world was aroused and took sides. Lamarck's name then came to the foreground, and his explanation of the causes of the variation of species was championed by many scientists. In 1908, France paid homage to his memory by holding a Fête Lamarck. Leland Ossian Howard (see page 253), the American entomologist who was present, wrote in a recent book, "The Paris celebra-

tion was impressive as well as charming. The opening meeting was held in the Jardin des Plantes where a temporary structure had been built facing the statue of Lamarck."

This fête was held a short time before England celebrated the hundredth anniversary of the birth of Charles Darwin, who was one of the most talked of men in the world during the latter part of the nineteenth and the beginning of the twentieth centuries.

Charles Robert Darwin was born February 12, 1809, the same day as Abraham Lincoln. Charles Darwin's father and grandfather were both doctors. It was decided that Charles should carry on the family tradition. He spent seven years at the Rev. Samuel Butler's school in his native town of Shrewsbury.

When he was sixteen years old, his father decided that he was not making the proper progress at the Rev. Mr. Butler's school. He transferred the boy to Edinburgh to begin his medical course. After two unsatisfactory years there, Darwin went to Cambridge with the idea of becoming a minister. Here he enjoyed life. He rode and hunted and led the happy, care-free life of an undergraduate, "studying only when an emergency arose." But riding and hunting indirectly helped his education, for he became interested in the breeds of horses and dogs and in the different kinds of game birds. Also, though geology in the classroom bored him, he examined the various formations he saw as he rode through the country.

Two books read during his life at Cambridge did much to direct the rest of his life. One was Humboldt's *Personal Narrative*, written about his explorations in South

America (see page 116). The other was a book by Sir John Herschel on the philosophy of science. These two books started him thinking.

At this time public lectures were given at Cambridge in several branches of learning. In some way, for he avoided lectures when he could, Darwin happened to attend those given in botany by John Stevens Henslow. Darwin did not become a regular student of botany. However, Henslow conducted field trips, sometimes in coaches, sometimes in barges down the river, and Darwin frequently accompanied him. Darwin had already won a place for himself as an amateur collector of insects, and his love of the outdoors made these trips attractive. Furthermore, he liked Henslow. After a time his friendship with Henslow grew so strong that Darwin was dubbed by his fellow students as the "man who walks with Henslow."

It was Henslow who persuaded Darwin to study geology under Adam Sedgwick, a man who bitterly attacked Lyell's *Principles of Geology* soon after its publication. Darwin in a short time became such an enthusiastic geologist that he accompanied Sedgwick on a geological tour through northern Wales.

By this time, the desire to see tropical vegetation which had been aroused by Humboldt's book made Darwin determine to take a voyage, at least as far as the Canary Islands. Some friends were interested, and the date had been tentatively set for the following summer of 1832. In preparation for the trip Darwin began to study Spanish. He was quite proud of himself when he learned enough words to call his dog names in that tongue.

Before the trip to the Canaries had gone beyond the planning stage, a most exciting thing happened. A naturalist was wanted for H. M. S. "Beagle," about to sail around the world to chart the waters along coast lines, make soundings, surveys, and so on. Professor Henslow was asked to suggest someone for the post. In spite of Darwin's slight training as a naturalist, Henslow recommended him.

Imagine Darwin's delight when he was offered the appointment. Then came hours of bitter disappointment. His father opposed the trip. It would interfere with the young man's career as a clergyman. Nothing would be gained by it to compensate for the cost, since the naturalist had to pay his own expenses. Unhappy but obedient to his father's wishes, Darwin went to see his uncle, Josiah Wedgwood. That gentleman, whose opinion carried weight in the family, thought that Darwin should go, and he soon converted the elder Darwin to the idea.

Thus it happened that in December, 1831, Charles Darwin, sportsman, theological student, and amateur scientist, sailed from England as the naturalist on H. M. S. "Beagle." One of the books Darwin was given to read on the boat was Lyell's *Principles of Geology*. His old friend Professor Henslow had given it to him with the advice that "he read it carefully, but by no means believe it." Darwin read it, and he could not help believing it. At the Cape Verde Islands where he went ashore, the very rocks convinced him that Lyell was right. From that time on, in examining all formations, he sought for causes that acting through long periods of time might have produced the results he saw.

In reading the journal that Darwin kept during the five-year trip, one is impressed by the physical activity of the naturalist and by his remarkable powers of observation.

Seasickness, to which he was a victim from the start, recurred at very frequent intervals during the time he was on the water and was a source of mental as well as physical anguish to him. It meant lost time that he might have used in observing the living things in the sea, or in classifying the specimens he drew up in nets behind the boat.

Whenever the "Beagle" spent any amount of time in making surveys in a limited section along the east coast of South America, Darwin lived on shore. Humboldt's description of tropical vegetation had stirred his imagination. Now, as he wandered through the luxuriant growth, it was a never ending source of delight and amazement to him.

With his geological hammer and collecting outfit, Darwin made excursions into the interior of South America at many points. Sometimes he traveled on foot or in a boat, but more often he went on horseback. He rode through the Pampas with half-savage guides, always in danger of attacks by Indians. With a few other men in two small boats he made a trip of three hundred miles through a channel along Tierra del Fuego, where the savage and uncivilized natives followed them menacingly. He climbed mountains that no white man had climbed before. He collected insects, gathered plants for pressing, killed animals for their skins, and all the while took notes on the strata of the rocks, the soil, in fact of everything that had any connection with geology.



THE GALÁPAGOS ISLANDS STILL ATTRACT BIOLOGISTS

Two modern scientists, equipped with a motion-picture camera, are watched with interest by large lizards known as iguanas (*Ewing Galloway*)

While the "Beagle" surveyed the west coast, Darwin made another overland trip to see the formations in the Andes Mountains.

Darwin spent several weeks on the Galápagos Islands, about which William Beebe (see page 426) has written such fascinating descriptions. They are strange islands, where sharp volcanic rocks cut through shoe leather like knives, where the birds are so unaccustomed to man that they are fearless. Here Darwin found tortoises so big that he rode on their backs and black lizards, called "imps of darkness," that grew to an astonishing size of three or four feet. His observations made him realize two important facts: the life on these islands was different from the life on the mainland of South America; and

the life on each island had its own peculiarities. The vice-governor of the islands told him that the inhabitants could detect the island from which a tortoise came by its size and other peculiarities. This statement caused Darwin to pay more attention than he might otherwise have done to the matter of keeping specimens from the different islands separate. As a result of this care, he was able to draw conclusions about the distribution of species on the islands, when he had time to study his collection after his return to England.

The islands of the South Seas were another collecting ground. He studied intensively the coral reefs because the living animals interested him and because the reefs and islands formed by the coral animals are a special type of geological formation.

In Australia and New Zealand he made trips into the interior. The ease with which some plants, introduced from England and European countries, spread impressed him greatly. In some instances foreign plants had crowded out those native to the country.

Darwin returned to England with a mass of notes and quantities of specimens. Besides these material results of the five years of travel, his mind was filled with unanswered questions. His health, however, was permanently broken and he was forced to lead a very quiet life. This very circumstance gave him time to turn his problems over and over in his mind. Working when he had the strength, he tried to make order out of what he had seen.

With the help of a trained botanist, he found out some remarkable things about the species of plants he had collected in the Galápagos Islands. For example, there

were seventy-one pod-producing plants (*Leguminosae*) on James Island. Thirty-three of these species were found in other parts of the world, but thirty-eight species were found only in the Galápagos Islands. More surprising than that, thirty species were found on James Island and nowhere else. Darwin was as puzzled by this as he had been by the numbers of species he had seen in the Pampas of South America.

There were many sets of plants and animals having the same general characteristics. At the same time Darwin found that they possessed enough different minor characteristics to cause him to classify them as different species. If all species had been created at the same time, why were so many created so nearly alike? Was there a special creation for each small island? Somehow the idea of special creation for thousands of species did not make sense. If they had come into existence in some other way, what was this way?

Darwin pondered over these questions; then in 1838 he happened to read a book by Thomas Malthus (1766–1834). Malthus was a clergyman and also an economist. He was alarmed by the rapid growth of population in England. In his *Essays on the Principle of Population*, he maintained that when a population increases faster than the food supply, famine, crime, and war result. From the reading of this book, Darwin gained the nucleus of the idea he applied to all animals and plants. These ideas became known as the laws of natural selection and the survival of the fittest.

Darwin knew that there was a continuous struggle between all organisms for food. He also knew that individuals of the same species varied in size, color,

strength, and other characteristics. He maintained that any plant or animal that was a little better fitted for its environment would have more chance to survive than those without this characteristic. For example, the deer that could run the fastest would have the best chance of escaping predatory animals. If the survivors in the struggle for existence in one generation bred together, the next generation would be slightly more fit for its environment. Thus new species arose and the less fit were crowded out of existence. In some ways this theory reminds one of Lamarck's, but Darwin himself made fun of Lamarck's supposition that there was a "willing" on the part of an organism to cause its characteristics to be changed.

Darwin had returned from his trip in 1836. For twenty years he worked on his material during the few hours a day that his health permitted. He discussed his ideas with his friends, especially with Charles Lyell. They encouraged him to write a book. Darwin was working on this book when he received a letter from Alfred Russel Wallace, who was then living in the Malay States. Wallace asked Darwin to read the paper he was sending, and if he thought it worth while to bring it to the attention of some scientific society. Darwin read the paper. His heart sank. Wallace had come to the same conclusions that he himself had. Darwin's hopes of priority for his theory diminished to the vanishing point.

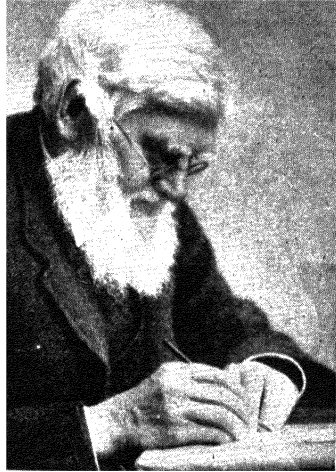
The letters Darwin wrote to his friends at this time reveal his emotional struggle. He knew that he had thought out his theory years before Wallace had. He possessed a preliminary draft he had written out in 1842. He had also written his thoughts to Asa Gray, the

American botanist years before. But here was Wallace's paper sent to him to be published. In his distress of mind, Darwin appealed to his two best friends, Sir Charles Lyell and Sir Joseph Dalton Hooker. They solved the problem with such tact that it was satisfactory to both Wallace and Darwin

Before the Linnaean Society on July 1, 1858, a "joint paper by Messrs Darwin and Wallace was read." It was prefaced by a letter from Lyell and Hooker giving the history of the ideas. The listeners were stunned by the new thought in the paper. They did not question Darwin's integrity, but they could scarcely comprehend the new ideas he was presenting. As for Darwin, he began at once to get his notes in form for the publication of a book.

On November 24, 1859, the first edition of *The Origin of Species by Means of Natural Selection or the Preservation of Favored Races in the Struggle for Life* was published. The entire edition of 1,250 copies was sold on the first day.

Without a thorough understanding of the beliefs of the nineteenth century, it is impossible today to understand why the book created such a furor. Darwin was



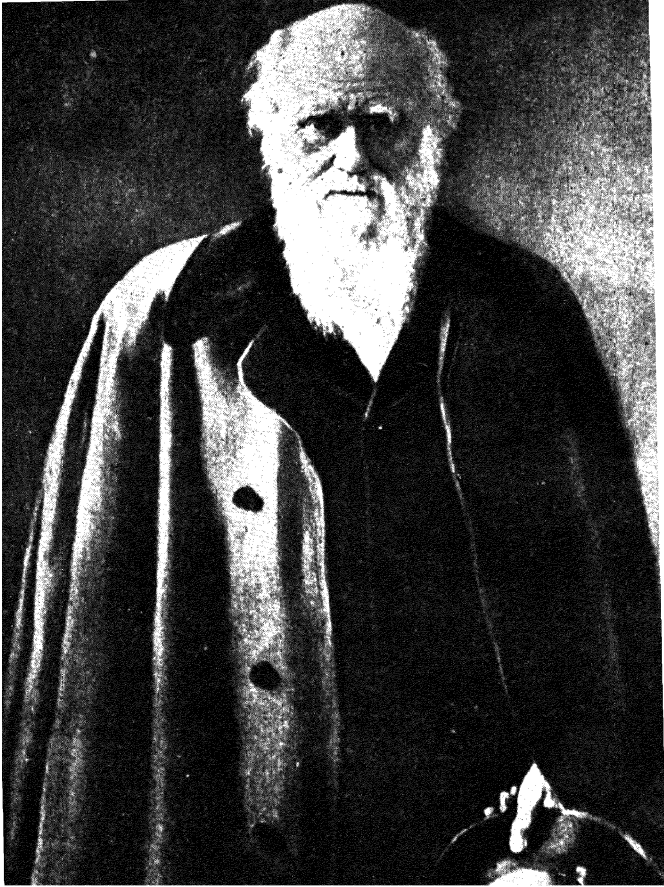
ALFRED WALLACE
Wallace and Darwin, working independently, came to many of the same conclusions about the origin of species (*Science Service*)

attacked from the pulpit. He was attacked in the newspapers. Some of his fellow scientists were most scathing in their remarks and writings. Debates were held. Many people did not believe that man was subject to the same laws of nature which controlled other living things.

Darwin's health did not permit his personal entry into the confusion that followed the publication of *The Origin*. In England his cause was championed by his friends, among whom was Thomas Huxley. Huxley wrote Darwin when he first read the book, "I am sharpening up my claws and beak in readiness" for the battle he knew would come.

Darwin continued to study and write. *Animals and Plants under Domestication* (1868) is one of his most important works on the experimental side of biology. *The Descent of Man* (1871) added fuel to the fire of dispute that was still raging. The years of patient work on the pollination of flowers, the observations on the structural adaptations of flowers to their insect visitors, the study of earthworms in relation to soil were all valuable contributions to biology.

Charles Darwin died in 1882. He was buried not far from Newton in Westminster Abbey. A few years ago, during the celebration in England in honor of Darwin, Julian Huxley, the grandson of Darwin's champion made an address in which he said, "It is right we should deliberately celebrate Charles Darwin's memory. But we are unconsciously paying tribute to him all the time, in our outlook and our habits of thinking which would be different if he had never lived. He was so great a man that his ideas have already become embedded in the general thought of humanity."



CHARLES DARWIN

Darwin's conception of the origin of species revolutionized biological thinking (*The Bettmann Archive.*)

In the years since Lamarck and Darwin brought forth their ideas that new species could be developed in the wild state from other species, a large body of facts has been accumulating. Today no one is able to explain satisfactorily all the details involved in the change of species through the ages. There is no simple answer to the problem.

Today the idea underlying the theory of evolution is accepted by many people. Five different lines of observation give evidence that life has been and is undergoing changes and that these changes have resulted in the development of simpler into specialized organisms:

1. The simplest fossils are found in the oldest strata of rocks. Fossils of mammals do not occur until comparatively recent geological times. There are some exceptions to the general statement that simple organisms have become more and more specialized, in that there are some forms which have undoubtedly degenerated. But by this degeneration they have become adapted to peculiar conditions of environment.

2. A thorough study of the embryos of vertebrate animals has shown that the very young embryos are strikingly alike and those characteristics which will later differentiate a rabbit from a pig, for example, do not show in the very early stages.

3. Comparative anatomy, that part of biology put on a firm scientific basis by Cuvier, shows a close relationship in the structures of individuals in each Class.

4. The geographic distribution of plants and animals is a further evidence of evolution.

5. Finally, there are the more recently discovered chemical evidences, such as blood tests, which show definite relationships between animals.

Hints for Further Reading

BARLOW, NORA (editor), *Charles Darwin's Diary of the Voyage of H. M. S. "Beagle."*

DARWIN, CHARLES, *Autobiography of Charles Darwin.*

HUXLEY, JULIAN, assisted by JAMES FISHER, *Living Thoughts of Darwin.*

WILLIAMS-ELLIS, AMABEL (editor), *Voyage of the Beagle.*

“Diverse Recipes”

GALTON, MENDEL, WEISMANN, DE VRIES, AND MORGAN

IN ONE of his books, Herbert Spencer Jennings wrote, “Different individuals are made up, as it were, on diverse recipes; and diverse recipes give different results.” (See page 362.)

Ever since man has been capable of making comparisons, the likenesses and differences of animals and plants have caused him to associate them into rough groups. Likenesses and differences are the basis of classification. But no two people, no two plants, no two animals are exactly alike. The finger-prints of individuals serve as a basis of classification. The leaves in a bed of nasturtiums at first glance give promise that two may be found that are absolutely alike, but hours of comparison will be futile. Always there is a little difference of color, or size, or shape.

Both Lamarck (see page 110) and Darwin based their theories of evolution on differences. Both Lamarck and Darwin (see page 119) were very much aware of the results of “diverse recipes.” Neither of them knew what made the results different. Lamarck and Darwin studied variations, particularly in plants and domestic animals.

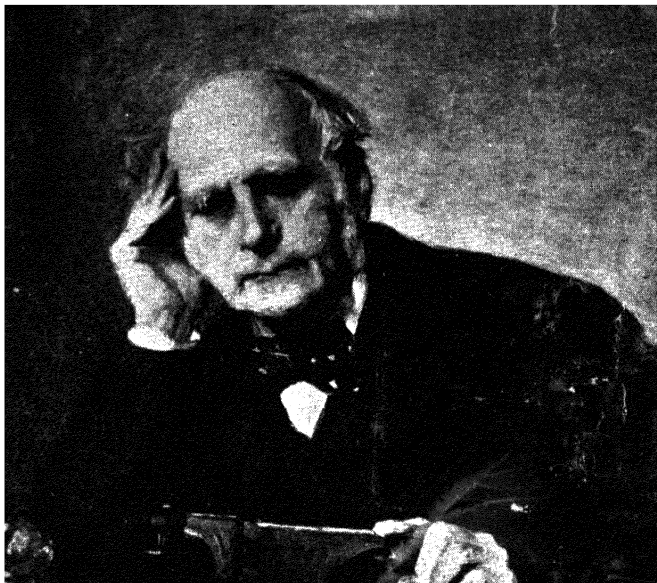
Sir Francis Galton, who lived from 1822 to 1911, paid especial attention to variations in human beings.

It is an interesting fact that the family of Charles Darwin is cited today in textbooks as an illustration of the inheritance of desirable characteristics in human beings. Francis Galton was a cousin of Charles Darwin. They were both the grandsons of Erasmus Darwin (1731–1802), an English physician. Erasmus Darwin was a student of natural history and philosophy. His *Zoonomia*, published in 1794, was translated into several languages and was widely read on the Continent.

The parents of Francis Galton and Charles Darwin wanted them to follow in the footsteps of their grandfather and become physicians. Each started this training. Darwin, it will be remembered, decided to enter the ministry and might have become a clergyman if the trip on the ‘‘Beagle’’ had not changed his entire life. Francis Galton continued his medical training longer, but upon inheriting a fortune, he found travel and experimentation more interesting.

Sir Francis Galton was born at Birmingham, in 1822. When he was about eight years old, he was sent to a school in Boulogne, France. At sixteen, Galton saw a post-mortem examination for the first time. A doctor, who was a friend of his family and knew that the boy intended to become a physician, took him to see an autopsy performed on a person who had died under unusual circumstances.

Not long after this, Galton entered the Birmingham General Hospital. Here he made pills, mixed medicines, and accompanied the surgeons on their rounds. This was before the use of antiseptics or anesthetics in surgery.



SIR FRANCIS GALTON

Galton, a cousin of Charles Darwin, by his unique scientific experiments laid a foundation for the study of eugenics (*Keystone View*)

The conditions which Galton saw every day would seem barbaric now. There was, however, a new instrument **just** coming into use, the stethoscope, for listening to the action of the heart and to the breathing. The younger doctors were enthusiastic about it, the older ones scorned it, although as Galton said most of them were getting a trifle deaf.

Galton's unquenchable desire to try things for himself was apparent during this period. In making pills and mixing medicines, reference had to be made to a pharmacopoeia. This might be called the dictionary of a druggist, in which the substances used are arranged in alpha-

betical order with notes about their properties, dosage, and so on. Galton decided that he wanted to know by personal experience how these medicines would react. He began by taking a small dose of the first substance stocked in the hospital, commencing with the letter A. He went through the A's and finished with the B's. He was partly through the C's when he took a dose, very small he thought, of croton oil, which is a violent cathartic and emetic. His self-imposed experiment ceased at that point.

Galton continued his studies at King's College and at Cambridge. In 1840 he went to Germany for the purpose of studying, but he changed his plans when he arrived there, for he soon came to the conclusion he did not know enough German or chemistry to make it worth his while to attend the lectures. Without consulting his family about his plans, he spent all the money he had with him on a trip through southern Europe to Constantinople.

In 1845, Galton had a better opportunity to satisfy his great desire to travel. He made a trip through Egypt and the Sudan into the little-known country beyond the Cataracts of the Nile. Five years later he went to southwest Africa and explored a large area of land around Lake Ngami. He was the first explorer to go into this region. *Narrative of an Explorer in Tropical South Africa* describes his two years of exploration there.

As a scientist Galton has received much criticism for his methods of investigation and for some absurd conclusions that he drew. There is ample justification for some of this criticism. On the other hand, Galton applied the use of statistics to biological facts in a way

that had never been done before. His enthusiasm and the unique experiments he tried directed attention to new phases of biological study. Now that people are considering his correct conclusions seriously and skipping over his absurdities, many references are being made to his experiments.

What were some of Galton's experiments that did not impress all his contemporaries as being particularly important, but which really gave a foundation to the study of eugenics? From the time of his student days in Cambridge, Galton was particularly interested in mathematics. At the same time he was a keen observer of characteristics in people. Gradually, he correlated these two interests and began to gather the results of his observations and to tabulate them. For example, he measured tall, short, and medium-height adults and their grown children. From these figures he computed the chances that children of tall parents would be taller than the average. He computed their chances of being medium height or shorter than the average. He did the same with the other groups and began to collect some interesting statistics on variation in human beings.

In Galton's opinion it was necessary to examine a great many people in order to find out what could be considered a normal characteristic and to show deviations from it. Naturally, if he could take advantage of a large number of people coming together for some purpose, he could get the information he wanted. An opportunity presented itself in 1884 when an International Health Exhibit was held in London.

At his own expense, Galton fitted up a laboratory. Appealing to that characteristic in people that makes

them try their lung capacity and strength at a carnival, he built an enclosure through which people could pass one at a time. One side of this was latticework, for he believed that the number of people who would be interested would be increased if the curiosity of those outside was aroused by seeing a little of what was going on within. A small fee was charged to each person as he entered, enough to cover the actual running expenses of the experiment. Each person then went through a series of tests. The keenness of his eyesight and hearing was tested. His strength when pulling or squeezing something was measured. He was weighed; his height and length of arm span were measured. Also, his reaction time to a stimulus and the strength of a blow he could strike were recorded. When he came out at the other end of the enclosure, he was given a card with all the data. Each individual now had a record he could use in comparing himself with his friends, and Galton, who kept a duplicate of each card, had a mass of information to reduce to tabular form. After the close of the exhibition, Galton's laboratory was continued for six years in South Kensington Museum.

In the study of human characteristics Galton had observed that the fingerprints of each individual are different from those of every other person. This led him to consider seriously the use of fingerprints as a means of identification. In 1892 he published *Finger Prints*, followed two years later by *Index of Finger Prints*. The far-reaching results of this means of identification in the detection of crime are known to everyone today.

Galton's interest in the inheritance of human characteristics may be measured by the fact that he considered

this branch of biology important enough to have a specific name. The term he introduced is "eugenics." This word is now defined in the dictionary as "the science which deals with the influences that improve the inborn or native qualities of a race or breed, especially the human race." In 1909, Galton published *Essays in Eugenics*.

In the realm of abstract thought Galton's name is well known to psychologists. He became interested in trying to determine how people thought, and in 1870 he made a general inquiry about mental imagery. He found great differences in people. Some people said they never were conscious of visual images, while others saw these images almost constantly. In 1883 the results of his study were included in *Inquiries into Human Faculty and Its Development*. Galton is given credit for being the first person to use modern methods while attempting to solve the question of how people think.

Galton died in 1911 at the age of eighty-nine. By his will he left money for the founding of a laboratory for the study of national eugenics. This laboratory has gathered a large amount of material on human heredity. So that the laboratory might be of the greatest use to science, the Rockefeller Foundation, in 1935, made an appropriation of \$35,000. The money was given to the Medical Research Council of Great Britain with the provision that the Galton Laboratory in London should provide the working space, and that Dr. Ronald Aylmer Fisher should direct the research work. The appropriation was made for a five-year period, ending in June, 1940.

While Galton was carrying on his experiments and compiling his statistics about human beings, another

man was studying the inheritable characteristics in peas. In 1820 or 1822, for the records are contradictory, this man, Gregor Johann Mendel, was born. The Mendel family lived in Heizendorf in Austrian Silesia. The boy was christened Johann, but took the name of Gregor when he became a monk. If the date 1822 is correct, Mendel and Galton were born in the same year, but their lives were as opposite as can be imagined, except perhaps for the fact that they were both interested in heredity, and applied mathematics in drawing conclusions from their observations.



GREGOR MENDEL

Mendel's laws of inheritance, which attracted little attention during his lifetime, are among the most important laws of biology today. (*Brown Brothers.*)

Gregor's father, Anton, was a peasant who, according to the law of the country, was forced to work three days out of each week for the lord of the manor. The remaining time he spent cultivating his own farm where he took great delight in grafting fruit trees with scions given him by a priest, who was anxious to see the farmers improve their fruits.

Gregor attended the village school and then went to Leipnik where there were enough pupils to have four classes. In 1834 he entered a school in Troppau that would be equivalent to an American high school. Troppau was twenty miles away from Heizendorf and

Mendel's family was too poor to pay full board for the boy; so each week they sent him bread and butter and other provisions they could spare. There is no doubt that young Mendel was frequently hungry, and that lack of proper nourishment and overwork were the causes of some serious illnesses he experienced.

In 1838 Anton Mendel was permanently disabled when a rolling log crushed his chest. No longer able to work, he turned his farm over to his son-in-law with the provision that Gregor should receive a small sum of money from its proceeds. This amount was very little, and if Gregor's younger sister had not given him her share of the inheritance, it would have been necessary for him to stop studying altogether. With this small sum and what he could earn by tutoring, Mendel was able to study philosophy at Olmütz.

At the completion of this course he entered the Augustine monastery at Brünn. At this time the monastery had large holdings of land and paid a great deal of attention to improving agriculture.

Two things early in his life at Brünn shaped Mendel's career. When he visited homes where there was sickness or death, he was so upset that he was often physically ill. This was, of course, a handicap to him in carrying on the regular duties of a priest. The other factor in his life at Brünn was the keen interest he took in natural history. The monastery had been left a large herbarium by Peter Aurelius Thaler, a monk who was an excellent botanist. Mendel spent a great deal of time studying the plants in his collection.

After four years in the monastery, Mendel was ordained as a priest. In 1849 a position well suited to his

abilities was offered to him, that of supply teacher in a technical high school. Mendel welcomed this opportunity in spite of the fact that his salary was very small, amounting only to about fifty cents a day in our money. He was to teach Latin, Greek and German literature, and mathematics.

As a teacher Mendel was a great success. Hugo Iltis, a fellow countryman who interviewed many of Mendel's former pupils when he was writing a biography of the monk, found that they remembered him with affection. Mendel showed a genuine friendship toward the boys in his classes.

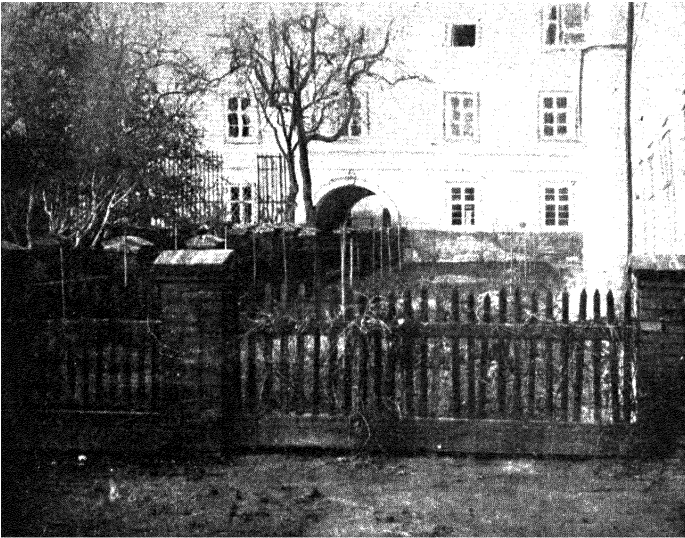
The experiments that led him to make the conclusions about inheritance that are now known to every pupil studying biology were carried on in the monastery garden. Other people had made experiments very similar to those of Mendel, but he was more painstaking, more definite in his procedure, and more thorough than his predecessors. In selecting the peas for his experiments, he chose those that differed from each other in a few but markedly distinct ways. For example, in one set of experiments he chose a variety that normally grows between six and seven feet tall and a dwarf variety that does not exceed a foot and a half in height. The flowers of peas are usually self-pollinated. To avoid this, Mendel removed the stamens of the flowers in which he wished seeds to form and artificially pollinated the pistil with pollen from the other variety. When the seeds resulting from the cross between the tall and dwarf plants were grown, all the plants were tall. He cross-pollinated these and found that in the next generation approximately one quarter of the plants were dwarf and the remainder

were tall. By further crossings in this generation (now designated as the F_2 generation), Mendel found that approximately one fourth would breed pure tall, one fourth pure dwarf, and that one half would breed like the hybrid F_1 generation.

The care with which Mendel carried on his experiments is shown in the fact that he did not gather the seeds from all like crosses and mix them before planting. Instead, he kept the seeds from each plant separate and tabulated the results. In all he used about thirty varieties of peas. He crossed plants having smooth seeds with those having rough; smooth-stemmed plants with rough-stemmed plants; and plants having different-colored flowers.

After working for a number of years, Mendel published the results of his experiments in 1866 and 1867. The three Mendelian laws resulted from his work. They are: the Law of Unit Characters; the Law of Dominance; and the Law of Segregation. The first law means that in organisms some characteristics are inherited generation after generation without being lost, such as tallness in peas. The second law means that some characteristics (dominant) develop in a hybrid at the expense of opposing characteristics (recessive). When a pure tall and a pure dwarf pea are crossed, all the F_1 generation will be tall. The third law means that when hybrids are crossed unit characters tend to separate. When hybrid peas are crossed, one fourth of the resulting plants will be pure tall, one half will have the dominant and recessive characteristic, and one fourth will be pure dwarf.

Unfortunately, Mendel's papers on heredity attracted almost no attention in the scientific world during his life-



MENDEL'S GARDEN AT BRUNN

In this garden of an Augustine monastery Gregor Mendel began the experiments with peas which resulted in the formulation of his laws of inheritance. (Courtesy Dr George H Shull and “*Journal of Heredity*”)

time. The only botanist with whom he is known to have carried on an extensive correspondence was Carl Wilhelm Nageli (1817–1891). Nageli was so wrapped up in his own theory of inheritance that he did not appreciate the importance of Mendel's experiments. Sixteen years after his death, Hugo de Vries of Holland, Karl Erich Correns of Germany, and Erich Tschermak of Austria, within a few months of one another, discovered that their work on hybridization had been anticipated by Mendel. It is known that Mendel himself was deeply disappointed that his work did not receive attention. He was convinced of its importance. He remarked to a friend that some day his writings would receive serious con-

sideration by the scientists interested in breeding. Unfortunately, he did not live long enough to see his prophecy fulfilled. His disappointment was one of the reasons why he turned to other fields of observation after he was elected prelate of the monastery at Brünn in 1868.

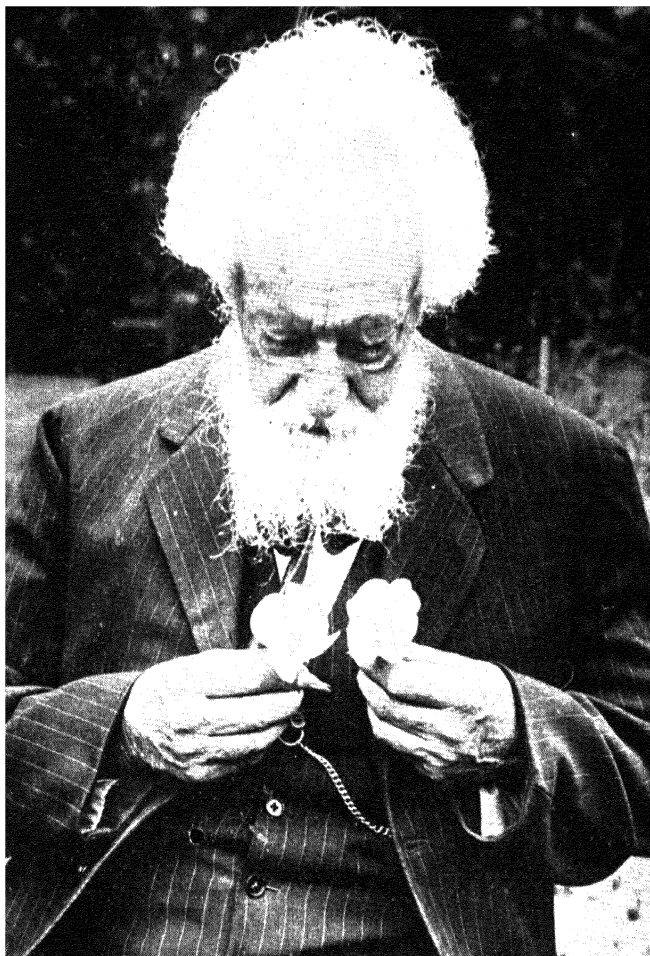
While at Brünn he gave special attention to varied subjects. He kept daily records of temperature, pressure, and humidity for the Meteorological Institute at Vienna. He experimented with bees and was an active member of an apicultural society. He gathered all the information he could about human heredity by questioning the monks about their families and by keeping records of his nephews.

Gregor Mendel died in January, 1884. He was honored and beloved by all who were associated with him. At the time of his death, Mendel was known to some extent beyond the region in which he lived for his meteorological reports and observations. As a great investigator of heredity he was unknown.

The discovery of Mendel's works in 1900 acted as a great stimulus to people interested in inherited characteristics. Both the research worker and the practical breeder have benefited by this knowledge. For example, a wheat that would resist the disease of rust was produced by following Mendel's Law of Segregation.

One of the three men who, in 1900, turned to Mendel's writings on hybridization was Hugo de Vries, born in Haarlem, Holland, in 1848. De Vries studied at Würzburg under the great botanist Sachs (see page 312).

De Vries, like most thoughtful botanists of his time, was considering the idea of species and Darwin's theory



HUGO DE VRIES

In this picture de VRIES is holding two primroses. His famous investigations of mutations were first carried on with primroses. De VRIES was one of three biologists who brought Mendel's laws to the attention of the scientific world (*Wide World*)

of natural selection. In 1866, in an uncultivated field, he found a colony of the American evening primroses which had escaped from a garden. He noticed at once that some of the young plants had marked differences from the parent species. De Vries felt that he had found something remarkable. Under careful observation, he allowed these plants to multiply by self-fertilization and found that some of the new offspring were enough different from the parent stock to be classified as new species. He felt, to use his own expression, that he had found a species in the process of "exploding." His observations led him to conclude that changes which appeared in the fossil records, upon which the theory of evolution is partly based, might have occurred rapidly if the mutation of species were common to many forms of plants and animals. Each mutant might thus form the parent organism for a new line, if as he said, the variation were of value in the survival of the organism.

In 1904 de Vries came to the United States. One of his main objects was to visit Luther Burbank and his experimental farm in California (see page 173). De Vries found Burbank's plants more interesting than anything else in America.

Hugo de Vries died in 1935. *Plant Breeding*, published in 1907, is one of his best known writings.

A discussion of crossbreeding would be incomplete without mention of the work of William Bateson, an Englishman. In a way his position is unusual. Before Mendel's writings were known to him, he approximated Mendel's methods and indicated that the statistical method of studying the crossings was the only way by which accurate results could be obtained. When Mendel's

work was discovered in 1900, Bateson immediately brought out *Mendel's Principles of Heredity; A Defense*.

William Bateson was born at Whitby, England, in 1861. He was educated at Cambridge and was graduated in 1882. The following year he came to the United States to study marine worms. Here he met William Keith Brooks, of Johns Hopkins University, and through his association with him became interested in the problem of variation in species. The more he studied this problem, the more dissatisfied he became with the conceptions held by Darwin and Lamarck about the causes of the changing of species during the process of evolution.

Hoping to find some direct evidence about natural variation of species in a region undergoing physical changes, Bateson spent eighteen months in western Central Asia, where the lakes were gradually drying up. He collected specimens from over five hundred bodies of water, but was disappointed in the lack of variation that he found.

For the next seven years after his return to England, Bateson spent much of his time collecting facts about variation in species. He considered that Darwin's greatest contribution to science was the mass of facts he had collected. With this in mind, he visited libraries, museums, shows where agricultural products were exhibited, and farms of practical breeders. The results of his observations were published in 1894 in his book, *Materials for the Study of Variation*.

During this same year, Galton suggested to the Royal Society that a committee be appointed to use statistical methods in measuring inheritable characteristics of plants and animals. Eventually, such a committee was

formed, and Bateson became its secretary. A short time later, he became connected with Cambridge University.

Mrs. Bateson, in her biography of her husband, tells about their strenuous days at the university. The house where they lived had enough ground so that experiments of different kinds could be undertaken. After lecturing at the university, Bateson would return home and together they would turn their attention to the experiments. Their work included sowing and gathering seeds, cross-fertilizing flowers, taking care of the eggs in the incubators, and examining the larvae of insects. Careful and complete records were kept of all experiments. Besides this less arduous labor, they hoed and weeded their experimental gardens, for there was not enough money to hire manual labor.

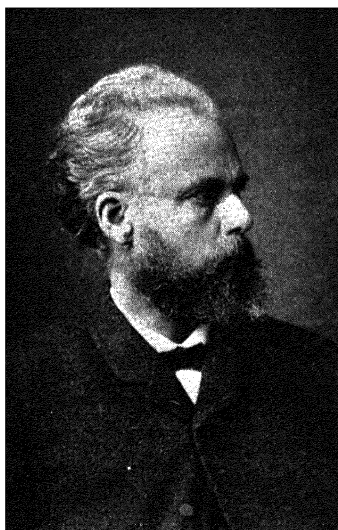
In 1910, Bateson was appointed the director of the John Innes Horticultural Institution at Merton. By this time the knowledge of Mendel's laws had given breeders an understanding of what might be expected from cross-breeding. At the institution, Bateson and his associates carried on many experiments which showed the wide application of the laws of inheritance. Also, Bateson did a great deal to increase co-operation between practical breeders and specialists in the field of genetics who were working from the point of view of pure science.

William Bateson died in 1926. H. F. Roberts, in *Plant Hybridization before Mendel*, writes that if Mendel's writings had not been discovered, the work of Bateson would eventually have led to the formulation of the same laws that the Austrian monk stated.

The work of Bateson was, nevertheless, important in several ways. His own investigations on variation prior



WILLIAM BATESON



AUGUST WEISMANN

Although Bateson did not formulate the laws of inheritance as Mendel did, his work closely paralleled that of the Austrian (*Brown Brothers*)

Weismann is known for his work which proved that many acquired characteristics are not inheritable (*The Bettmann Archive*)

to 1910 yielded a great deal of useful information. When Mendel's writings came to his attention, he immediately realized their importance and became the champion of Mendelism to the English-speaking world. Furthermore, by conducting and supervising a great many experiments on the crossbreeding of both plants and animals, he proved the validity of the laws of inheritance and interpreted them so that they could be applied in horticulture and animal husbandry.

While Mendel and Bateson were trying to establish laws of inheritance, a German scientist was attacking the problem from a different point of view. He did not

believe that acquired characteristics could be inherited, and he conducted many experiments to prove his point.

This scientist, August Weismann, was born in Frankfurt on the Main in 1834. His father was a professor in a school in that city and his mother was an artist of considerable ability. Nearly every boy goes through the stage of collecting things—marbles, stamps, or odds and ends. The instinct for collecting turned August to plants and butterflies. Raising caterpillars was also a hobby. His mother encouraged his interest in natural history and brought him into contact with the botanists in her circle of friends. At school, chemistry and physics were his favorite studies. In 1852, his father and the famous chemist Wöhler (see page 313) advised him to study medicine. For this purpose he attended the University of Göttingen and upon leaving there became an assistant doctor in Rostock. His love of chemistry and other branches of science was greater than his desire to build up his practice, and for several years he spent most of his time studying. This was made possible by the financial circumstances of his family.

In 1860 he went to Paris where he heard Geoffroy Saint-Hilaire lecture and obtained the right to work in the Jardin des Plantes, in which the statute of Lamarck now stands. The following year he went to Giessen where he spent two months under Karl Leuckart, the zoologist, who was famous as a teacher and as the author of a textbook on the parasites of humans. Weismann considered this short time as one of the most important periods of his life, for he was deeply inspired by Leuckart.

Weismann's first published article on hippuric acid had showed his ability as a chemist. His next treatise to

attract attention, published after his stay in Giessen, was on the evolution of flies. In this treatise Weismann proved himself an excellent entomologist. This study was made while he was the personal physician of Stephan, Archduke of Austria. A short time later he became a professor of zoology at Freiburg and from then on devoted himself very seriously to the study of evolution. A painful disease of his eyes kept him from doing as much microscopic work as he wished.

In his experiments to prove that acquired characteristics could not be inherited, Weismann cut the tails from generation after generation of rats. He found that the offspring of the mutilated animals were born with normal length tails. On the other hand, he found that when he interbred rats with short tails, some of the offspring had even shorter tails than the parents. The results of his own experiments led him to support Darwin's theory of natural selection, and from 1868 he became a leading exponent of evolution, with, of course, some modifications of his own.

To explain the impossibility of inheriting acquired characteristics, Weismann developed the so-called germ plasm theory. He stated that the reproductive cells were apart from the body, or somatic, cells and could not be influenced by changes in the body cells unless such a change affected the reproductive cells themselves. His experiments on rats proved this to his satisfaction.

It seemed for a time that Weismann had settled once and for all the impossibility of inheriting acquired characteristics. In some respects he undoubtedly did, but at present research workers are trying to prove that the offspring of rats and other animals that have been

taught to do certain things may learn these same things more rapidly than the offspring of untrained animals. Other experimenters are working on the effects of injections of substances producing chemical changes in the blood of the parent animals. The results in both types of experiments have raised doubts as to the absolute inability of inheriting some acquired characteristics. Further experiments, hundreds of them, will be necessary before the matter is entirely cleared up.

In explaining the process of inheritance, Weismann made some predictions that have proved to be true. He believed that the chromosomes in the nuclei of the sex cells were the bodies responsible for inheritance. He even suggested that the determiners, now called "genes," were arranged in lines.

Weismann became a powerful force on the side of the evolutionists. He was a stimulating speaker; his thoughts were carefully arranged and expressed in beautiful language. At the close of a speech he was in the habit of making a summary. In this he tried to connect his subject with some broad aspect of living. Weismann did not believe that the knowledge of science should be limited to a few research workers. Every intelligent person should be acquainted with scientific thought because science could do so much to solve the problems of the world. He believed scientific advancement should not be confined to a country or to a continent; it should belong to the world.

Weismann was invited to leave Freiburg and become a professor at Breslau and at Munich. He declined these offers because the authorities at Freiburg appreciated him enough to allow him to have time for research and

travel. As a champion of Darwinism, he was interested in England and knew that country well. He often spent time in Genoa where his wife's family lived. He traveled in Corsica and Sardinia. In the nineties he visited Greece and Constantinople.

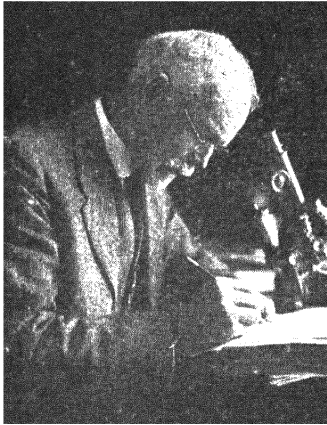
Weismann died in November, 1914. He was always a loyal German citizen. In the sixties, he worked for the union of the German States under the leadership of Prussia. It was a bold thing to do and made him some enemies. He was, however, the recipient of many honors in his own country and in other lands. The city of Freiburg made him its honor citizen.

Edmund Beecher Wilson, the great American cytologist, wrote of Weismann: "It has been Weismann's great service to place the keystone between the work of the evolutionists and that of the cytologists, and thus bring the cell theory and the evolution theory into organic connection."

What is a cytologist? A person who studies cytology, or the structure of cells. So far in this chapter, heredity has been discussed principally in relation to visible effects. As the structure of the cell was studied more and more carefully, certain conditions became evident. In the first place it was discovered that cells have definite numbers of chromosomes. In man, for example, the number of chromosomes characteristic of the body cells is forty-eight. In the body cells of the vinegar fly there are eight chromosomes.

Edmund Beecher Wilson, who was born in Geneva, Illinois, in 1856, became the leading cytologist in the United States in the last decade of the nineteenth century. Wilson studied in this country and in Europe. In 1881 he

received the degree of Ph D from Johns Hopkins University, after which he studied in England and Germany. He



EDMUND B. WILSON

The work of Dr. Wilson made him a leading cytologist in the United States (Science Service)

taught in several American colleges before going to Columbia University in 1891. He retired in 1928 from active teaching, but continued as a consultant and adviser to graduate students as long as his health permitted. He died in March, 1939

In 1896 he published a book titled *The Cell in Development and Inheritance*. In this work he brought together the results of research that had been made on the cell during the pre-

ceding twenty years. The book immediately became a standard text and in revised editions has continued to be extensively used.

The many investigations carried on in connection with inheritance during the nineteenth century brought cytology, which is a branch of biology, into great prominence in the early part of the twentieth century. At the same time it offered opportunities in different types of research. Men who wanted to know how to improve plants and animals became interested in the application of the laws of inheritance from the practical point of view. Sociologists and others who believed that the human race could be improved were interested in

eugenics. Cytologists used different techniques and studied cell structures with new purpose in their attempt to solve the exact role of the chromosomes in the phenomenon of inheritance.

In the United States, Dr. Charles Benedict Davenport pioneered in the analytical study of variations in plants, domestic animals, and man. He was born in Stamford, Connecticut, in 1866. He was graduated from Brooklyn Polytechnic Institute when he was twenty years old and received his Ph.D. from Harvard three years later.

In 1902 Davenport wrote a letter to the Carnegie Institution of Washington in which he outlined his ideas for the establishment of a biological experiment station. The purpose of this station would be to make an analytical study of individual and racial differences. He proposed that the crossbreeding of animals and plants, the effects of changes of environment, and the variations due to isolation and geographical distribution should be studied. Davenport's interest in heredity had been aroused by a lecture given by Sir Francis Galton at Harvard, when Davenport was a young man.

Davenport's plan met with approval and on June 11, 1904, the laboratory at Cold Spring Harbor, Long Island, New York, was formally opened. Dr. Davenport was made director at that time and held this position until he retired in 1934.

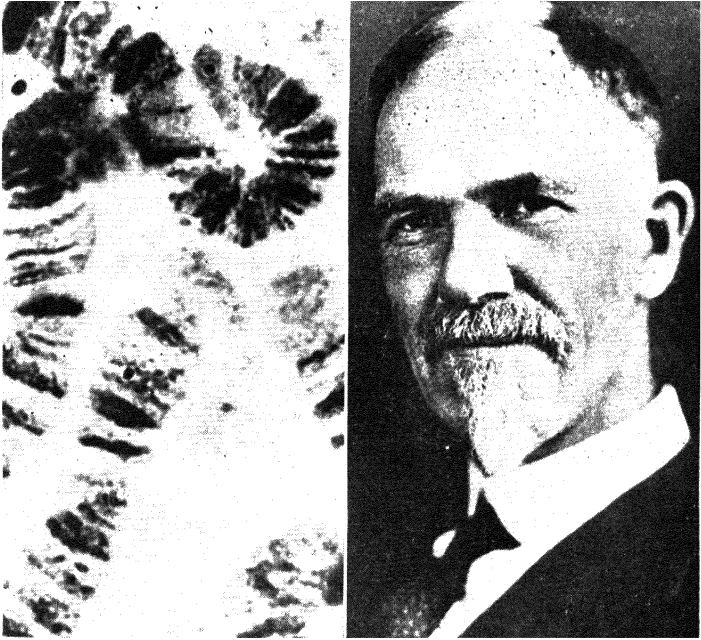
The opening of the Cold Spring Harbor Laboratory was an event among the scientists in the United States because it was established especially for the study of problems of variation and heredity. One of the features of the opening day was a speech by Hugo de Vries. Some of the seeds grown the first year in the experimental

garden had been selected by him. The Dutch botanist was made an honorary member of the staff and continued his interest in the laboratory throughout his life.

The laboratory made a modest beginning. A number of experimental animals were donated, among them some sheep given by Alexander Graham Bell. In 1918, the Eugenics Record Office came under the control of the laboratory. This service had been established in 1910 by Mrs. E. H. Harriman and was active in gathering information about human heredity. A book, published by Davenport in 1911, titled *Heredity in Relation to Eugenics*, gives a very comprehensive idea of the purpose and methods of the science of eugenics. Extensive records of families are gathered. With the cooperation of institutions for the feeble-minded and insane, eugenists have increased the understanding of certain types of mental deficiencies that are apparently inherited. On the other hand, by tracing the families in which there are a large number of people who are outstanding in their professions, the more encouraging side of eugenics is presented.

Besides gathering statistics about the genealogies of families, Davenport is interested in race crossings. In the island of Jamaica where the black and white populations have intermarried, he conducted tests on mental ability of the pure blacks, the pure whites, and the browns who are the offspring of these mixed marriages. He found that on the whole the scorings of the browns was below that of the pure strains. However, there were a few browns who tested considerably higher than either the blacks or the whites.

By experimenting with animals, he further strengthened his belief that racial crosses may lead to inharmonious behavior in individuals. He crossed white leghorn and



CHARLES B. DAVENPORT

Dr Davenport, an outstanding eugenicist in the United States, was instrumental in establishing the Cold Spring Harbor Laboratories, where many experiments on heredity are carried on. The photograph at the left shows chromosomes in a cell, greatly magnified (*Keystone View*).

brahma fowls. White leghorns are valuable from a commercial point of view because they are continuous layers. The brahma hen does not lay so continuously, as it broods and hatches its eggs and shows marked parental care toward the young chicks. When these two strains were crossed, the leghorn-brahma hens showed characteristics of both strains, but in some ways these characteristics were opposed. The hens would hatch the eggs, but abandon the chicks and start laying more eggs.

Immigration was another problem which Davenport studied very seriously. In the first decade of this century, there were as many as five thousand immigrants in one day passing through Ellis Island. Davenport recognized the fact that the children of these new comers would influence for better or worse the communities in which they lived. He advocated that field workers be maintained in the countries from which immigrants came, who would trace the families of those desiring to enter the United States and determine whether or not they could be expected to make desirable citizens. In the last fifteen or twenty years the government has restricted immigration, at least in the matter of the health of the individuals and their ability to be self-supporting or provided for by relatives in this country.

The improvement of human beings by selective breeding caught the fancy of early workers on heredity. Further work has shown that many idealistic plans for the improvement of the race are impractical, if not impossible, under present conditions of civilization. Nevertheless, the work of Davenport and his associates is of tremendous importance in explaining what defects and superior qualities seem to follow the Mendelian laws of inheritance. It also gives a physiological reason for some of the mental as well as physical disharmonies that appear in human beings.

Davenport and his associates are, of course, interested in the conditions in the cells which cause variation as well as in the external results. They have done some excellent research work upon the genes in cells.

The word "gene" is a recent addition to the English language. Unfortunately, there is no simple definition of

a gene; and for present purposes a gene may be considered as an infinitesimally small chemical particle in a chromosome. The present conception of the gene cannot be traced to one investigator. Thomas Hunt Morgan, Hermann Joseph Muller, T. S. Painter, Calvin Blackman Bridges, Albert F. Blakeslee, and many others have added a bit of information here and a bit of information there in the building up of the gene theory. Because these five men worked at the same time and are still working, it is impossible to give a chronological order to their contributions or to evaluate definitely their importance.

Thomas Hunt Morgan was born in Lexington, Kentucky, in 1866. His family records show that John E. Howard, a colonel in the Revolutionary War, and Francis Scott Key, author of "The Star-Spangled Banner," were both his ancestors. At the age of twenty, he was graduated from the State College of Kentucky.

Among the people to whom Wilson makes acknowledgements in the 1896 edition of *The Cell in Development and Inheritance*, is Morgan, then thirty years old and a professor at Bryn Mawr College. At Columbia University, where he became a professor in 1904, Morgan gathered together a group of scientists, among whom were C. B. Bridges, A. H. Sturtevant and H. J. Muller. These men brought the study of the gene to the foreground in the United States and the rest of the world. Mrs. Morgan also helped her husband in his investigations.

In 1933, Morgan was awarded the Nobel Prize. Nobel Prizes are given to men who have contributed to the benefit of mankind in the fields of physics, chemistry, medicine, literature, and in the promotion of peace. The money for the prizes comes from a fund left by a

Swedish scientist, Alfred Bernhard Nobel, who died in 1896. He was the inventor of dynamite. The prizes amount to about \$40,000 apiece and are awarded each year if, in the opinion of the administrators of the fund, they are deserved.

The award of the Nobel Prize does not guarantee that the results of a man's work may not be questioned at some future time. Later investigations, with more refined technique, may cast doubt on what he has considered an unquestionable conclusion. His conclusion may be reinterpreted or perhaps totally discarded. Nevertheless, the fact remains that if a man wins the Nobel Prize he is considered worthy of recognition by his contemporaries.

The award was made to Morgan not only because the new knowledge of the genes was a contribution to pure science, but also because it is believed that the understanding of these units will be of great importance in the field of medicine in the future.

Since 1928, Dr. Morgan has been connected with the California Institute of Technology. This institution was given an appropriation of \$40,000 in 1935 by the Rockefeller Foundation so that Morgan could develop a department of physiology. Much of his earlier experimental work was done at the Woods Hole Laboratory in Massachusetts.

For an experimental animal Morgan selected the vinegar fly, *Drosophila melanogaster*, because its cells contain few chromosomes and because only ten days are required for it to complete its life cycle. The shortness of time necessary for the development from egg to adult makes it possible to raise thirty generations in a year.



THOMAS H MORGAN

Morgan's name is inseparably connected with the gene theory of inheritance (*Keystone View*)

Muller bombarded vinegar flies with X rays and speeded up the rate of mutation about one hundred and fifty times (*Science Service*)



HERMANN J MULLER

Millions and millions of flies have been raised and examined by Morgan and his associates. The colors of their eyes have been recorded. The numbers of hairs on the bodies have been counted. The shape and venation of the wings have been noted and many other details which, considering the size of the vinegar fly, would seem like a lot of nonsense to some people. But it has been by this careful observation that Morgan has come to his conclusions. For one thing, he found that certain inheritable traits in these flies follow the Mendelian laws. He has also been able to throw light on the so-called sex-linked characteristics. In human beings these characteristics have been known for a long time by the facts that women are seldom color blind and that haemophilia,

a condition in which the blood does not clot properly, rarely occurs in women.

Further than this, the vinegar fly is something like the evening primrose upon which de Vries experimented. It is subject to mutations. Several hundred mutants have appeared in Morgan's flies. Experimenters are always on the watch for mutations, for they may be of use in changing the characteristics of plants or animals. The advice given by Bateson a number of years ago, "Treasure your exceptions," is followed by those interested in heredity.

Hermann Joseph Muller, after extensive experimentation with X rays on vinegar flies, has been able to produce mutations artificially. How these mutants were produced is of interest. In the fall of 1926, Muller enclosed adult vinegar flies in gelatine capsules and exposed them to X rays powerful enough to produce partial sterility; that is, the reproductive cells were affected. The flies after the treatment were mated with untreated flies. The offspring of these unions were examined and amazing results were observed. There were flies with bulging eyes, with flat eyes, and with no eyes at all. There were flies with coarse hair and flies with fine hair and bald flies. There were even flies that had legs growing on their heads in the place of feelers or antennae. By counting the normal and mutant offspring from many matings in which one fly had been treated, Muller came to the conclusion that he had speeded up the rate of mutation about one hundred and fifty times.

Most mutations are a disadvantage to the organism and may even cause its death, but there are some mutants which have desirable characteristics. Since Muller found

that mutations caused by X ray followed the Mendelian laws, if desirable qualities can be made to appear in this way, a new method of improving organisms is available. He explains a mutation as a chemical change in a gene.

Muller was born in New York City, in 1890. He studied at Columbia and received his Ph.D. there in 1915. His interest in genetics was first aroused when, as a boy, he saw models representing the development of a horse through geological periods. At Columbia, he was inspired by the work of Morgan under whom he studied. From 1933 to 1937 H. J. Muller was the senior geneticist at the Institute of Genetics in Moscow, Russia.

Since Muller began to do strange things to genes with X rays, many other geneticists have used them. At Cold Spring Harbor, Albert F. Blakeslee and his associates are carrying on experiments with Jimson weed that somewhat parallel Muller's experiments on the vinegar fly. The Jimson weed as an experimental plant was used by Kolreuter (see page 168) in his hybridizing experiments before heredity was discussed in terms of chromosomes and genes. It is still useful.

Albert F. Blakeslee was made assistant director of the Cold Spring Harbor Laboratory in 1923. He was born in Geneseo, New York, in 1874. Soon after his graduation from Wesleyan University he joined the summer staff at Cold Spring Harbor. In 1904 he received a degree of Ph.D. from Harvard and in the same year was sent to Europe as an investigator for the Carnegie Institution. Blakeslee has taught botany in several colleges, including the Connecticut Agricultural College.

His book, *Trees in Winter*, makes it possible to identify trees by the bark, buds, leaf scars, and other character-

istics. In 1931 Blakeslee and his associates announced the results of tests on the sense of taste. It has been found



ALBERT F. BLAKESLEE

Dr Blakeslee, an authority on heredity, has used the Jimson weed in his experiments. This plant, which is shown behind him, is useful for studying variations of different kinds. (*Science Service*)

that the sense of taste is much more acute in some individuals than in others. Furthermore, one substance may taste bitter to one person and sweet to another. The senses of taste and smell have not been investigated as thoroughly as the other senses. This is one reason why the language has so few words to describe the taste and smell of different substances. At Cold Spring Harbor these two senses are being studied to determine whether they follow accepted laws of inheritance.

In 1937 Blakeslee announced that the number of chromosomes in some plants could be doubled by treatment with colchicine, an old remedy for gout in human beings. This opened a new field of producing mutants by the use of chemicals.

The research of the scientist today has been made possible by the pioneering of the scientist of yesterday.

Lamarck, Darwin, Mendel, and de Vries clearly perceived the differences in species and individuals. They tried many breeding experiments in order to get facts upon which to formulate laws. Mendel first stated these laws.

Galton and Davenport saw in the study of human heredity a possible way to improve the human race and thereby made eugenics a separate branch of biology. Galton defined the term ‘‘eugenics’’ and made other people realize the importance of developing this branch of biology on scientific lines. The work of Davenport and his associates in the Eugenics Record Office is internationally known.

Weismann called the attention of the scientific world to the difference between the somatic, or body, cells and the reproductive cells, and prophesied much about the functioning of the reproductive cells. The work of Morgan, Muller, Painter, Bridges, Blakeslee, and other investigators has caused the geneticists to focus their attention on the genes.

A new era in experimentation began when it was found that bombardment with X rays changed the genes in the reproductive cells. If a gene in one of these cells is changed, the change is inherited in the body cells of the new organism that results from the union of the X-rayed cell with another reproductive cell. Therefore, further study of changed genes is made possible.

Thus, Jennings’s statement about diverse recipes, which was quoted at the opening of this chapter, might be elaborated in terms of genes to read: Different individuals are made up, as it were, on diverse recipes, combinations of genes; and diverse combinations of genes give different results.

Hints for Further Reading

- “Award of the Nobel Prize for Medicine” (re: T. H. Morgan), *Nation*, CXXXVII (Nov. 1, 1933), 497.
- BATESON, BEATRICE, *William Bateson, F.R.S., Naturalist*.
- BLAKESLEE, ALBERT F., “The Work of Hugo de Vries,” *Scientific Monthly*, XXXVI (April, 1933), 379–380.
- CUMLEY, RUSSELL W., “The Story of the Gene,” *School Science and Mathematics*, XXXV (Dec., 1935), 943–954.
- DEMEREK, MILISLAV, “What Is a Gene?” *Studies in Heredity*, Carnegie Institution of Washington, Supplementary Publications, No. 8. (July, 1934), Pp. 42.
- GALTON, FRANCIS, *Memories of My Life*.
- GAUPP, ERNST, *August Weismann* (in German).
- ILTIS, HUGO, *Life of Mendel*.
- JENNINGS, HERBERT S., “Thomas Hunt Morgan, Nobel Laureate,” *Scientific Monthly*, XXXVII (Dec., 1933), 567.
- MORGAN, THOMAS HUNT, “William Bateson,” *Smithsonian Institution Annual Report* (1926), 521–532.
- , “William Bateson,” *Science*, LXIII (May 28, 1926), 531–535.
- MULLER, HERMANN J., “Heritable Variations, Their Production by X Rays and Their Relation to Evolution,” *Smithsonian Institution Annual Report* (1929), 345–362.
- , “Physics in the Attack on the Fundamental Problems of Genetics,” *Scientific Monthly*, XLIV (March, 1937), 210–214.
- PAINTER, T. S., “A New Method for the Study of Chromosome Rearrangements and the Plotting of

Chromosome Maps,” *Science*, LXXVIII (Dec. 22, 1933), 585-586.

THONE, F., “New Discovery Speeds Up Evolution,” *Scientific American*, CXXXVIII (March, 1928), 235.

WALSH, JAMES J., *Catholic Churchmen in Science*.

WILSON, EDMUND B., *The Cell in Development and Heredity*.

Made-to-order Plants

GREW, KOLREUTER, AND BURBANK

MANY primitive people, when they buried their dead, put food for the spirits in the graves or in the burial chambers. Archeologists today examine the remnants of food they find when making excavations. They are interested in the diet of the people who lived thousands of years ago. They want to know what these people ate and how their foods differed from those in the same locality today. What were the original wild plants which, after hundreds of years of domestication, now furnish the world with its cereal crops? How much of the improvement in plants was a result of favorable circumstances? What direct methods have been used in the past to improve crops?

Fertility of soil and cultivation may account for some improvement in plants; but cross-pollination and vegetative propagation, such as grafting, produce more marked changes in varieties. It is the purpose of this chapter to deal with some of the history and practices of pollination and grafting.

In some flowers the pollen produced in the stamens may fall on the pistil of the same flower. This is known as self-pollination. If, on the other hand, pollen is carried

from one flower to another by insects or the wind, the process is known as cross-pollination. Flowers differ in their adaptations for self- or cross-pollination. In some species all of the flowers on one plant produce stamens while all the flowers on another contain only pistils. Such plants are called *dioecious*, and it is only the females or pistillate flowers which will develop fruits.

Some time, so far back in antiquity that there is no record of its beginning, the people of Assyria became conscious of the fact that date trees are dioecious. The practice of artificial pollination began. Staminate flowers were taken from male trees and fastened in the clusters of pistillate flowers. This artificial pollination was of great economic importance. Comparatively few male trees were needed. This made it possible to use the land for the fruit-bearing female trees. The method also resulted in more fruit per tree. Date trees are wind-pollinated, and unless staminate trees were close to pistillate trees, the chance of fertilization was diminished. When this practice became common in Assyria is not known, but it is mentioned in writings of the seventh century B.C. Fragments of bas-relief from a palace built about this time also represent the process as it was carried out. From Babylonian records, it has been possible to trace artificial pollination to an even more remote time. From the translation of some business contracts made about 2000 B.C., it is known that the pistillate flowers were articles of commerce at that time.

There are other plants that might have been benefited by the same process of artificial pollination, but for some unknown reason the practice never became widespread in the ancient world except with the dates.



Nehemiah Grew

Cosmologia Sacra :
 OR A
 DISCOURSE
 OF THE
 UNIVERSE
 As it is the
 Creature and Kingdom
 OF
 G O D.

Chiefly Written,

To Demonstrate the *Truth* and *Excellency* of the
 BIBLE; which contains the *Laws* of his
 Kingdom in this Lower World.

J. S. Amicorum
 In FIVE BOOKS.

By Dr. NEHEMIAH GREW,
 Fellow of the College of Physicians, and of the Royal Society.

LONDON:

Printed for W. Rogers, S. Smith, and B. Walford: At the Sun
 against St. Dunstons Church in Fleetstreet; and at the Printer's
 Arms in St. Pauls Church-Yard, MDCCCL

NEHEMIAH GREW

Grew was a physician and botanist. The title page of his book published in 1701 shows in a striking way how the naturalist was influenced by the religious thought of the time.

After the invention of the microscope, the structure of the reproductive organs of plants received a great deal of attention. Among the men who carried on serious investigations was Nehemiah Grew (1628–1712). Grew was an Englishman who studied in Leyden. Although he was a practicing physician in London, he found time to carry on research work. He described the organs and cells in plants in great detail and eventually decided that the pistil could be considered the female and the stamen, the male part of a flower.

Grew's ideas on the sexuality of plants were largely theoretical and not the result of actual experimentation.

Rudolf Camerarius, basing his conclusions on both the descriptions in the ancient writings of the pollination of dates and upon his own experiments, wrote *Letter on the Sex of Plants* in 1694. In this book he told of growing plants having male and female flowers. He observed that if the male flowers were destroyed before they matured, the female flowers would not develop fruits unless pollen were put on the pistils. For some reason, the experiments of Camerarius were ignored for more than half a century. Then Linnaeus (see page 21) in an essay written in 1760 and Kolreuter in a report written in 1761 referred to Camerarius as the person who first proved by experimentation the sexuality of plants.

Rudolf Camerarius was born in Tübingen, in Germany, in 1665 and died in 1721. He studied philosophy and medicine in the university in that city where his father was a professor. During the years 1685–1687 he traveled on the Continent and in England. In 1688 he was made director of the Botanic Garden at Tübingen, and the following year he became a professor of natural philosophy in the university.

Kolreuter, who helped to save the work of Camerarius from oblivion, made a serious and scientific study of pollination. A number of papers written by Kolreuter have been preserved, but very little is known about his personal life. Joseph Gottlieb Kolreuter was born in the village of Sulz in the Black Forest in southwest Germany, in 1733. He conducted his many experiments on cross-pollination in his garden at Sulz, in the garden of a friend in Calw, and in Berlin, Leipzig, and St. Petersburg. From 1764 until 1806 he taught natural history in the University of Karlsruhe.

At the time he began his studies, there was little accurate knowledge about pollination. Kolreuter examined flowers and was convinced that in some forms self-pollination or cross-pollination by the wind were not possible. He watched the insects which visited the flowers and concluded that they were agents of pollination. Why no one else had noted the relationship between insects and pollination seemed as surprising to Kolreuter as it does to a person today. He wrote that anyone who had watched the insects carefully might have come to the same conclusions that he did.

Kolreuter's conception of the way in which pollen acted on the pistil of a flower was very different from the modern one. He believed that the sticky fluid secreted on the stigma of a flower united with an oily substance given off by pollen grains. In his mind this mixing of the two liquids caused fertilization. He did not know that a pollen grain germinates and grows a tube through the pistil, from the stigma to the ovary. Because of his incorrect interpretation of what he saw, Kolreuter thought that enough pollen must fall on each stigma to produce a sufficient amount of the oily substance to react with the liquid on the stigma. In explaining fertilization, he compared the reactions of these two liquids to that which takes place when an acid and an alkali react to form a salt.

It is interesting to note that in his calculations of the number of pollen grains necessary to produce a full pod of seeds, Kolreuter's figures were about the same as those given today, in spite of the fact that the explanations of fertilization today and in the eighteenth century are entirely different. Whereas Kolreuter explained the amount



JOSEPH KOLREUTER

Kolreuter was one of the first men to make a careful and scientific study of hybridization. (Courtesy A. F. Shull from "Heredity," and "Journal of Heredity.")

of pollen necessary in terms of the fluid it would exude, the modern experimenter knows that for every pollen grain that successfully reaches an ovule there are a number which either do not germinate at all or do not reach an ovule.

Kolreuter's study of pollination led him to the question of hybrids, forms that result from the crossing of two different species. Hybrid animals, such as the mule, a cross between a horse and an ass, had been known for centuries. Kolreuter wondered why hybrid plants were not

found in botanical gardens where different kinds of plants were grown near together. In order to answer this question and to prove whether or not hybrid plants were sterile, Kolreuter began a series of experiments. He crossed plants which were closely related but had distinguishing characteristics. By crossing two species of tobacco plants, in 1760, Kolreuter obtained seeds which grew into plants having characteristics of each parent. The hybrid plants resulting from this crossing are frequently mentioned as examples of the first hybrids experimentally produced. In recent times, however, careful study of the writings of less well-known men has brought out the fact that hybrid plants had been produced experimentally nearly fifty years before Kolreuter did his work.

Kolreuter performed experiments with other plants besides species of tobacco. He crossed white and violet-flowered Jimson weed and grew plants from the resulting seeds. Some of the flowers on these plants were paler violet than those on the parent plants, and others were very blue. He also crossed a single pink with a double pink and found that the flowers raised from these seeds tended to have more petals than those of the single parents. In some instances he artificially pollinated the hybrids. Although he kept a careful record of his work, he did not formulate laws about the inheritance of characteristics such as Gregor Mendel (see page 136) did in the nineteenth century.

If we only knew more about Kolreuter's life, we might understand why he did not put the results of his experiments to practical use, for he was confident that by cross-breeding he could improve plants. He even prophesied

in what ways certain hybrids would be of greater use than the parent stock. Although no improved varieties of plants can be traced directly to his experiments, he did influence other botanists, notably, Karl Freidrich Gärtner (1772–1850). The observations of Kolreuter and Gärtner were used by Darwin when he carried on his prolonged investigations on hybrids.

Grafting, another means by which the yield and quality of fruits have been improved, has been practiced for centuries. In his poem, "Of the Nature of Things," written in the first century B.C., Lucretius has these lines:

“ men’s fondness for ingrafting slips
Upon the boughs and setting out in holes
The young shrubs o’er the fields.”

Pliny in the first century A.D. describes the splitting of the branch on a tree and the insertion of the scions, the small cuttings, in much the same manner as it is done today. He also directs that the scions should be put between the bark and the wood, for if they are put in the pith they will not grow. These directions must have been the result of purely practical experience, for in Pliny’s time the different functions of the cambium layer, the xylem, and the phloem were not known.

Grafting fruit trees was a common practice in the gardens connected with monasteries during the Middle Ages. Later, when botanical gardens were numerous, many people amused themselves by grafting plants in unusual combinations. In the last half of the nineteenth century, Luther Burbank surprised the horticultural world with the new varieties of plants he was able to grow successfully. Burbank used both artificial cross-

pollination and grafting in the production of new varieties and the improvement of old ones.

Luther Burbank was born in Lancaster, Massachusetts, in 1849. For several winters he attended the academy at Lancaster, but the remainder of the year he worked on the land or in a factory in Worcester. Here he was employed as a wood turner and patternmaker. It was not long before his inventive ability was shown. He made a machine by which one man could do the work of six. His family and friends had his future all settled for him: he would be an inventor. Burbank decided otherwise. He left the factory and began a nursery.

Burbank wanted to improve the quality of potatoes. Many potatoes were being raised in New England at that time, but they were small and did not keep well during the winter. Burbank had studied what he could find about methods of improving plants. Naturally, artificial pollination occurred to him as a possible way by which he could improve potatoes. He tried this method, but seeds did not develop in the artificially pollinated flowers.

One day, however, to his great joy, he found a seed ball that had developed naturally. He watched it carefully until it was ripe and then planted the twenty-three seeds that were in it. All the seeds germinated, but he kept only two plants on which grew potatoes that were of unusual quality. He said of them in *The Harvest of Years*: "They were as different from the old early rose as the beef cattle of today are different from the old Texas longhorn." From these potatoes he developed the famous Burbank potato, and what was of greater importance, he turned more enthusiastically than ever to the task of developing other plants. He sold *all* except ten of these



LUTHER BURBANK

Burbank is shown in his California garden examining poppies. He did a great deal of work with these flowers. Among other things he was able to breed a red poppy by starting with plants bearing yellow-petaled flowers slightly streaked with red (*Culver Service*).

improved potatoes to a seed merchant. The ten potatoes he took with him to California, where he went because the climate was more suitable for his experiments and for his physical condition. He had never been robust, and a sunstroke had further impaired his health.

Arriving in California in 1875, Burbank found living at first difficult. He had practically no resources, and jobs were not plentiful. He worked at anything he could find to do, and eventually he saved enough money to buy a small plot of ground where he started a nursery business. Success came slowly and only as a result of great effort on his part; but by 1904 his name was internationally known among the horticulturists. In that year Hugo de Vries, one of the most noted botanists in Europe (see page 140), came to America principally to visit Burbank's farms in California and to talk with the plant breeder himself.

One of Burbank's most famous early successes in fruit tree growing resulted from a rush order for twenty thousand prune trees. The prospective customer wanted the trees in nine months. Burbank did not have any trees started at the time, and under normal circumstances it would take two years or more to grow them to the desired size. He wanted to fill the order, so he planted twenty thousand almonds, and enough more to allow a margin in case they did not all grow. Almonds not only sprout quickly but also can be planted as late in the season as it was when the order came. When the young almond trees were big enough, Burbank grafted prune buds on them. The twenty thousand trees were delivered to the customer on time and grew into one of the best prune orchards in California.

Burbank also developed in California the plumcot, nearly a dozen kinds of plums, and several kinds of roses. The well-known Shasta daisy is a flower that was produced by artificial pollination. Burbank had found beauty in the common wild daisy when he was a young man living in New England. Later at his experimental farms in California he crossed this flower with a daisy from Japan that had exceptionally white petals, and with a daisy from England that had larger flowers than the other two. From these crosses he grew a large, hardy, beautiful daisy, now found in gardens and greenhouses throughout the country under the name of Shasta daisy.

One reason for Burbank's success in developing plants was his almost uncanny ability to select from young stock the plants he knew would develop into what he desired. Often he would reject several thousand plants of one kind and keep perhaps a half dozen which showed the characteristics he wished to develop. Burbank's ability to select unerringly a few plants from hundreds showed a peculiarly keen power of observation. At different times some of his friends took plants he had rejected and replanted them. They could not see at the time why they were different from the ones he chose. In every case, however, the plants Burbank kept showed, when they matured, the greatest development of the characteristics he desired. This ability to select was not a thing he could write rules about; it developed through the constant handling of thousands of plants, with his attention so alert that the smallest details did not escape him.

After he became a recognized specialist in plant breeding, Burbank was a lecturer on evolution at the Leland Stanford Junior University. His writings include:

Methods and Discoveries (12 volumes) and *How Plants Are Trained to Work for Man*.

Luther Burbank died in 1926. At that time he had more than three thousand experiments under way. His work has been continued, and every year both the farmer and consumer are benefited by the results of the experiments he began. Burbank had two great aims in his work: to improve plants for commercial use, as food and lumber; and to create more beautiful flowers for the sake of enjoyment. He achieved great success in accomplishing both of his aims.

If no scientific explanation of the laws of heredity had been made, practical horticulturists would have continued improving plants and producing new varieties. However, the greater understanding of the physical factors of inheritance has taken much of the guess work out of breeding and made it more purposeful.

Hints for Further Reading

BURBANK, LUTHER, and WILBUR HALL, *The Harvest of the Years*.

COHEN, JOSEPH G., and WILL. SCARLET, *Modern Pioneers*.

FAIRCHILD, DAVID, *The World Was My Garden*.

WILLIAMS, HENRY S., *Luther Burbank*.

Before and after the Germ Theory

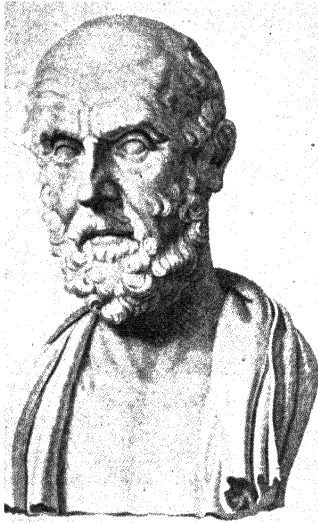
JENNER, PASTEUR, KOCH, AND LISTER

MEDICINE and magic are so closely bound together in the traditions and folklore of early civilization that it is impossible to separate one from the other. For centuries disease was believed to be caused by some spirit, god, malicious imp, or even by some human being who was under the influence of an evil spirit. A person might be afflicted as a punishment for a sin or simply because he had incurred the ill will of some supernatural being. Since the causes of diseases were supposed to be of supernatural origin, the cures naturally consisted of rites and magical ceremonies.

In Greece, the combination of religion and healing reached its greatest development in the cult of the Asclepiads, those priests whose lives were devoted to the service of the god of healing (see page 8). It will be remembered that Aristotle's father belonged to this cult and that Aristotle himself received some training from the friends of his father.

The names of individual Asclepiads are in most cases forgotten, but the name of the man who separated the gods from medicine has been perpetuated. Every modern

physician is familiar with the Hippocratic Oath. This oath, which states an admirable code of medical ethics,



HIPPOCRATES

This early physician believed in the importance of rest, fresh air, and proper diet for his patients.

history of medicine would be very different from what it is.

As far as his knowledge of anatomy was concerned, Hippocrates's ideas seem very amusing today. He believed, for example, that one function of the brain was to cool the blood. He thought that the pupil of the eye, the opening through which light rays reach the retina, reflected the object looked at and produced the sensation of sight. In many instances he did not differentiate between the nerves and tendons. This, of course, led to confusion.

is said to have been imposed by Hippocrates on his disciples. It is even administered today to the graduates of some medical schools.

Hippocrates was born about 460 B. C. on the island of Cos, off the coast of Asia Minor. His writings were little known in Europe until after the fall of Constantinople in the fifteenth century. Scholars who fled to Italy at this time brought the books of Hippocrates with them. If his teachings had been followed immediately after his death, the

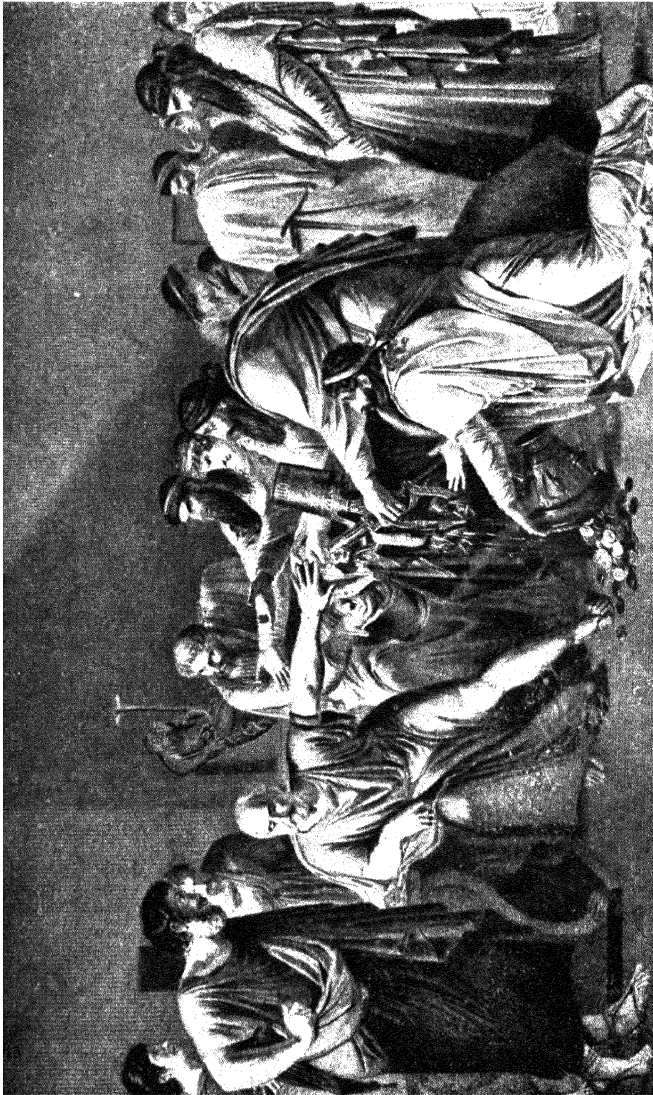
However, in spite of these incorrect ideas on anatomy, Hippocrates's treatment of his patients was much more sensible than that of his contemporaries. In the first place, he did not believe that the gods inflicted diseases on people. In the second place, he had faith that the body had great powers of recuperation if it were not interfered with too much, and that rest, fresh air, and proper diet were important. He was firmly opposed to the violent exercises and rites that other doctors prescribed.

In the fifth century B.C., strange concoctions of herbs and animal substances were used as medicines. Hippocrates recommended only simple medicines and held in disfavor those which caused violent reactions in his patients.

The accounts that Hippocrates wrote of his cases have become classics in medical literature. He described the symptoms of his patients with the greatest care and noted the effects of remedies on the progress of the disease. He was honest enough to record the cases of the patients he failed to cure, as well as those he cured.

So great was the reputation of Hippocrates throughout the ancient world that, according to legend, Artaxerxes, the king of Persia, offered him gifts of great value in an attempt to get him to come to his court. However, Hippocrates could not be tempted by them to leave his native Greece. This incident in the life of Hippocrates has been portrayed by the artist in the picture which is reproduced on page 178.

The name and teachings of Hippocrates were obscured for centuries by the influence of Galen. Claudius Galen was born in Pergamum in Asia Minor, about 130 A.D. He was a contemporary of Ptolemy (see page 81). Like



HIPPOCRATES REFUSING THE PRESENTS OF ARGAEUS

the astronomer, he studied in Alexandria. When he was about thirty years old, he went to Rome where he won great fame. The influence he had in the field of medicine has already been mentioned in connection with William Harvey's discovery of the circulation of the blood (see page 38).

Galen firmly believed in the use of herbs. A remedy he compounded for toothache contained black pepper, saffron, opium, carrot seeds, aniseed, and parsley seeds. A remedy for colic, not invented by him but which he recommended highly, contained the first three substances just mentioned and several other plant products. His writings show that herbs were very plentifully used during the second century A.D. They did not lose popularity in the following twelve centuries. In fact, the number of plants supposed to have medicinal value increased as exploration opened new countries, for in these countries the natives were using herbs indigenous to their locality. Spices from the East brought high prices, not as flavoring, but because of their supposed medicinal value.

Eventually, the efficiency of herbs was challenged by one of the strangest men in the history of science. This man was born about 1490. His real name was Theophrastus von Hohenheim, but he is best known as Paracelsus, the name he signed to some of his writings. He attempted to replace herbs with mineral substances. Paracelsus was something of an alchemist, so it is natural that mercury found a place in his cures. While he was teaching the use of minerals, he was attempting also to turn his students from Galen to Hippocrates. He burned the writings of Galen in front of his students and urged them to follow the more simple methods of Hippocrates.



CONSULTING ROOM OF A PHYSICIAN OF THE MIDDLE AGES

The first patient is being bled. The circle over the cabinet indicates the influence of astrology at this period. (*The Bettmann Archive, from British Museum*)

His attitude toward medicine and the teachings of Galen had little effect during his lifetime or for several centuries thereafter.

The state of affairs in medicine in England as late as the seventeenth century is illustrated by the treatment of Charles II during his last illness in 1685. In the few days before his death more than forty substances were administered to the king. Among them were solutions of violets, beet roots, lilies of the valley, peonies, and pearls. At one time when his condition was very grave he was given forty drops of an extract made from a human skull. This was supposed to keep him from having convulsions.

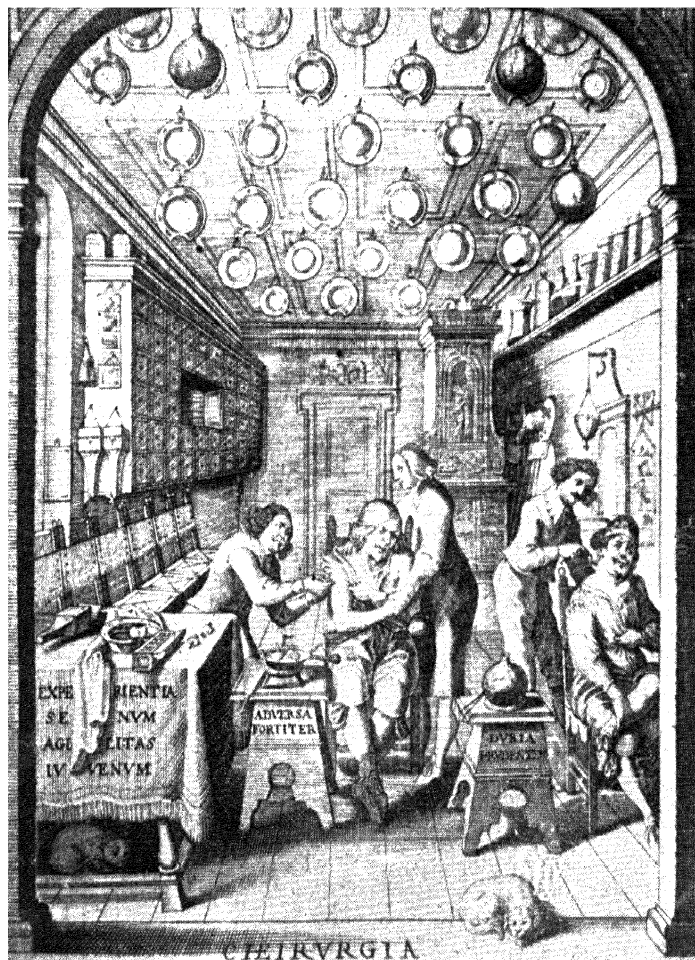
A plaster made of pigeon's dung and pitch was applied to his feet, while a blister was raised on his head with a poultice. Raleigh's antidote was given him at least twice during his illness. The antidote, which contained a large number of substances, had been invented while Sir Walter was serving a prison term.

But all the herbs, the nauseating concoctions of human skull, and the excrement of animals had no effect on the plagues of one kind or another that swept over Europe. Among these plagues was smallpox. In the year 1721, in London, there were 2,375 deaths from this disease. The population of London at this time was only about six hundred thousand. Many people had the disease in a mild form, but the disfiguring scars remained throughout their lives. A person whose face had no pock marks was unusual enough to attract attention.

The first method used in the attempt to control smallpox was inoculation. Matter from a smallpox sore on a patient who had a mild case was introduced under the skin of a well person. Unfortunately, not all of the induced cases were mild, and the person, while ill, was a source of infection to other people.

It had been noticed that girls who worked on dairy farms frequently escaped smallpox. One day a dairy maid remarked to Edward Jenner that she could not have smallpox because she had had cowpox. The idea was not original with her, but was held by many people who worked in dairies. This set Edward Jenner to thinking.

Edward Jenner was born in Berkeley, in Gloucestershire, in 1749. His father was a vicar who died when Edward was five. An older brother succeeded his father as vicar and brought Edward up.



A CONSULTING ROOM IN THE SEVENTEENTH CENTURY

The basins hanging from the ceiling with notches in the rims indicate that this is an establishment of a barber-surgeon. These basins were held under a man's chin while he was being shaved. Blood-letting and amputations were performed by barber-surgeons. (*The Bettmann Archive*)

Jenner studied surgery and pharmacy under a physician in a near-by town and then went to London where he became a pupil of John Hunter, one of the most important physicians in London at the time.

While in London, Jenner worked on the classification of the plants that Banks (see page 58) had collected on his voyage with Captain Cook. Jenner was offered a position as naturalist on the next voyage Cook made. He refused this offer as he did one from John Hunter to go into partnership with him in developing his museum. Hunter was gathering together a collection of animals, larger and more complete than any other collection of its kind. It was of enough importance to be visited by Cuvier and other scientists from Europe. The Hunterian Museum is in existence today at the Royal College of Surgeons in London. Jenner's refusal to join Hunter's London museum shows something of his attitude toward life. Even in these days he found the city's bustle annoying, and he preferred to return to the small village of Berkeley. There he began to practice medicine in 1773.

In this rural village he had much to take up his mind besides his rapidly growing practice. He played the violin in a local musical club, and like many other people of that period he kept a detailed diary. These diaries give much information about Jenner's life and personality. From day to day he lists the birds he sees, the letters he writes, and the calls he makes. Prescriptions and comments on the weather appear on the pages, and there are many verses which he wrote. Jenner had the happy faculty of being able to express himself in verse upon all sorts of occasions. When a friend inquired about one of his patients, he wrote the answer which is quoted on the next page.

“I’ve dispatched, my dear madam, this scrap of a letter
To say that the patient is very much better.
A regular doctor no longer she lacks,
And therefore I’ve sent her a couple of quacks.”

The quacks were two ducks he had sent as a gift to his patient

Jenner’s poem, “Signs of Rain,” is better known than his other writings. It is frequently quoted in books about the weather because it contains all the common signs which are associated with the approach of a rain storm.

May 14, 1796, is an outstanding day in medical history. It was on this day that Jenner vaccinated James Phipps with serum taken from a cowpox vesicle on a milkmaid’s hand. Later Phipps was inoculated and did not contract smallpox. This was the beginning of the very active fight against smallpox.

Jenner met with many discouragements, however, before his method was generally accepted. Some doctors violently opposed vaccination. Other doctors who tried the treatment were careless in their procedure, and deaths resulted. The conservative laymen, always ready to put obstacles in the way of new scientific achievements, exaggerated the dangers and bad effects of vaccination. Active antivaccination groups were formed in England and in America. There were times when Jenner himself had to leave his peaceful country town and carry on the work in London.

Nevertheless, before his death he had the satisfaction of seeing vaccination successfully used in England, Russia, France, and America. In 1803 the King of Spain fitted out an expedition to spread the knowledge of vaccination



EDWARD JENNER VACCINATING A BOY

An artist's representation of the first vaccination ever performed. Into the arm of eight-year-old James Phipps, Jenner inserted the serum from the cowpox-infected hand of Sarah Nelmes, a dairymaid, who may be seen at the right bandaging her hand. Later Jenner inoculated the boy with smallpox serum, and he failed to contract the disease (*Culver Service*).

throughout South America where the disease had made such ravages on the natives. The expedition continued to China, where pamphlets were translated into the Chinese language, and then went on to India.

For a man who deliberately shunned fame and adulation, Jenner had great influence and importance even in his lifetime. Napoleon, during a war with England, released an English prisoner at Jenner's request. A slip of paper signed by the doctor was as good as an official passport in France. From Russia, Jenner was sent a ring worth about fifteen hundred pounds. In 1807 the English government granted him twenty thousand pounds.

F. Dawtrey Drewitt in his *Life of Edward Jenner* quotes the doctor as writing: "The joy I felt at the prospect of being the instrument destined to take away from the world one of its greatest calamities . . . was so excessive that I sometimes found myself in a kind of reverie." To Jenner this joy was his greatest reward.

After the death of his wife in 1815, Jenner retired more than ever from public life, although he allowed himself to be made a magistrate in Berkeley where he was deeply loved. His kindnesses were many. When James Phipps, the boy he had first vaccinated, became tubercular in later years, Jenner had a cottage built for him and with his own hands helped plant the garden. His last act was typical of his life. On January 25, 1823, he walked to a near-by village to arrange for the distribution of fuel to the poor. Two days later he died.

To this big-hearted country doctor we are indebted for the conquest of smallpox, the first great victory of medical science over a disease that was a world-wide menace.

At the time Jenner died only one of the three men, Pasteur, Koch, and Lister, who changed the entire direction of medicine and science, had been born.

Louis Pasteur was born in Dôle, France, in 1822. His father was a tanner. When Louis was very small, the family moved to Arbois, the village now thought of in connection with Pasteur's later work. Although his parents had only a limited amount of schooling, they were interested in the boy's education.

Driven by a desire to study in Paris, Pasteur when fifteen started out with another boy for a school in the great city. The trip by stagecoach in rainy October weather was a poor beginning for this shy country lad. He was homesick before the coach had rattled through the next village. The strange new sights in Paris failed to cheer him. After a few weeks, the family with whom he lived became alarmed because his health was being undermined by his homesickness. They sent word to his parents. Pasteur's father came and took him home.

The next four years were spent at the colleges in Arbois and Besançon. In the latter place he began to teach some of the younger pupils. In 1842, Pasteur returned to Paris and entered the *École Normale*. Here he soon attracted attention by his brilliant work in chemistry. The formation and properties of crystals led him further and further into the mysteries of chemistry, and it was not long before he turned his attention to fermentation.

Examining drops of sour milk under his microscope, he detected the presence of micro-organisms. When some of these minute saprophytes were transferred to a fresh saccharine solution, lactic acid was formed as it had been in the milk. Pasteur concluded correctly that these



LOUIS PASTEUR IN HIS LABORATORY

In this picture the artist caught something of the spirit of earnestness with which Pasteur attacked his problems and successfully defended his opinions against the assault of many prominent members of the medical profession. In spite of the handicaps resulting from a paralytic stroke, he gave the world usable knowledge about the prevention of anthrax and hydrophobia (*Culver Service*)

organisms, in carrying on the life processes of nutrition, caused the chemical changes he could detect. He saw that fermentation was caused by organisms, not that organisms were produced by fermentation. The believers in spontaneous generation were up in arms. The battle between the two sides was long and furiously fought.

Amidst attacks from all sides, Pasteur continued his researches. How could fermentation be prevented when it was not desired? From where did the micro-organisms come that caused fermentation? Pasteur believed they were in dust in the air. His opponents ridiculed the idea.

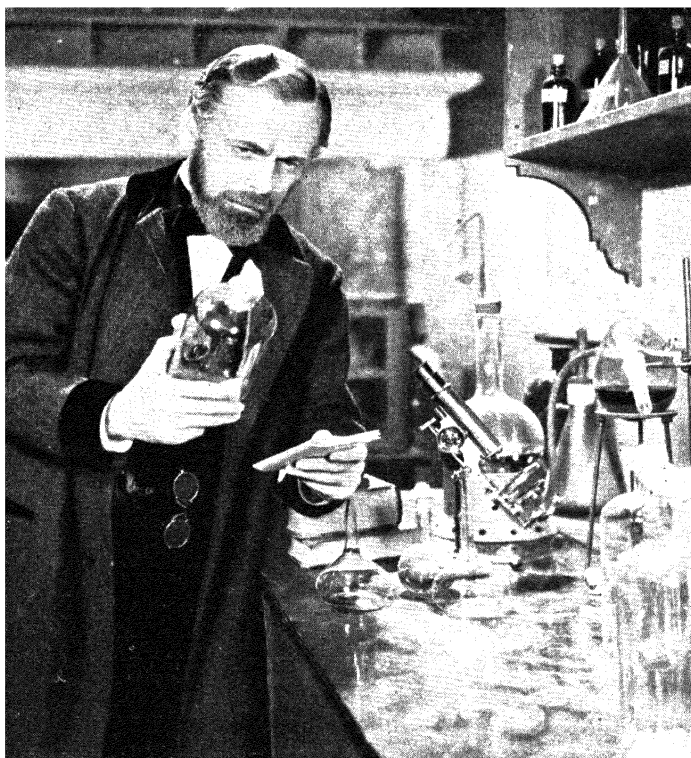
Early in the fall of 1860, Pasteur set out on his now famous trip to the Alps. It was a strange expedition that started up the Montanvert. There was a guide and a mule with the thirty-three glass vessels, each sealed and containing sterile liquid. Pasteur walked beside the mule to steady the easily broken apparatus over the rough places on the way. That night thirteen vessels were unsealed and exposed to the air in the dilapidated old inn where Pasteur stayed. The next morning the remaining twenty vessels were unsealed in the high clear air on Mer de Glace. The partial vacuum present in each vessel caused air to rush in as soon as there was an opening. There was no doubt that air entered each flask. After the inrush of air, each vessel was quickly sealed by fusing the glass over a flame.

Of course, changes due to fermentation are not visible until some time has elapsed. One can imagine the impatience Pasteur felt as he examined first one and then another of the thirty-three flasks. This was more than an experiment to satisfy his curiosity; his position in the scientific world was at stake. At last results began to

show. Of the thirteen flasks exposed to the air in the inn, nearly all showed a change was taking place in the liquids. Of the twenty opened and closed on the Mer de Glace, only one showed any change. Pasteur to his satisfaction, proved that the dust in air was one of the great factors in fermentation or putrefaction, because by it micro-organisms were carried from place to place.

Pasteur turned from his studies of crystals and "sick wine" to the causes of diseases in domestic animals. In May and June of 1881, one of most dramatic incidents in the history of medicine took place. Pasteur believed that he could make animals immune to anthrax, a disease then killing thousands of domestic animals every year. His belief was opposed. Finally matters reached such a point that Pasteur was invited to give a public demonstration to prove that he could immunize animals. Pasteur readily accepted the challenge.

On May 5, at the Pouilly le Fort farm, the experimental animals, mostly sheep, were divided into two lots. Twenty-five of the sheep received an injection of five drops of liquid containing the weakened anthrax bacteria. On May 17, the same twenty-five sheep were given a stronger injection. Finally on May 31, all the animals were given inoculations that would, under natural conditions, be fatal. Everyone waited. Pasteur was confident yet uneasy. His friends hoped for his success. The men who had ridiculed his ideas were waiting to laugh at him. But they did not have this opportunity. All the sheep protected by the first two inoculations lived; all the others were dead or dying when Pasteur arrived at Pouilly le Fort farm at two o'clock, in the afternoon of June 2.



A MODERN CONCEPTION OF PASTEUR

Paul Muni, who played the role of Pasteur in the photoplay "The Story of Louis Pasteur," is shown here in that part. Some of the flasks of sterile broth prepared by Pasteur during his lifetime are still on display in the Pasteur Institute. The significance of Pasteur's work makes everything connected with his life of great interest to the world. (Courtesy Warner Brothers and Vitagraph, Inc.)

Before this public experiment was carried out, an editor's notice in the *Veterinary Press* contained this sentence, "These experiments are solemn ones, and they will become memorable if, as M. Pasteur asserts with such confidence, they confirm all those he has already instituted." The outcome of this experiment is more than memorable. If Pasteur had done nothing else, he would have been entitled to an important place in the history of conquering diseases.

Pasteur had helped wine-makers, silk-growers, and farmers; then in 1885, he treated a human being for hydrophobia. All the world knows of his development of the hydrophobia serum. When Joseph Meister, the nine-year-old Alsatian boy, was brought to Pasteur, he might have been just another victim doomed to die from the bite of a mad dog. Fourteen wounds from the dog's teeth could leave no doubt that his body was infected. To work on animals was one thing; to try a serum on a child was a different matter. Pasteur hesitated. He consulted his co-workers. His struggle was with his conscience. Did he have any right to try his serum on a human being? Death was certain, if he did nothing. Death might result in spite of the treatment. At last he decided to try the serum. In her letters to her children, Mme. Pasteur described the sleepless nights that followed after Pasteur began the inoculations.

Joseph Meister lived. He grew up and returned to Paris to work in the Pasteur Institute. A number of years later, when the play based on Pasteur's life by Sacha Guitry was presented in Paris, a silent, middle aged man was found in the wings, absorbedly watching the play. An



JOSEPH MEISTER BEFORE THE STATUE OF PASTEUR

Meister when a small boy was bitten by a mad dog Pasteur, after much serious thought, decided to try a serum that he had used successfully on animals Meister lived and, when he grew up, went to the Pasteur Institute to work This picture was taken at the Institute (*Keystone View*)

outsider had no business back stage, and he was asked who he was. He answered that he was Joseph Meister.

In September, 1895, Louis Pasteur died. His death was mourned throughout the world. The many honors he received during his life are not so important as the fact that his name is known wherever the treatment of diseases has passed beyond the stage of incantations and charms.

Finding a treatment for a few diseases was important, but much less so than Pasteur's theory that each infectious disease was caused by a definite organism. Pasteur was positive of this. However, the work of Robert Koch, his contemporary and often his enemy in scientific fields, gave the world a technique by which the theory was proved.

Robert Koch was born in Klausthal, in the Harz Mountains in Germany, in 1843. He was one of thirteen children. His father, a miner, received such poor pay that black bread and milk formed a large part of the food of the family. There was meat on the table only twice a week, and once a week, on Sunday morning, there was white bread. As a boy, Koch did not even know the taste of sugar.

He received an indifferent education in the local school. As he grew older, the finances of the family seem to have improved. It may have been that his father was given a better position, for at some time in his life he received a title corresponding to that of expert mining engineer, and it is known that his reputation in this field extended beyond the community in which he lived. At any rate, Koch was graduated from the University of Göttingen when he was nineteen. This was the same university at which August Weismann (see page 144)

received his medical training. Koch had hoped to be a ship's doctor, for all his early life he dreamed of traveling. Circumstances did not work out that way; so for a time he served as an interne in a hospital for the insane near Hanover. After this he became a general practitioner in the small town of Rachwitz.

Service in the army during the Franco-Prussian War interrupted his life. When he returned from the war, he settled in the district of Posen. Living here in a rural district where Polish influence was greater than German, he was far away from contact with the scientific thought of cities and universities. Days and nights he rode from one humble farm to another. However, he did possess a microscope, a birthday present from his wife, and he had a curiosity to see things that was nearly as great as Leeuwenhoek's (see page 55).

An epidemic of anthrax among the cattle in the district attracted his attention and set him examining under his microscope specimens from the dead animals. He had heard of Pasteur's work and knew that another Frenchman believed that the rod-shaped bodies in the blood of the sick animals were the cause of this disease.

In a room in his home, a crude laboratory equipped with apparatus he had built himself, he began to experiment. He could not afford to use cattle, so he worked with mice. Holding a healthy mouse in his hand, he would make a cut near the base of its tail. Then with a clean splinter of wood, he would put a drop of infected blood into the cut. Mice so treated soon died. He was not satisfied with this result alone. He wanted to see the rod-shaped organisms multiply, because he knew that the number in a drop of infected blood was infinitely smaller

than the number in an animal when it died. Suddenly, it occurred to him to make a slide with a hanging drop. For a liquid to make the drop he used the fluid from the eye of a recently killed ox. In this he put a fragment of spleen from an anthrax victim. He watched. At first nothing happened. But before long there were more organisms in the field of vision than there had been. In a few hours the mass of rod-shaped cells was greater than the piece of spleen. For anyone who might question that these rods were alive, and there were many doubters, Koch had a visible answer.

Up to this time cultures of bacteria had been grown in test tubes with beef broth or some other liquid as a medium. This method had the obvious disadvantage that one kind of organism could not be separated from another. It happened one day that Koch noticed spots of different colors on a piece of cooked potato that had been lying for some time on his laboratory table. What could this mean? He examined bits from these spots and found that each contained only one kind of organism. Here was a way of isolating different kinds of bacteria! He experimented and found that, when a small amount of liquid containing more than one kind of organism was brushed over the surface of a cooked potato, it was only a matter of a few days until he could find pure cultures. Further work led him to substitute a gelatin medium for the potato. Thus, with a solid medium and the possibility of isolating different organisms, the science of bacteriology really began.

Koch kept on with his microscopic examinations. Before a meeting of the Physiological Society in Berlin on the evening of March 24, 1882, he announced that he



ROBERT KOCH IN HIS LABORATORY

A piece of cooked potato left on a cluttered laboratory table gave Koch the clue to the importance of a solid medium for cultures of bacteria. Koch's table may have been disorderly, but the formulation of his postulates proved that he was systematic in his thinking (*The Bettmann Archive*)

had discovered the bacillus causing tuberculosis. Eight years later he claimed to have discovered a cure for the dreaded disease. By this time, Koch was no longer a general practitioner in a rural community. He was an internationally known scientist. The announcement of a remedy coming from so great a man put courage in the hearts of many sufferers, but in this instance Koch was wrong.

The tuberculin he prepared from filtered glycerin extract of tubercle bacilli did not cure the disease. But his preparation and others that have been developed

since, under the name of tuberculin, are in widespread use in detecting the disease in cattle and human beings.

Besides the actual isolation of bacteria and his improvements in the technique of studying them, Koch outlined a procedure he thought must be followed in the study of disease-producing organisms. The statements of procedure are often spoken of as "Koch's postulates." Koch himself gave Jakob Henle (1809-1885) credit for the origin of the postulates. Henle had been a teacher at Göttingen and was well known in the latter part of the nineteenth century for his *General Anatomy*. From a historical point of view the book is important because it was the first one "based entirely on cytology." The influence of the cell theory as developed by Schleiden and Schwann (see page 68) is seen in it, although Henle did not agree completely with their ideas about cell formation.

Koch's postulates were stated in connection with his study of anthrax. First, the disease-producing germ must be found in the tissues of a diseased animal. Second, the germ must be grown in a pure culture. Third, when this culture is introduced into the body of a susceptible animal, the same disease must be produced. Fourth, the germs causing the disease in the second animal must in turn be obtained. The following of these postulates made possible a rapid advance in the study of organisms causing disease.

During the last fifteen years of his life, Koch had plenty of opportunity to satisfy his desire to travel. In 1896, when a cattle plague was sweeping through the British colonies in South Africa, Koch was asked to go there. He devised effective methods to check the disease.

Two years later he studied malaria in Italy. Ehrlich, one of his students (see page 267), believed that Koch knew before Ross did that the mosquito was actually the carrier of malaria (see page 213).

Two years before his death, Koch went to Japan where one of his former pupils, Shibasaburo Kitazato, was the leading bacteriologist. Kitazato is particularly well known for his discovery of the bacillus causing plague and for his work on tetanus. Koch's reception in Japan was astonishing. Among other acts of homage, a temple was erected in his honor at Kitazato's estate. Everywhere he was "welcomed as a prince."

Science owes more to Koch for his methods than for the discovery of disease-producing organisms. In addition to his development of the solid culture medium, he furthered the use of aniline dyes as stains. In 1891, Koch demonstrated that the filtering of drinking water will, to a large extent, prevent epidemics of water-borne diseases such as typhoid. Five years before his death, in 1910, Koch was awarded the Nobel Prize (see page 153).

While Pasteur and Koch were growing cultures of bacteria on the Continent, Joseph Lister was doing all he could in England to prevent the growth of bacteria in wounds in human beings.

Baron Joseph Lister's parents were Quakers. His father was a well-to-do merchant living in Upton, where Joseph was born in 1827. Lister was educated in two private schools. When about fifteen or sixteen, he began to write essays based on the dissections he had been making for several years on animals. His father, for religious reasons, opposed his son's desire to be a surgeon, but his opposition

was overcome. After completing three years of work in the University College of London, Lister entered a hospital. Two years later he passed the examinations necessary to become a Fellow in the Royal College of Surgeons.

Lister felt that he needed more experience before starting to practice surgery in London. Therefore, he went to Edinburgh, expecting to spend a month observing Dr. James Syme who had the reputation of being "the most original surgeon in the British Isles." Dr. Syme was attracted to Lister and offered him a humble position as his assistant. Although Lister had already earned the rank of a consulting surgeon with the right to practice in London, he did not hesitate to accept this offer. A year later he was advanced to the position of resident house surgeon in the hospital where Syme did his operating. Lister's ability was recognized and the following year he became a lecturer in the College of Surgeons; at the same time he moved into his own offices across the street from Dr. Syme. Between the college in which Lister lectured and the university to which Syme was attached, there was a rivalry of long standing. However, the relationship between the two men was strengthened by Lister's marriage to Syme's daughter, Agnes.

A few years later Lister became professor of surgery in the University of Glasgow. His biographer, Cuthbert Dukes, writes that Lister's lectures were so interesting that the students forgot to scratch the shiny new desks provided for them. What greater compliment could be given a lecturer?

Lister had one great object in his life. That was to be able to cure wounds without having infections set in. The number of deaths following wounds and operations

was appalling. Today one looks back and says, "No wonder so many died." But in those days before bacteria were known to cause blood poisoning, a surgeon could see nothing menacing in the conditions of the operating room. The surgical table was of wood. There was a small washbasin in one corner of the room. The coat the surgeon put on to save his street clothes was indicative of the size of his practice: the more blood stains and dirt, the more patients he had operated on. And where could he find a more convenient place to carry the silk for tying up arteries than in his pocket?

In 1865 a professor of chemistry advised Lister to read about Pasteur's experiments on fermentation. When he did this, he knew that he had found the clue to solve the problem of infection. The first opportunity to test his theory came when an eleven-year-old boy was brought to the hospital. He had been run over by a cart. A bone in his left leg was broken and the flesh cut. Lister soaked a piece of lint in strong carbolic acid and put it over the wounds. The splints were then put in place. If the wounded tissue acted as usual, in four days blood poisoning would be well developed, and the boy would recover only if his body successfully overcame this infection. If his leg had to be amputated, there was a chance of another infection. At the end of four days, anxious days for Lister, the splints were removed. There was no odor of putrefying flesh. The wounds healed, and the boy made a rapid recovery.

Lister continued the use of carbolic-acid dressings for wounds and extended their use to abscesses, which were often fatal in those days. He changed his treatments from time to time, using more dilute acid and different

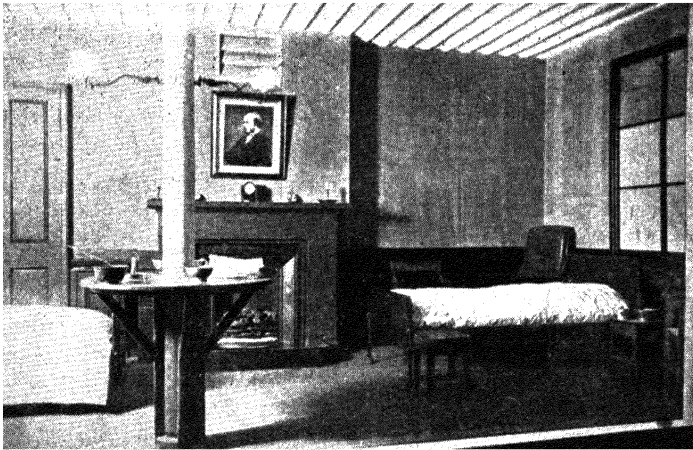
kinds of coverings for the wounds. Later, when he heard that boracic acid would kill bacteria, he used that for some dressings. Now that he knew that the bacteria which entered the wound were to be feared, he began to soak the silk used in tying up the arteries in acid to make it sterile.

It seems almost impossible to believe, but Lister's method met with much opposition in England. In Copenhagen, however, when the results of his work were known, his method was put into practice with much success.

Though no one would condone war for this reason, more than once the care of sick and wounded soldiers has added to the knowledge of physicians. In Germany, during the Franco-Prussian War in 1870, a surgeon treated wounds by Lister's method. One verse of a poem written about Lister at this time is quaint, but expresses a truly thankful spirit for his pioneer work. It reads:

“Mankind looks grateful now to Thee
For what Thou didst in surgery
And Death must often go amiss
By smelling antiseptic bliss.”

When Lister was forty-seven years old, his father-in-law, Dr. Syme, became paralyzed and Lister succeeded him as professor of surgery in the University of Edinburgh. About this same time he introduced to surgery catgut, made from the intestines of sheep, in place of silk. Silk was not absorbed by the tissues and was, therefore, unsatisfactory in operations where the stitches could



THE LISTER WARD IN THE OLD GLASGOW ROYAL INFIRMARY

This is a reproduction of part of the ward in the Wellcome Historical Medical Museum. A picture of Joseph Lister hangs over the mantel. (*Culver Service*)

not be removed when the wound healed. During a holiday at his father's home, Lister chloroformed a calf and tied the ends of some arteries in the neck with this catgut, previously soaked in carbolic acid. Later the calf was killed, and the examination showed that the catgut had been absorbed and healthy tissue had grown in the region.

From 1880 to 1887, Lister was famous for his carbolic acid spray. The spray went through a series of metamorphoses from a hand spray, about the size of a present nose and throat atomizer, to an enormous apparatus operated by a long handle like that of a pump. In this last phase the spray was so large that people on the street could tell when Lister was going to an operation because the handle always stuck out of the window of his carriage.

The purpose of the spray was to keep a mist of carbolic acid around the wound during an operation or dressing. It was annoying to both the doctor and the patient. Lister himself abandoned it after seven years because he found that surgeons who did not use it were having good results, and because he was afraid that the phagocytes, recently discovered by Ilya Mechnikov (see page 277), might be killed together with the harmful bacteria.

In 1877 Lister was called to King's Hospital in London. Accustomed to great popularity in his classes in Scotland, he was hurt by the smallness of the number of pupils who attended his London lectures. The truth of the matter was that the London surgeons would not accept antiseptic surgery. The loyalty of one of his former students is shown by the fact that, whenever he could possibly spare the time from his own work, he went to Lister's lectures to make one more in the audience.

Even if his methods were scorned by the London surgeons, patients from all over the world, who could afford to make the journey, came to Lister for operations.

Lister was always devoted to his wife, who at any time of day or night was ready to act as his secretary. Although he never wrote a book, he published a very large number of papers. After the death of his wife in 1893, Lister was overcome with grief.

To take his mind from his sorrow, his friends had him made secretary of the Royal Society (see page 49), to which he had belonged for many years. From 1895 to 1900 he was president of the Society. Despite the fact that physicians were seldom raised to the peerage, Lister was given this honor in 1897.

By 1907, when he was eighty years old, the medical world had unanimously accepted Lister's ideas that bacteria must be kept out of wounds or destroyed if they had entered them. Progress had gone farther than he hoped. Operating rooms, instruments, dressings, and the clothing of the doctors and nurses were now made sterile. Lister was one of the few fortunate people who sees the dream of a lifetime come true. By the tokens of esteem that were sent him on his eightieth birthday, and by the personal calls of eminent men from England and the Continent, Lister himself was assured of the importance of his contributions in saving human life. He died in 1912 and was buried, as he had desired, beside his wife in West Hamstead Cemetery, London.

A high school pupil today does not realize the revolutionary changes in the treatment and prevention of disease that have occurred since the memorable day when Jenner vaccinated James Phipps. A modern youth is so familiar with the idea that many diseases are caused by micro-organisms that he may not appreciate the significance of the work of Pasteur, Koch, and Lister. The concoctions of the physicians of Charles II may amuse him. The death rate from blood poisoning following operations before antiseptics were used may shock him. But it does not occur to him that if he had lived a few centuries earlier, his physician would have known almost nothing about the true causes and the possible prevention of infectious diseases.

Hints for Further Reading

BROWN, LAWRASON, "Robert Koch," *Annals of Medical History*, VII (March, 1935), 99-112.

GARRISON, FIELDING H., *An Introduction to the History of Medicine.*

HELLMEN, DORIS C. (editor), "An Unpublished Diary of Robert Jenner," *Annals of Medical History*, III (July, 1931), 412-438.

ROBINSON, VICTOR, *Pathfinders in Medicine.*

VALLERY-RADOT, RENÉ, *The Life of Pasteur.*

Malaria, Yellow Fever, and Viruses

ROSS, GORGAS, REED, AND STANLEY

THE prevalence of diseases may hinder the spread of civilization. This has been the case with malaria and yellow fever which have existed for untold generations in tropical and semitropical countries.

Malaria was the first insect-carried disease to be understood fully. The pieces of the puzzle, which when finally put together gave a complete story of the disease, were contributed by several men. The names of Alphonse Laveran and Ronald Ross stand out among the other workers.

Charles Louis Alphonse Laveran was born in Paris, in 1845. His father was a well-known army surgeon whose father had also been a physician. On his mother's side, Laveran could boast that two relatives had been colonels in the French army at the battle of Waterloo.

Laveran entered the military medical school at Strasbourg in 1863. Three years later, when he was graduated, his thesis was on the regeneration of nerves.

For a time he taught at the Val-de-Grace Military Hospital in Paris. In 1878, he was transferred to a military hospital in Algeria. Here he became interested in malaria. On November 6, 1880, while peering through his microscope at a blood sample from one of his patients, ill of the disease, he saw the parasite. Shortly after this he published a small book about parasites he had seen in human blood. A description of the malaria parasite was included in the book, but it received no serious attention at that time.

Laveran had heard that a physician in the United States believed there was some connection between mosquitoes and malaria. He came to the same conclusion and would doubtless have followed up the idea with investigations, but he was recalled to Paris and made a professor in the Val-de-Grace. Teaching and administrative duties piled up, leaving him no time for research work. In 1896 he resigned from the army and joined the small band of enthusiastic workers at the Pasteur Institute. In 1907, when he was awarded the Nobel Prize (see page 153), he contributed a large part of the money to the institute for new buildings. A laboratory for the study of tropical diseases eventually grew from this beginning. Laveran himself discovered many unknown micro-organisms during the years he worked at the institute.

Alphonse Laveran died in May, 1922. On November 6, 1930, a ceremony in honor of his discovery of the malaria parasite was held at the Val-de-Grace by the students and graduates of the school connected with the hospital. A bronze medallion of Laveran was unveiled. The square in front of the hospital was rechristened in his honor.



ALPHONSE LAVÉRIAN

This bronze medallion was unveiled at the time the Municipal Council of Paris gave Laveran's name to the square in front of the hospital where he had been so active. His microscope is on the table (*Keystone View*)

Mme Laveran on this occasion gave the manuscripts of her husband to the school, where they are now cherished.

The hunt for the missing knowledge in the story of malaria was taken up by Ronald Ross. He might never have succeeded, if he had not been influenced by Sir Patrick Manson, an English physician who had lived many years in the Orient. Manson had discovered that a disease of the tropics known as elephantiasis was caused by a parasitic worm. Manson thought this disease was

spread by insects, and he readily accepted the idea that malaria might be spread in the same way.

Sir Ronald Ross was born in India, in 1857. His father, an officer in the English army, was stationed at that time at a post in the Himalayan Mountains. The boy spent his first years in this section of India. Then his father's regiment was ordered to Benares. Ronald's father rode with the troops during this transfer, while Mrs. Ross and the children traveled in a bullock cart. At Benares, Ronald saw his first train and was completely puzzled. He thought that the steam blowing against the wheels made them turn.

Ross was sent to school in England when he was eight. At the age when he was expected to choose a profession, he wanted to be an artist or to join the army or navy. His father, a military man by profession, who spent all his spare time painting Indian landscapes, would not consider either of these choices. He was determined that his son should be a doctor. Therefore, on October 1, 1874, Ronald entered St. Bartholomew's Hospital in London.

None of the courses in the hospital aroused Ross's interest except those in which microscopes were used. During the second year of his work, he hired a piano and spent his time studying music—the compositions of Mozart, Beethoven and Mendelssohn. With equal seriousness he practiced on his grandfather's flute and began several compositions of his own.

In the meantime, he had become a dresser and assistant at the hospital. Here he came in contact with his first case of malaria. He asked the patient so many questions that her anger was aroused, and she left the hospital.

During the winter of 1877-1878, Ross was an assistant house surgeon in a hospital at Shrewsbury. A physician who was a pupil of Lister's (see page 199) was appointed house surgeon at this hospital. The new-comer was anxious to follow Lister's methods in his new position, and, in spite of opposition from two other surgeons, used carbolic acid and sterile dressings. In a week or two the results were so favorable that Ross was completely convinced of the importance of the Lister method.

Ross spent his spare time at Shrewsbury in painting, sketching, and writing poetry. In 1879, the elder Ross began to bring some pressure to bear on his son. He was expecting to retire soon and wanted his son to enter the Indian Medical Service before his retirement. To enter this service, it was necessary for the candidate to pass the examination of the College of Surgeons. Ross, who had never taken the lectures in medical school very seriously, began to study three days before the examination in surgery. A friend who had already spent months preparing for the examination condescended to help him in what seemed an impossible task. Ross passed the examination. His friend failed.

But Ross was not so fortunate in the examination in medicine. He began to study texts at three o'clock in the morning of the very day he was to be examined. He did not have time to read the sections on poisons and their antidotes. The examiner happened to select this topic for questioning, and Ross was lost. His father threatened to cut his allowance, whereupon Ross decided to start out for himself and got an appointment on an Atlantic steamer. He made four or five crossings.

Ross finally passed the necessary examination in 1881 and in the fall sailed for India. The story of the next few years of Ross's life is one of moving from station to station, taking care of the patients in the hospitals, writing poetry, playing the piano, and working on his problems of mathematics and schemes of shorthand writing.

After seven years in India he went home on leave. In England he found the attention of doctors turned to bacteriology. The discoveries of Pasteur (see page 187) and Koch (see page 195) were new. Ross was enough interested to study for a diploma in public health during his leave. Before he returned to India, he married Rosa Bloxam.

By the time of his next leave, in 1894, Ross had made a beginning of his work on malaria. He was interested in mosquitoes for the very personal reason that at some of the posts they had nearly devoured him. Furthermore, interest in parasitic forms was on the increase. The medical papers which he read contained articles by doctors describing what they saw in blood samples from their patients. Some believed they had seen the parasites Laveran had described. Ross thought they were wrong. In fact, he had begun to doubt Laveran's observations, but while he was in England he visited Dr. Manson. The doctor showed him the parasites in some prepared slides and voiced his opinion that mosquitoes were the carriers. In some way Dr. Manson must have inspired Ross, for he returned to India determined to find out all he could about malaria.

The hunt was not so easy as it might seem. In the first place, there are many kinds of mosquitoes in India. In the second place, the malaria parasite goes through a

complicated life history. So complete are its changes that if a person saw the stages separately he might think they were different organisms and not merely different forms of the same organism. The twentieth of August, Ross afterward called "Mosquito Day," for on that day, in 1895, he found what he was searching for. The martyr of the experiment was mosquito No. 38, which four days before had fed on a patient suffering from malaria. It was now killed and dissected. In his *Memoirs*, Ross gives many details of this day. It was hot. In the past weeks he had examined the stomachs of thousands of mosquitoes without finding what he wanted. With little enthusiasm he slid the stomach of mosquito No. 38 under the microscope. What was that? A dark circular object that looked like the pigmented matter in the blood cells of a patient. There were more, many of them in the tissue.

That night he wrote to his wife who was in England, "I have seen something very suspicious in my mosquitoes today and hope it may lead to something." Then he dismissed the matter and told her about the poetry he was writing.

Ross made a guess about the pigmented cells. The guess was not exactly right, but the next day, when mosquito No. 39 gave up its life for the cause, he found that the pigmented masses were larger than those in the mosquito dissected the day before. As both mosquitoes had bitten the patient on the same day, the increase in the size of the pigmented masses meant that they were alive. Ross had discovered two important things at once: the parasites in the body of the mosquito, and the kind of mosquito responsible for spreading malaria.

The next step was to produce cases of malaria under controlled conditions. Experimenting on human beings was not feasible. However, birds were known to have a disease similar to, if not identical with, malaria. So birds became the experimental animals.

On July 9, 1898, Ross wrote to Dr. Manson that he had successfully transmitted the disease from a sick bird to a healthy one by the bites of mosquitoes. The parasite of the bird disease, like the parasite of the human disease, underwent changes in the stomach of the mosquito and then migrated to the salivary glands. When the skin of a bird was punctured by a mosquito after the parasite had reached the salivary glands, some of these minute organisms entered the blood of the healthy bird.

The following year Ross returned to England and became connected with the Liverpool School of Tropical Medicine. The school was formally opened in April, 1899, by Lord Lister, who was then president of the Royal Society. After the opening, Ross made a short trip to Paris. At the Pasteur Institute he met Laveran for the first time. Ilya Mechnikov (see page 278) was also working there. Ross, always a hero-worshiper, was thrilled that Lister and Laveran should unquestionably accept his conclusions about malaria.

Having discovered how malaria was spread, Ross felt that the authorities lagged in wiping out the disease. He made a trip to Freetown in Africa during 1899, conducted experiments and tried to interest the local authorities in destroying the breeding places of mosquitoes. The authorities did not respond as he had hoped. Two years later, financed by an interested individual, Ross sailed for Africa with barrels of cement to fill up



SIR RONALD ROSS

In 1895 Ross, who was then working in India, proved what several men had suspected about the transmission of malaria. Not only did he follow the development of the parasite in the body of the mosquito, but also he determined the kind of mosquito which was a carrier. After proving how malaria was spread, he realized at once the necessity of destroying the breeding places of these insects. (*Acme*)

depressions where stagnant water collected, with shovels and pickaxes to dig drainage ditches in swamps, and with oil sprays and insecticides. These plans met with more success. But by this time, the world was becoming mosquito conscious, and war had been declared on these disease-spreading insects in many parts of the world.

In 1902, Ross received the Nobel Prize (see page 153). Two years later he attended the World's Fair in St. Louis, where he read a paper before a group of distinguished physicians. Unfortunately, at this time Ross was in the midst of one of his periods of absorption in mathematics, and the paper he read was so full of calculations that it was over the heads of his audience.

While on this continent, at the invitation of William Crawford Gorgas, Ross took a trip to the Canal Zone. There he could see one of the greatest achievements in the construction of the canal, the eradication of disease-carrying insects.

Ross continued to work on the control of mosquitoes. He visited many places where their extermination was being undertaken. During the World War he visited the troops at Alexandria and Salonika. He had been made a lieutenant-colonel in 1913. Five years later he was made a colonel and remained in service until 1919.

After the war he devoted a great deal of time to the treatment of soldiers who had contracted malaria while in service. *Memoirs*, which contains a full account of the problem of malaria, interspersed with poetry and the ideas for other writings, was published in 1923.

Ronald Ross died in 1932. For the part he played in the control of malaria, he received honors from many

countries. His poetry and fiction, so dear and important to him, never received the appreciation he thought they deserved and are now practically unknown.

The names of Laveran, Ross, and Manson are not the only ones that should be connected with the conquest of malaria. In Italy, Giovanni Grassi (1854–1925), who was a professor of zoology in Rome, carried on important investigations. The swampy regions in Italy had been shunned for centuries because of the prevalence of malaria. In 1900 Grassi went to Capaccio where he was given complete authority over a group of railroad employees and their families. In all, they numbered about 120 people. He had the houses screened, and ruled these people with a combination of military authority and bribes to keep them from being bitten by *Anopheles* mosquitoes. The Queen of Italy furnished the money for the experiment. Some of the money was used as prizes to keep the people inside their screened houses during the nights when the *Anopheles* were buzzing about in swarms. Only five of the group under Grassi's care contracted malaria, while in a near-by village of about the same population, where no precautions were taken, nearly every inhabitant had an attack.

While the battle against malaria was being fought in Europe and Asia, a similar battle against yellow fever was waged in America. The results of the campaign against yellow fever have been incorporated in the history of this country, so that every school child is familiar with the names of Reed, Lazear and Gorgas.

Dr. Walter Reed and Dr. Jesse William Lazear, together with Dr. James Carroll and Dr. Aristides Agramonte, were the officers of the Yellow Fever Com-

mission in Cuba, in 1900. Dr. William C. Gorgas was already there as chief sanitary officer in Havana.

Walter Reed was born in Gloucester County, Virginia, in 1851. He spent the first few years of his life on a farm. When he was about ten, the Civil War began. Soon after the close of the war, the Reed family moved to Charlottesville, Virginia. Here Walter attended a private school for a year and at sixteen entered the University of Virginia. Special permission had to be gained for him because he was so young. Since two of his older brothers were also in the university, the matter of expense became a difficult problem. Walter took matters into his own hands. He asked the faculty whether he could receive a degree in medicine, if he could pass the examinations. The faculty promised lightly enough, for they thought such a feat impossible. Nine months later, before he was eighteen, Reed had completed his studies, passed his examinations, and had come up for his degree. There was nothing for the surprised faculty to do but grant the degree. It had been no easy accomplishment for Reed. Three or four hours of sleep were all he allowed himself during the time of his preparation.

Reed then went to Bellevue Hospital, New York City, where a year later, he received a second degree in medicine. The next few years he spent as an interne in hospitals in and near New York. Later he became a district physician in one of the poorest sections in New York City. Next he served as a member of the Brooklyn Board of Health.

In 1874, Reed decided to give up the idea of general practice and to enter the medical corps of the army. He studied hard for the examinations and passed them in

1875 The following year, after serving in New York Harbor, he was sent to Fort Lowell, Arizona.

Those were real frontier days in the West. Fort Lowell was seven hundred miles from a railroad. Mail came but once a week. Travel was by horseback or wagon over almost impassable roads that ran through miles of uninhabited country where unfriendly Indians might be lurking. From Fort Lowell, Reed was sent to Camp Apache. The Indians there became staunch friends of the doctor.



WALTER REED

Dr. Reed was head of the Yellow Fever Commission that was sent to Havana in 1900 (*Keystone View*)

Ten years before he was sent to Cuba, Reed went to Baltimore to study bacteriology at Johns Hopkins University. Because recent formulation of the germ theory of disease was revolutionizing the practice of medicine, Reed wanted to be abreast of the times. After the completion of his studies, he was sent to Dakota and soon after recalled to Washington to teach bacteriology in the United States Army School. The following year he was sent to Havana.

When Reed arrived in Cuba, the yellow-fever situation was very puzzling. Gorgas (see page 227) had been sent to Havana two years before and had set to work cleaning up the city. To the surprise of those interested

in sanitation, the number of cases of yellow fever increased rather than declined. Filth, evidently, was not a contributing cause to the prevalence of the disease. As to the way in which it spread, two opinions were held. Many people thought that it could be contracted by contact with the clothing and bedding used by a sick person, or from the patient himself. But Reed noticed that nurses who took care of the yellow-fever patients seldom contracted the disease, even though they were not immune. What other way could the dreaded disease be spread? Some people, and among them Dr. Carlos J. Finlay, believed that mosquitoes transmitted the disease from one person to another.

As early as 1881, Finlay had read a paper before a group of people in Washington in which he stated his belief that mosquitoes were responsible for spreading yellow fever. Unfortunately, he had been unable to prove his theory, although he and others were firmly convinced of the correctness of his belief. The possibility that he was right was strengthened by the work of Ross in India.

When the Yellow Fever Commission was sent to Havana, it went determined to leave no stone unturned in its search for the cause of yellow fever and for preventive measures to control it.

After studying all angles of the problem, Reed and the other members decided that the only way by which they could prove anything was to try to transmit the disease from one person to another by means of mosquitoes. If this could be done, they would know what to do as a next step in the control of the disease. If it could not be done, they would have to begin a new line of experi-

mentation. Accordingly, mosquitoes were caught and allowed to bite patients fatally ill with yellow fever. Then these insects were kept for about two weeks, for it had been found from observation that about two weeks was the usual time elapsing between cases in one household.

When the period of waiting was up, what was to be done next? Human beings were needed, and Dr. James Carroll, a member of the commission, was one of the men who volunteered to be an "experimental animal." Dr. Carroll contracted the disease. He was the first person to contract it during a controlled experiment with mosquitoes. It must be mentioned that Finlay and others, who thought insects were responsible for the spread of yellow fever, had tried much the same experiment, but they had not waited long enough between the time the mosquito bit a patient and the time it took another meal from a healthy person.

James Carroll nearly died. A private in the army was bitten by the same mosquito that had bitten Carroll and by four other mosquitoes which had been fed on the blood of the fever patients. He contracted the disease. Fortunately, he also recovered. But all the experiments did not come to such a happy conclusion, for Dr. Lazear was a victim of the fatal disease he was trying to conquer. While feeding mosquitoes on patients in the yellow-fever ward, he was bitten on the hand, not by one of the experimental insects, but by a free one that happened to be in the ward.

To less scientifically-minded men, it would have seemed that the problem of the spread of the disease had been solved. But no. Reed and the others kept on, for they could see that, so far, the work was indicative

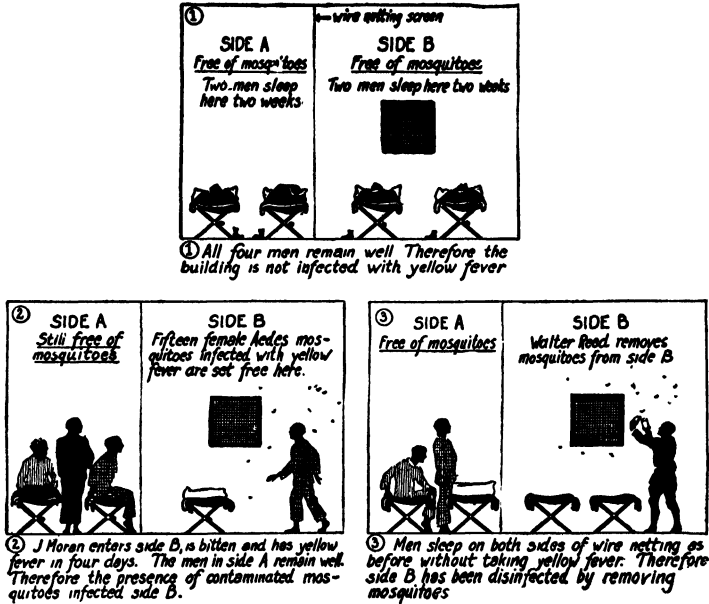


DIAGRAM OF THE FAMOUS EXPERIMENT AT CAMP LAZEAR

This experiment proved beyond a doubt that yellow fever is transmitted by mosquitoes. (Courtesy Metropolitan Life Insurance Co.)

rather than conclusive. Carroll, Lazear, and others who seemed to have contracted the disease from the bites of the mosquitoes might have been exposed some other way. The idea that the clothing and bedding of yellow fever patients was dangerous still persisted and must be proved correct or incorrect.

What was the next thing to do? A series of more rigidly controlled experiments must be undertaken. For this purpose the now famous Camp Lazear was constructed. Briefly, the experiment was as follows: John Kissenger and James Moran, who were willing to be "experimental animals," were kept away from all cases of yellow fever

long enough to show that they had not contracted the disease. At the end of that time they were bitten by infected mosquitoes. Kissinger contracted the disease and recovered. So far so good. Kissenger had not gotten the disease from another source, or he would have been taken ill while he was in quarantine. The mosquitoes had transmitted it to him.

Now Reed and his associates turned their attention to the possibility of infections from soiled bedding and clothes. But although men packed and unpacked the soiled linen and clothes of soldiers who had died with the fever and even slept in the filthy linen, in a hot, poorly-ventilated house that had been built for the experiments, nothing happened. Could it be that they were immune? Reed and Carroll soon settled that; for, when their men were bitten by infected mosquitoes, they came down with yellow fever.

One more experiment was necessary. A second house was built not far from the one where the men had slept in the soiled linen. This was clean, well-ventilated; the bedding was sterile. A wire screen of very fine mesh divided the house into two rooms. Into one room a number of infected mosquitoes were introduced, and then Moran, who had volunteered with Kissenger but had not contracted the disease, came in. He had had a hot bath just before entering the room, and he wore a freshly laundered nightshirt. On the other side of the screen were two men who were not immune and no mosquitoes. Moran was bitten and subsequently contracted the disease but recovered. The finger of guilt pointed to the mosquitoes and the mosquitoes only as the carriers of the dread disease.

When Dr. Reed's work in Cuba was finished in 1901, he resumed his work in the Army Medical School. He was a very successful teacher, and his associates expected him to add many more successes to his career. But in November, 1902, he was stricken with appendicitis, and in spite of all that could be done for him, he died following a difficult operation. The Walter Reed Veterans Hospital in Washington is a lasting memorial to his name.



JESSE LAZEAR

Dr. Lazear, a member of the Yellow Fever Commission, died of yellow fever during the experiment (*Science Service*)

Jesse William Lazear, the member of the Yellow Fever Commission who lost his life during the early stage of

experimentation, was born in Baltimore, in 1866. His education was thorough. After being graduated from Johns Hopkins University, he studied medicine in Columbia University and then spent two years in Bellevue Hospital, New York City. This was followed by a year's residence in Europe. Part of the time in Europe was spent at the Pasteur Institute. When he returned from abroad, he joined the medical staff at Johns Hopkins as a bacteriologist.

When Lazear was very ill with yellow fever, he told Gorgas how he had been bitten by a mosquito that did not belong to the experimental lot. Knowing the danger of allowing himself to be bitten, he let the mosquito

remain on his hand and suck the blood. He recognized it as an *Aedes*. Lazear lost his life as a result of his courage. He was only thirty-four years old.

In Johns Hopkins Hospital there is a memorial tablet to Jesse Lazear. Part of the inscription reads:

“With more than the courage and devotion of the soldier, he risked and lost his life to show how a fearful pestilence is communicated and how its ravages may be prevented.”

It has been mentioned that William Gorgas preceded Reed to Havana and had made excellent progress in cleaning up the city, but that this clean-up did not reduce the number of yellow fever cases.

The discoveries of Reed and his associates gave his work a new impetus and a new direction. Havana, under his supervision, was eventually changed from one of the most dreaded ports in the Western Hemisphere to one of the healthiest.

William Crawford Gorgas, who became one of the greatest advocates of sanitation in the world, was born near Mobile, Alabama, in 1854. His father, a West Point graduate, had married the daughter of Governor John Gayle of Alabama while he was stationed in the South. From that time on his sympathies were with the South. At the time of the Civil War he whole-heartedly supported the cause of the Confederacy.

At an early age William Gorgas showed that he was a fighter. On one occasion when he was a small boy, he held the rest of his classmates at bay by hurling slates at them. His sister loyally kept him supplied with these missiles.

When the Civil War broke out, William's father was made Chief of Ordnance for the Confederate forces. William was, of course, too young to do anything to help the cause, but he went barefooted during one winter to show his sympathy for the poorly-provisioned soldiers.

At the close of the Civil War, the elder Gorgas worked with his hands at what he could find to do until he was appointed head of the University of the South at Sewanee.

William's plans for his own life were influenced by the example of his father and the stories of army life he told. The boy's greatest desire was to go to West Point. Appointments to West Point are political, and so many had been promised in advance that William reached the age limit of twenty-one without having a chance to enter the military school. The next best thing seemed to be to study medicine and enter the army as a doctor. With that in mind he went to Bellevue Hospital, New York City, in 1876, and was graduated four years later.

Following his graduation he served at posts in Texas and North Dakota. In 1898 he was sent to Havana. The unsanitary conditions in that city are graphically described in a biography of Gorgas: "The city which now came under Gorgas's jurisdiction was little better than a cesspool. Unspeakable odors assailed one everywhere; streets were filled with decaying vegetables, dead animals, miscellaneous sewage, and refuse of all kinds. . . . Many sick could find no place of refuge and lay stricken in the streets."* Gorgas determined at once to clean up the city.

* GORGAS, MARIE D., and BURTON J. HENDRICK, *William Crawford Gorgas; His Life and Work*. New York: Doubleday, Doran and Co., Inc., 1935. P. 82.

But, as we have seen, the yellow-fever cases increased as the city became cleaner. Today we know the reason for this apparently contradictory situation. In the years 1898–1900, there was a large migration of Spaniards to Cuba. The natives in the poorer quarters of Havana were immune to yellow fever because most of them had had it in childhood. The influx of people who were not immune caused the rapid increase of the disease.

When it was definitely proved that the *Aedes* mosquito was the carrier, Gorgas undertook the extermination of this insect. The *Aedes* lives near habitations. Barrels, tin cans, jars, and dishes that contain water are selected by the female as a place for depositing eggs.

For every household the workers made out a card on which were listed the vessels that might be used for water. When the households were inspected, every vessel must be accounted for. Until the importance of the eradication of the pest was understood, it is no wonder that the natives thought the doctors from the United States had lost their minds. No one was exempt from inspection; hotels and private dwellings of the wealthier class alike came under the watchful eyes of the workers.

Gorgas began his work in March, 1901. In that year there were eighteen deaths from this fever in Havana. In the three following years there were no deaths. Compare this with the more than twelve hundred deaths in 1896, and nothing further needs to be said about the effectiveness of the method of control. At the same time the death rate from malaria dropped, for the *Anopheles* mosquitoes were being exterminated with the *Aedes*.

When the United States undertook the building of the Panama Canal, one of the greatest problems was



WILLIAM C. GORGAS

The Panama Canal Zone was changed from a disease-ridden to a healthful region under the direction of Gorgas (*Keystone View*)

that of sanitation. The French had lost twenty thousand men from disease in the eight years they spent attempting to build a canal across the isthmus.

Gorgas was sent to Panama. At first red tape and unsympathetic officials handicapped his work. However, before the canal was finished, malaria and yellow fever were practically wiped out of the Zone. Gorgas believed, and eventually proved his point, that army sanitation should be a science by itself and that men trained in this work should not be subjected to control by military men whose job it is to plan actual fighting and movement of troops.

Gorgas was very popular with the workmen at the Zone. He had a quick and ready sense of humor. One day a man ill of typhoid was brought to a ward in the Ancon Hospital. Gorgas happened to be there. The man was assigned to bed No. 13. When he saw the number, he turned to the doctor and told him with pathetic seriousness that he could never get well in a bed with that number. Gorgas did not argue that superstitions were foolish. He turned to an orderly and told him to renumber the bed and make it twelve and a half.

When his work was completed in Panama, Gorgas went to Rhodesia in Africa to study the problems of sanitation there. While he was in Africa, President Woodrow Wilson raised his rank to that of a general.

During the World War, Gorgas was a surgeon-general, and the great efficiency of the medical corps reflects his ability as an administrator. Three days after the Armistice was signed, he retired from his post because he was past the age limit. He was now recognized as the authority on yellow fever by the International Health

Board. This board intrusted him with the task of eradicating the disease in those places in the world where it was still prevalent. When he was sixty-six, an outbreak in Senegal and Belgian Congo assumed such importance that Gorgas started for Africa.

In London he had a stroke of paralysis. The King of England demonstrated the great regard held for this American by visiting him in the hospital and conferring upon him the insignia of Knight Commander of the Most Distinguished Order of St. Michael and St. George. Soon after this, Gorgas died in London. His funeral ceremony in St. Paul's Cathedral was that of a British major-general, the greatest honor that could be given to a citizen of the United States. His body was brought to Arlington for burial.

Nine years after his death, in 1929, a laboratory for the Gorgas Memorial Institute of Tropical Research and Preventive Medicine was dedicated in Panama.

Although the extermination of mosquitoes brought most gratifying results in decreasing yellow fever in definite areas, no scrums or immunizing methods could be developed until the cause of the disease was known. Since malaria, transmitted by the *Anopheles* mosquito, was caused by a protozoan, it seemed reasonable to expect that yellow fever might also be caused by a protozoan.

In 1918 the Japanese scientist, Hideyo Noguchi, believed that he had found the organism that causes yellow fever. Experimental work during the next few years, however, seemed to discredit this discovery. By 1925 it was suspected that a filterable virus was the excitant. Today at the laboratories of the Rockefeller Institute

for Medical Research, methods of immunization against yellow fever are being worked out. It had been found possible to reduce the virulence of the virus by growing it in tissue cultures. The organism found by Noguchi is now believed to be the cause of a type of jaundice very common in South America. The presence of this parasite in the blood of a patient makes it possible to recognize the disease. This is important because the symptoms of patients with this type of jaundice and with yellow fever are very much the same.

The fact that yellow fever is now believed to be caused by a filterable virus and not by a protozoan should not mar Noguchi's reputation as a microscopist. He was born in Inawashiro, Japan, in 1875. His father never took much responsibility for his family. In order to keep her children provided with food, Noguchi's mother worked in the rice fields in the day time and fished late into the night.

In the homes of the poor in Japan, a round hole is made in the center of the earth floor where charcoal is burned. When Noguchi was about three years old, his mother left him playing on the floor while she worked in the fields. In some way he rolled into this hole, and his left hand was cruelly burned. The burns healed, but the hand was deformed. As he grew older, the boy became more and more sensitive about his deformity, hiding his hand in the sleeve of his kimono and avoiding games with other children.

Then one day a doctor saw the hand and performed an operation that made it less repulsive to look at and gave the boy the use of the stubs of his fingers. Noguchi decided during the operation to become a doctor himself



HIDYO NOGUCHI

The Japanese scientist made important contributions to medical science by his study of Protozoa (*Science Service*)

and offered his services in payment for the operation. He began his preparation for his chosen career as a drug boy for his doctor friend. Fortunately for Noguchi, the doctor owned many books. The youth learned to read French, English, and German in his spare time and at night when he should have been sleeping. One day while he was still a drug boy the physician, Dr. Kanae Watanabe, called him to look through a microscope. Noguchi made up his mind at that moment to be a bacteriologist.

Noguchi could not select a goal and then work directly toward it, for he had no money, and in order to get any education he had to take advantage of the opportunities that presented themselves to him. Eventually, he went to a dental school in Tokyo. To pay his way, he cleaned

lamps and rang bells between classes; that is, when he could remember, for he often became so absorbed in reading at the library that he was unconscious of the passage of time. In 1896 he entered the medical school in Tokyo. About this time, as was the custom in his country, he took a new name "Hideyo" by which he is always known. "Hide" means superior or eminent, and "yo" means world. Thus, together the name might be translated as "Great-man-of-the-world."

All the time he was in school he dreamed of going to America, but could find no way to raise the money. After his graduation, an opportunity came for him to go to China as a quarantine officer. He had no money to pay for this trip, but a loyal friend sold his bride's wedding kimono and gave him the money. Every minute of the time on the boat he spent in the hold learning Chinese from the coolies.

The work in China did not last long. He returned to Japan more heartsick than ever because he could not go to America. Again, a friend raised the necessary money. Hideyo, full of enthusiasm, went to Yokohama to buy his passage. Then he thought that his departure for America should be celebrated. He gave a party, spent his passage money, and returned to his friend asking for another chance. This time he was given only enough for steerage passage. Noguchi's friends in Japan and the United States deserve a great deal of credit for the patience they had with this brilliant, though temperamental, person.

At last in America, in 1901, Noguchi went to the University of Pennsylvania where Dr. Simon Flexner (see page 270) became interested in him and found a patron, Silas Weir Mitchell, for him. For a number of

years, Mitchell had been interested in the poisons of snakes, and Noguchi was set to work on them. Fame came quickly. Before a year had passed, he gave a demonstration of these poisons before the National Academy of Science in Washington.

In 1904, Dr. Flexner, who was now the director of the newly founded Rockefeller Institute for Medical Research, selected Noguchi as a laboratory worker. At that time both men were interested in snake venoms. Noguchi's interest soon centered in pathological microorganisms. He improved the technique of bacteriology in several ways. He was the first person to grow a pure culture of the spirochaete causing syphilis.

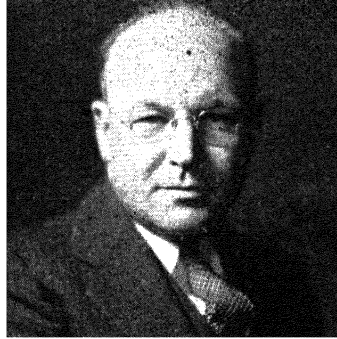
Noguchi did not spend all his time in the laboratory in New York. He made trips to localities where yellow fever was occurring. One of these trips took him to Ecuador. While studying yellow fever in Africa, in 1928, Noguchi contracted the disease and died.

As has been said before, yellow fever is now listed among the diseases produced by a virus. There is as yet no definition for a virus that is accepted by all scientists without question. Since 1932, however, the work of Wendell M. Stanley on the tobacco mosaic disease has focused much attention on viruses.

The virus theory of disease is even younger than the germ theory of disease. The tobacco mosaic, a disease affecting the leaves of tobacco plants, was the first disease to be recognized as a virus disease. In 1892 a Russian scientist, Dmitri Iwanowski, found that whatever it was that caused the mosaic disease was so minute that it passed through a Chamberland porcelain filter. Since bacteria and protozoa that are visible with a

microscope will not pass through this filter, the disease-producing elements must be very minute, indeed.

Four years after Iwanowski made this observation on the tobacco-mosaic disease, Friedrich Löffler, known as the discoverer of the diphtheria bacillus, found out something puzzling about the hoof and mouth disease in animals. He took serum from animals suffering from hoof and mouth disease. Examined under the microscope, this serum showed no bacteria, but when it was



WENDELL M. STANLEY

Stanley's work on viruses may mark the beginning of a new era in the prevention and cure of certain diseases (*Wide World*)

injected into a healthy animal, symptoms of hoof and mouth disease appeared. Before long it was discovered that many diseases could be transmitted in a similar way.

What were the invisible substances? They might be submicroscopic bacteria or protozoa. They might be chemical substances. Some investigators supported one supposition; some, another. The work of Stanley indicates that the tobacco-mosaic disease, at least, is caused by a protein substance.

Wendell M. Stanley was born in Ridgeville, Indiana, in 1904. He was graduated from Earlham College in 1926. Three years later he received his Ph.D. from the University of Illinois, where he had specialized in organic chemistry, physical chemistry, and bacteriology. In 1930 he went to the University of Munich where he

did research work in chemistry. Upon his return to the United States, he assisted Winthrop John Vanleuven Osterhout in his development of the artificial cell at Rockefeller Institute.

In 1932 Dr. Flexner (see page 270) wanted a chemist to work on the virus problem. Up until that time most of the research work on viruses had been carried on by biologists. Dr. Flexner felt that Stanley was qualified for the work; so the latter began his study of tobacco-mosaic disease at Princeton, N. J., where the institute has facilities for experimentation on plants.

Stanley succeeded in isolating a crystalline protein substance of high molecular weight which has the same effect on healthy plants as has the juice from diseased ones. In comparison with other protein molecules, this is described as being a giant. To a chemist the size may seem very impressive, but to the layman it does not, for this molecule is estimated at about one fourteenth the diameter of the smallest bacteria.

Viruses may be borderline substances between living and nonliving matter. The protein of the tobacco-mosaic disease crystallizes in needle-shaped crystals. When a very dilute solution of this material is used, the amount of poisonous protein increases in the plant. This increase in the number of molecules seems to be like reproduction. Another characteristic of the protein which makes it like a living organism is the ability to mutate.

On the other hand, it is not improbable in the least that when the substances or organisms, now included under the broad term of virus, are isolated and identified, they may represent living, nonliving, and border line matter. In other words, there are scientists who believe

that the term virus now includes micro-organisms that have never been seen; micro-organisms that are partially degenerate, that is, have become parasitic on certain types of cells; and chemical substances which do not possess any of the peculiar properties of living matter. The study of viruses presents a fascinating problem to biologists and chemists at the present time.

The importance of Stanley's work is far-reaching, because about forty diseases common to man and domesticated animals are believed to be caused by viruses. A more thorough understanding of viruses will lead to better immunizing methods, just as the discovery of bacteria and protozoa led to effective means for preventing and controlling many diseases caused by them.

Hints for Further Reading

- BUCHBINDER, LEON, "Yellow Fever, a Filterable Virus Disease," *Archives of Pathology*, X (Oct., 1930), 598-605.
- "Professor Laveran," *British Medical Journal*, I (June 17, 1922), 979.
- STANLEY, W. M., "Isolation of Crystalline Protein, Possessing the Properties of Tobacco-Mosaic Virus," *Science*, LXXXI (June 28, 1935), 644-645.
- , and H. S. LORING, "Isolation of Crystalline Tobacco-Mosaic Virus Protein from Diseased Tomato Plants," *Science*, LXXXIII (Jan. 24, 1936), 85.
- RELEASE, SAM F., "Award of the American Association Prize to Dr. Stanley," *Scientific Monthly*, XLIV (Feb. 1937), 193-195.

Ticks, Worms, and Insects

SMITH, STILES, AND HOWARD

THE study of the causes and spread of diseases that has been carried on since the middle of the nineteenth century has brought to light some strange relationships among the organism that causes a disease, and the carrier of this causative organism, and the organism that is affected. For example, bacteria and protozoa may be blamed for a large number of diseases. Mosquitoes and flies transmit many diseases. However, the causes and spread of all diseases cannot be traced to the organisms mentioned, nor to viruses, whatever research may prove them to be. Worms and ticks are also serious menaces to health.

Insects not only carry diseases to plants and animals, but they rival man for his food supply; and since they may destroy enough vegetation to cause a famine, they are of tremendous economic significance.

Three men who were pioneers in the study of ticks, worms, and insects are Theobald Smith, Charles Wardell Stiles, and Leland Ossian Howard. Each was at some time connected with the United States Department of Agriculture.

The United States Department of Agriculture has cause to boast of the fact that Theobald Smith had been connected with it. A few months after his death, it was written of Dr. Smith: "It is certain that America in days to come will look on him with that veneration with which France cherishes the name of Pasteur, and Germany that of Robert Koch."* That statement may seem extravagant, for Smith's name is not well known outside scientific circles, except in connection with Texas fever, which was only one of the many subjects he investigated.

Theobald Smith was born in Albany, New York, in 1859. His parents had come to the United States from Germany, about 1850. His father's name was originally Schmidt. In Albany the father conducted a small tailoring shop. From his mother, Smith inherited a love for music and became a skillful pianist. He was eighteen when he was graduated from high school. As high school graduates do today, he took examinations for a State scholarship and was successful. He entered Cornell University, where he was recognized as an unusually brilliant student. His brilliant record was made in spite of the fact that he had to spend part of his time earning his living. One of his sources of revenue came from playing the chapel organ.

Smith expected to teach after he obtained his degree. However, since he did not find a position at once, in 1881 he entered the Albany Medical School. Two years later he was graduated and then returned to Cornell for graduate work.

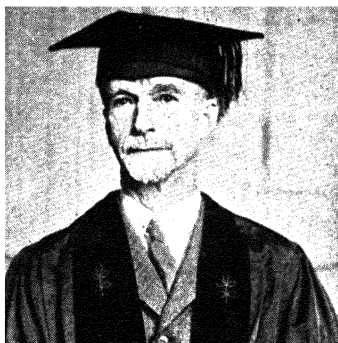
* *Journal of Pathology and Bacteriology*, May, 1935, 621-635.

In 1884 Smith was called to Washington to work on diseases in domestic animals. He did not feel that his training in bacteriology and pathology was adequate for his position. To make up for his deficiency, he studied by himself, using the papers of Pasteur (see page 187) and Koch (see page 197), which were opening up a new era in medical history. It was not long before Smith became the director of the pathological laboratory in the Department of Agriculture.

In an article written by Dr. Earl Baldwin McKinley, Smith's interests are divided into periods. His first interest, beginning in the year he went to Washington and continuing until his death, was tuberculosis. Undoubtedly, this interest was a direct result of reading Koch's articles, for the German scientist had discovered the tubercle bacillus in 1882. Smith was particularly interested in tuberculosis in cattle, and the relation that this disease might have to human beings who used milk and meat products from tubercular animals. After years of study, he came to the conclusion that human beings may become infected from cows, but that the danger of infection from one human being to another is greater.

From 1885 to 1899, Smith worked on diseases of domestic animals, such as swine plague, hog cholera, and Texas fever. It is in connection with the latter disease that Smith's name first became known. In a biographical memoir, the author, Hans Zinsser, emphasizes the fact that Smith was not a lone worker on this problem. He started with the practical knowledge common to cattle men, and other scientists interested in the disease cooperated with him. However much help Smith received, the fact remains that his part was an important one.

Texas fever was of great economic importance to cattle raisers in the South because of the high death rate among the animals. It was brought to northern cattle by those shipped from the South. One of the facts noticed by cattle men was that northern cattle could contract the disease if they were put in pens where southern cattle had been. In a hazy way many practical men believed that there was a relation between the cattle ticks and the disease. It must be remembered that Smith and his associates began to work on this problem before it had been proved that any disease was spread by insects or their near relatives, the ticks. Experiments were carried on. Animals with ticks were placed in a pen with northern cattle. In another pen animals from the South, from which the ticks had been removed, were placed with northern cattle. Cattle were also put to graze in fields where ticks had been scattered on the ground. The results of these experiments pointed to the ticks as carriers.



THEOBALD SMITH

Smith, who is widely known for discovering the cause of Texas fever, was also a pioneer investigator in the study of immunology (*Wide World*)

It must be remembered that Smith and his associates began to work on this problem before it had been proved that any disease was spread by insects or their near relatives, the ticks. Experiments were carried on. Animals with ticks were placed in a pen with northern cattle. In another pen animals from the South, from which the ticks had been removed, were placed with northern cattle. Cattle were also put to graze in fields where ticks had been scattered on the ground. The results of these experiments pointed to the ticks as carriers.

In 1891, Smith found a protozoan in the blood of sick cattle. Eventually, the whole story was worked out. These protozoa destroy the red blood corpuscles. Normally, there are between five and six million red corpuscles in a cubic millimeter of blood. In the blood of cattle suffering from Texas fever, the rate of destruction

of these cells is so great that there may be less than two million in a cubic millimeter. The ticks proved to be the hosts of this protozoan, and by them it was carried from one animal to another. Further study of the relationship of the protozoan and the tick brought to light a curious fact. A tick infected by protozoa can pass the infection on to its offspring.

After the cause of the disease was known, a plan to eradicate it was worked out. Two methods have resulted in considerable success. Cattle are dipped in vats containing a solution harmless to them but deadly to the ticks. A system of pasture rotation has also been used in many places. The ticks will eventually starve, if they do not find a host. Therefore, after using a piece of land for pasturage, stock is not put on it again until the ticks have died. In 1906 there were fifteen states under quarantine for Texas fever. By 1930 only parts of five states were still quarantined.

In 1895, Smith left Washington and went to Boston as director of the State Antitoxin Laboratory. The following year he also became a professor of comparative pathology at Harvard. This position was created for him. The period from 1896 to 1915 is marked by his contributions to the knowledge and control of diseases in human beings. He standardized the production of small-pox vaccine and of tetanus and diphtheria antitoxins. This work naturally led him to the consideration of immunity, which he continued to study until his death. His contributions to the understanding of this phenomenon were many and important.

In 1914, Smith accepted the directorship of a branch of the Rockefeller Institute in Princeton, established to

study animal diseases. Thirteen years before, when the Rockefeller Institute for Medical Research was new, he had been asked to consider the directorship, but had refused. Administrative duties worried him, and at that time he "was suspicious of organized research." However, by 1914 he had changed his opinion. At Princeton, Smith did a great deal of work on the subject of parasitism in animals.

Theobald Smith was a very productive writer. Approximately 250 articles and bulletins appear in his bibliography. For his discoveries in the study of diseases the name of Theobald Smith will become better known. As a teacher, he was a great inspiration to the men investigating the all-important problems of bacteriology and pathology. Theobald Smith resigned from the directorship of the Princeton branch of Rockefeller Institute in 1929. He died in 1934. The large number of articles which appeared in the scientific journals in the few months following his death show the high regard in which he was held by fellow scientists.

Theobald Smith was the recipient of many honors. One of them was the Copley Medal of the Royal Society of London (see page 153). This award is probably the most prized one that a man of science may receive.

While Theobald Smith was studying parasitism in animals and man, Charles W. Stiles was conducting a battle against the hookworm, a parasite that exists throughout large areas of the world.

Charles Wardell Stiles was born in Spring Valley, New York, in 1867. Both his father and grandfather were Methodist ministers, and they hoped that Charles would carry on the family tradition. When Charles was a boy,

Sunday amusements were considered unchristian. The three things he was allowed to do were to sing hymns, visit the cemetery, and read the Bible. Since he had learned French when very young, for variety, Stiles read the Bible in French. When he had mastered this, he read it in Latin, Greek, German, and Italian. By the time he was a pupil in the high school at Hartford, Connecticut, where his family had moved, he was an exceptional student of languages.

It was his week-day interests, however, that shaped his career. He was an untiring collector and dissector of insects, frogs, worms, and the small animals he could find. Once he found a dead cat in a vacant lot and smuggled it home, expecting to mount the skeleton. But while he was waiting for the flesh to be cooked so he could remove it, his attention was called elsewhere. The water boiled out, and both the cat and his mother's kettle were ruined.

In 1885 Stiles entered Wesleyan College where he stayed for a little over a year. Then he went to Europe, where he studied in the Collège de France, University of Berlin, University of Leipzig, the Trieste Zoological Station, and Pasteur Institute. His specialty was medical zoology and this, of course, included the study of parasitic worms.

The hookworm had been known since 1782 when a German zoologist found it in the intestine of a small animal he was dissecting. In 1838 it was found in a human being. A number of years later it came to the attention of zoologists in connection with the building of the St. Gotthard railway tunnel in the Alps. During the digging of this nine-and-a-quarter-mile tunnel, so

many laborers became ill that work came to a standstill. The ignorant laborers believed that some supernatural force was the cause of their sickness. Some even thought the disease was brought on because the mountain was angry at having the tunnel built.

In 1888, while Stiles was studying in France, a book was published in which the distribution of the hookworm was discussed. Although there was lack of evidence that the hookworm was prevalent in the United States, it was suggested that climatic conditions in the Gulf States were favorable to this parasite.

When Stiles returned to the United States in 1891, he was "hookworm conscious." He received an appointment as consulting zoologist in the Bureau of Animal Industry of the Department of Agriculture. Among his duties was that of custodian of the collection of worms, which included both the flatworms and the roundworms. While studying this collection, Stiles was impressed with the fact that he found no species of hookworm that infects man. Stiles studied the medical literature pertaining to diseases in the South where the hookworm might be expected. He found many cases where the symptoms, such as anemia and dirt-eating, pointed to the presence of the parasite. In Europe, dirt-eating was considered an almost infallible sign of hookworm infection.

While Stiles was in Washington studying the hookworm situation, an army surgeon, Bailey K. Ashford, had found hookworms in a number of patients in Porto Rico. In October, 1901, Stiles read in a medical journal that Dr. Allen J. Smith of Galveston, Texas, had found cases of hookworm in medical students in the University

of Texas. Stiles wrote for specimens. Examining them under the microscope, he observed that they were slightly different from the species he had studied in the European universities, but were identical with those found in Porto Rico by Ashford. He had now found what he had searched for so ardently.

This study of the human hookworm was not a part of his duties in the Bureau of Animal Industry. It had been carried on as a side line. The Bureau of Animal Industry was not the logical agency to carry on extensive work in a disease of human beings. Fortunately, at this time Stiles was transferred to the United States Public Health and Marine Hospital Service. Of equal importance with the transfer, was the fact that the head of the Public Health Service, Surgeon General Walter Wyman, had great confidence in Stiles and his work

For some time Stiles had wanted to confirm his beliefs about the hookworm by making a trip through the South. Wyman now made such a trip possible. Mark Sullivan in *Our Times*, Vol. III, writes: "In September, 1902, Stiles set out. Now began one of the strangest odysseys ever recorded in the annals of any people." He took with him few belongings except his microscope. In the small communities he visited, microscopes were unknown, and in at least one place he was regarded with so much suspicion that he had to leave the town in a hurry.

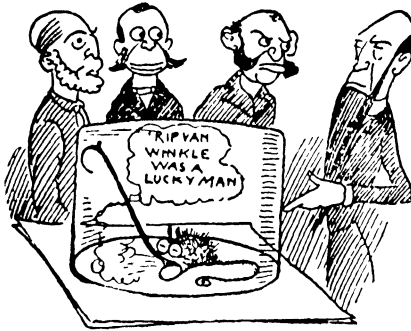
At first it seemed that Stiles was on the wrong track, for after traveling five hundred miles and making many examinations, he found little or no evidence that the hookworm was a menace to health in the South. When he considered the negative results of this much of his trip, he realized that a condition of the soil might account

for the scarcity of hookworms. He knew that hookworms affecting animals were found where the soil was sandy; for that reason he turned to districts where there was considerable sand. He was at once rewarded by finding many people, adults and children, who showed the symptoms of hookworm infection. Microscopic examination of the excreta confirmed the diagnosis.

Before the Pan-American Sanitary Conference in Washington, in December of 1902, Stiles read a paper on the results of his trip. He stated that the so-called cotton-mill anemia, from which so many people in the South suffered, was in reality the result of hookworm infection. It was also a well-known fact that many children of fourteen or fifteen, in the poorer communities, were in physical development no larger than a normal child of seven or eight, while their facial expression was like that of a person in the middle twenties. Here again he blamed the hookworm.

It was necessary for Stiles to convert doctors to his beliefs and to soothe the resentment of Southerners who believed that he had made them appear in an unfavorable light. He might have done that without too much difficulty had not a newspaper reporter at the Sanitary Conference reported that Dr. Stiles had found the "germ of laziness." The idea struck the public as funny, very funny. The hookworm was the subject of editorials, cartoons, and humorous verse. How could he expect to get any concerted help in wiping out the hookworm when it had become the laughing stock of the country?

For the next five years Stiles carried on a lone campaign in the South. Getting rid of the hookworm from the intestinal tract was simple and inexpensive. A dose



THE UNCINARIASIS
OR GERM OF
LAZINESS

RESPONSIBLE
FOR THE FOLLOWING PHRASES!
"NOTHING DOING"
"THAT TIRED FEELING"
"WHAT'S THE USE"
"DEAD TO THE WORLD"



"THE GERM OF LAZINESS"

After Dr Charles W Stiles's lecture before the Sanitary Conference, the hookworm was renamed by a New York paper "the germ of laziness". This name and the imagination of cartoonists brought the hookworm much unscientific publicity. These cartoons appeared in 1902 (Courtesy Powers and "The New York Evening Journal")

of thymol was given to the person. This caused the heads of the hookworms to release their hold on the intestinal wall. The thymol was followed by a dose of epsom salts, which caused the worms to be eliminated.

From town to town he traveled, stopping at cabins on the way, talking before schools, clubs, and colleges,

teaching the simple remedy, and trying to get other people interested in spreading the knowledge of the cure for the infection. Everywhere he preached sanitation, for the hookworm infects a person by entering through abrasions in the skin. Soil that has become infected is a danger to anyone walking barefooted, and shoes were seldom worn in many of the poorer districts.

By 1905 Stiles was convinced that no great victory over the disease could be won without friends to establish an organization to combat the hookworm. He succeeded in interesting a wealthy man in the project, but the man died before the organization was effected.

The trips Stiles had made through the southern states while crusading against the hookworm had made him so familiar with conditions that in 1908 President Theodore Roosevelt made him an attaché to the Commission on Country Life. During a trip of this commission, Stiles interested Walter Hines Page in hookworm and its economic effects in the South. Page, in turn, brought it to the attention of John D. Rockefeller. The result was that in November, 1908, a million dollars was given to fight the hookworm.

This was the beginning of a most effective campaign against a disease that was prevalent in the worm countries of the world. The extent of the campaign may be realized by the fact that it has been carried on in the United States, India, Australia, the South Sea Islands, and the Fiji Islands.

Dr. Victor G. Heiser in *An American Doctor's Odyssey* writes that in 1916 the Indians in Fiji "lived in miserable houses and filthy villages and seemed to have no desire for anything better." In 1934, when he visited the islands

again, an almost unbelievable change had taken place. The people were healthy, prosperous, and happy. He attributes this remarkable change to mass treatment for hookworm and adds "Nothing like it has ever happened in history."

By 1927 about seven million people had been treated in the United States. This treatment, together with the improved sanitary conditions for the disposal of human wastes, has greatly lowered the number of infections. The eradication of the hookworm is an economic problem as may be seen from the effects in the Fiji Islands. In the United States many thousands of people are alive and self-supporting who would have died or led unproductive lives if they had not been freed of the parasite.

Dr. Stiles was connected with the United States Public Health Service from 1902 until 1931. During his last year with the service, he was the director. For some years Dr. Stiles has been professor of zoology on the winter faculty of Rollins College, Winter Park, Florida. He has published a great many papers on parasites and subjects relating to medical zoology. Between 1925 and 1932, Dr. Stiles published a *Key-Catalogue of the Protozoa, Worms, Crustacea, Arachnoids and Insects of Man, Primates, Chiroptera, Insectivora, Carnivora*.

Entomologists in the United States have been active in classifying insects and studying their life histories. Such information is important to men in other fields who are studying insects as possible carriers of diseases. Furthermore, parasitism involves many details which, if clearly understood, might be practically used and might also fill in some of the more or less empty spots in the theory of the origin of species.

But in the last analysis, no individual or nation can be at its maximum of efficiency unless it is well fed. Millions of insects in the world are man's rival for the same food. Locusts have caused famines in limited areas of the world since biblical times. Other insects yearly threaten, or actually cause, great shortages of crops. The results of a famine or of a restricted diet over several months or years are not measured by the immediate sensations of hunger, but by the deficiency diseases, the underdeveloped children, and the lowering of resistance to infectious diseases that follow in the wake of a famine.

An insect in its natural environment may be of little economic importance, but when suddenly transported into a new region where it has no natural enemies, its board bill may be huge. The reason is that the normal balance in nature has been disturbed.

One of the early immigrants to America was the Hessian fly, brought over by the mercenary troops during the Revolutionary War. It has never been exterminated and each year destroys thousands of bushels of wheat. The gypsy moth, the brown-tail moth, the European corn borer, and the Japanese beetle are other expensive immigrants.

The story of the Japanese beetle gives a striking example of the rapidity with which insects can increase when introduced to a region where there is abundant food and freedom from natural enemies. These beetles were probably brought into the country on ornamental shrubs. In 1916 two inspectors for the New Jersey State Department of Agriculture discovered about a dozen of these green and brown insects. Three years later it



CHARLES W. STILES

With the spirit of a crusader Stiles traveled through the southern states preaching sanitation and teaching the people how to keep free of hook-worm infection (*Science Service*)

Under Howard's direction it has been possible to gain control of many insect pests by parasites, which is a service of inestimable importance to agriculture (*Science Service*)



LELAND O. HOWARD

was estimated that they were so numerous that one person could collect twenty thousand in a day .

To control insects is a tremendous task. Various kinds of sprays and poisons are used, but the most efficient method of control is through parasitic insects, insects that eventually kill their hosts. Parasitology is a large branch of biology. Only one small part of it will be considered here. In insects there are all degrees of parasitism from those that are parasitic only during short periods in their life histories, to others that are so markedly parasitic that they have lost some of their independent functions.

The Bureau of Entomology in the United States has been very successful in using parasitic insects to fight pests that destroy food crops. This success has been due to the combined efforts of many men, one of whom is

L. O. Howard, who was connected with the bureau for fifty years.

Leland Ossian Howard was born in Rockford, Illinois, in 1857. Soon after his birth the family returned to Ithaca, New York, where his father had previously studied law. From an early age Howard was interested in insects. In the spring that he was seven or eight, he watched with delight as *Cecropia* and *Prometheus* moths emerged from the cocoons he had treasured all winter. His parents encouraged his efforts as an amateur collector by buying books about insects. Besides this, there were other boys who used their eyes as they wandered through the gorges and along the shore of Cayuga Lake. They formed a natural history club and held very serious meetings, which were, in their opinion, much more interesting than the public lectures they attended at the recently founded college on the hill. The thing that impressed Howard, when he heard Agassiz (see page 100) lecture at Cornell, was not the man's knowledge, but his ability to draw symmetrical figures on the blackboard with a piece of chalk in each hand.

On his sixteenth birthday, Howard passed the entrance examination for Cornell. His father had died in the spring, and financial matters were a serious consideration. Howard wanted to study natural history, but friends of the family persuaded him that he could never make a good living in that field. He entered the engineering school. A course in differential calculus changed all his plans. He failed the examination. Without discussing the situation at home, he then proceeded to take the courses he liked. They included botany, geology, and chemistry. Naturally, a program selected because of

likes and dislikes led to trouble about a degree. However, after intensive cramming in some required subjects, he was graduated in 1877. He wanted to teach natural history. Again, friends insisted that there were no financial opportunities in that; therefore, he returned to Cornell in the fall as a postgraduate student to begin studying for a degree in medicine.

Howard finally received the degree of M.D., but it was an honorary one granted by George Washington University in 1911. His pre-medical studies at Cornell lasted only a year, for in 1878 he was called to Washington as an assistant to C. V. Riley, head of the Bureau of Entomology. Sixteen years later Howard himself became head of the bureau. He held this position until his resignation in 1927.

Dr. Howard has always been keenly interested in parasitic insects. His observations of natural control began early in his services for the government. For example, not long after Howard entered the bureau, he made a field trip to Virginia. A farmer asked for help against the army worms that were destroying his acres of timothy. This "worm" is the larval or caterpillar stage of a moth. Howard went to the field. Every stem of timothy seemed to have one or more of these caterpillars feeding on it. In a caterpillar's life, eating is not a matter of three square meals a day; it is a nearly continuous process.

Howard inspected one of these caterpillars. To his relief he saw white spots on its back; these white spots he identified as eggs of a tachina fly. Following some curious instinct, the females of this fly lay their eggs on the backs of the soft-bodied larvae. For four hours

Howard examined caterpillars, hundreds of them. On each he found eggs. No man-made control could equal this. True, the timothy crop for the year was ruined, but the caterpillars would never develop into adults capable of laying eggs for another generation. They would become the extremely convenient food supply for the tachina larvae.

In 1905, Howard went to Europe to study the parasites of the gypsy and brown-tail moths. Near Budapest he found a man who gave him information that resulted in thousands of silken cocoons being collected in Central Europe and sent to America. In these cocoons the parasites of the brown-tail had laid their eggs. The introduction of these parasites into Massachusetts was an important factor in gaining some control over the moth. The records of the Bureau of Entomology are filled with attempts, successful and otherwise, to find parasitic insects.

One other case in which Howard played a part in the war against insects is of interest, because the destructive insect was native to America and was accidentally carried to Europe. This insect, the woolly root-lice, is very small. In most parts of America it lives on the roots of apple and pear trees, but in England and France it attacked the trees above the ground, greatly lessening their vitality. The situation was serious in France before the World War, but it was not until 1920 that an attempt was made to introduce its parasite from America. In the spring of that year, Howard had men gather twigs from apple and pear trees on which some of the bodies of the dead woolly root-lice had appeared.

From the condition of these bodies it was known that they contained the dormant parasites, *Aphelinus*.

With a package of these twigs in his luggage, Howard sailed for Europe. Temperature was the important factor. If the parasites became active and died before reaching Europe, the experiment would be useless. Therefore, on shipboard the box was placed in the meat refrigerator. Every day the temperature was reported to Howard. It was cool enough to satisfy him. He arrived in London. The box was kept on the window sill during the night after his arrival, and the next morning he found a fish store where he could leave it while he attended to some business before leaving for France.

At four o'clock in the afternoon, a few days later, Howard was met at the station in Paris by Dr. Paul Marchal. They crossed the city in a taxi, no doubt congratulating themselves that the solution to the woolly root-louse problem lay in the box they carried. At the laboratory a small pear tree was ready in a pot. The earth in the pot was covered with a white paper, and a piece of gauze was at hand to put over the tree. The boxes were opened, and the twigs poured out on the paper. Tiny black spots showed against the white surface, dead bodies of the parasites that had emerged too soon. At the time, it was believed that all the parasites were dead.

A few days later when Marchal and Howard were at Montpellier a telegram came. Ten living *Aphelinus* had been counted. There was cause for rejoicing. A few days later another telegram came—two hundred had emerged. The descendants of these insects established themselves in France and became the allies of the

fruit growers. Species of this same parasitic insect were later sent from the United States to South America, New Zealand, and Australia.

The problem of insect control by parasites is international. In the last few years, parasites from Japan, Korea, and China have been shipped to the United States to combat the Japanese beetle. More than thirty species of the parasites of the European corn borer have been raised in European laboratories and shipped to America.

The direct importance of destructive insects in curtailing man's food supply has long been evident. The part played by insects in the carrying of disease-producing parasites has not been known until recently. Two diseases that have checked the spread of civilization in the world are malaria and yellow fever. Both of these diseases are spread by mosquitoes. As early as 1892, Howard used kerosene oil as a mosquito control. Only a few of the many species of mosquitoes have been proved guilty of transmitting diseases to man. But in order to find the culprits, many mosquitoes had to be studied thoroughly. *Mosquitoes of North and Central America and the West Indies* is one of the most outstanding of Howard's works.

The housefly has also been another subject of research for Howard. Today it seems common sense to swat the housefly, because it is known to carry disease germs. However, the direct connection between flies and the spread of diseases, such as typhoid, has been known only a relatively short time. Even after Howard had definitely proved the fly was as dangerous as polluted water in the spread of typhoid, there was opposition to its slaughter.

One amusing incident is given by Howard in his book, *Fighting the Insects*, published in 1933. Early in the crusade against flies, Dr. Woods Hutchinson pointed them out as a menace to health at a meeting of the American Civic Association in Washington. When he had finished speaking a woman arose and declared with much feeling, "in the name of the women of the United States and that of the Society for the Prevention of Cruelty to Animals, I protest against the wholesale murder of these defenseless creatures."

Dr. Howard has received recognition and honors from colleges, scientific societies, and governments. In 1931 he received the much prized Capper Award of \$5,000, for distinguished service to agriculture. In connection with the awarding of the prize it was said of Howard: "His remarkable work in the utilization of natural enemies of insects in the control of injurious species has been the standard and inspiration for all similar work in this and other countries."

There can be no doubt in anyone's mind that the entomologist has a very important role to play in the fight against diseases which are carried by insects. Malaria, yellow fever, Rocky Mountain spotted fever, bubonic plague, the sleeping sickness of Africa, and typhoid are a few of the diseases transmitted to mammals by insects. Bacteria, the spores of fungus diseases, and probably viruses are also transferred from plant to plant by insects.

The real warfare against insects and some of the closely related organisms, such as ticks, has only begun. A decisive victory over all injurious insects is beyond hope. Only by constant vigilance, by using all the natural

methods of control, and by inventing more effective methods in the use of chemicals can man reduce the number of these pests and keep them reduced.

Hints for Further Reading

BOYLE, JAMES E., "Insects and Men," *Atlantic Monthly*, CXLIV (Oct., 1929), 529-535.

"The Bureau of Entomology and Dr. L. O. Howard," *Science*, LXVI (Oct. 28, 1927), 391.

GAGE, SIMON H., "Theobald Smith; Investigator and Man," *Science*, LXXXIV (Aug. 7, 1936), 117-122.

HERRICK, GLENN W., "Dr. L. O. Howard and the Capper Award," *Scientific Monthly*, XXXIII (Aug., 1931), 189-192.

HOWARD, LELAND O., *Fighting the Insects*.

———, *History of Applied Entomology*.

———, "Striking Entomological Events of the Last Decade of the Nineteenth Century," *Scientific Monthly*, XXXI (July, 1930), 5-18.

McKINLEY, EARL B., "Theobald Smith," *Science*, LXXXII (Dec. 20, 1935), 575-586.

WRIGHT, WILLARD H., "Unhooking the Hookworm," *Hygeia*, XII (April, 1934), 328-330.

Antitoxins, Toxin-antitoxins and Serums

ROUX, VON BEHRING, EHRLICH, AND FLEXNER

WHEN you were small, you may have had an injection of toxin-antitoxin. If you were old enough to take any interest in the procedure, you may have wondered why, when you felt perfectly well, you were being given an injection. Toxin-antitoxin was given you to make you immune to diphtheria. It saves the lives of thousands of children every year who would contract the disease if they had not been made immune.

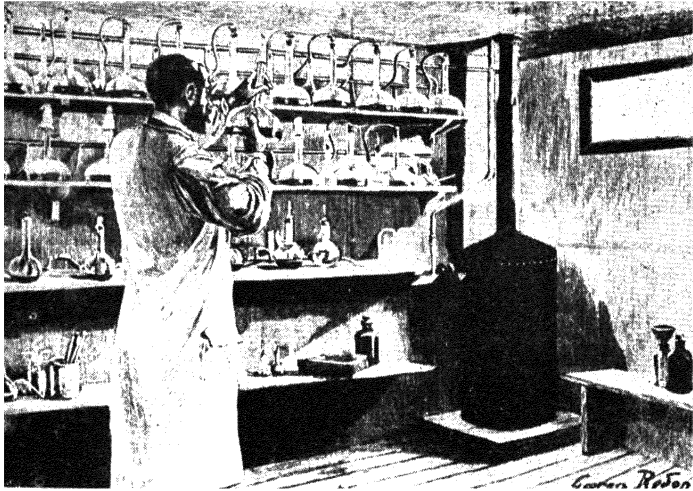
Ten years is a very short period in the entire history of medicine; but during the decade that began in 1883, weapons were found for one of the most pronounced victories ever gained by the medical profession. The bacillus causing diphtheria was recognized in 1883 by Edwin Klebs (1834–1913) and was soon isolated by Friedrich Löffler (1852–1915). Within five years after the isolation of the diphtheria bacilli, a rather startling discovery was made. These microscopic organisms were found to produce a poison called a toxin. Emile Roux and Alexandre Emile John Yersin at the Pasteur Institute

recognized it as a definite substance. This discovery was important to the workers in Paris, and it was not long before it came to the attention of Emil von Behring in Germany, who was eventually able to produce an antitoxin.

It was upon Pasteur's suggestion that Roux and Yersin took up the investigation of the toxin. Roux continued his work on diphtheria. Yersin went to China where he attempted to find the cause of the plague.

Emile Roux was born at Confolens in France, in 1853. He received his medical training in French colleges. When he was about twenty-five years old, he went to Pasteur Institute as an assistant. Under Pasteur's direction (see page 192) he carried on much of the experimental work on anthrax and hydrophobia. When he turned to the study of diphtheria, Roux was able to prove that the poison given off by the bacilli would pass through a filter; in other words, that it could be separated from the bacilli. This discovery was the first step toward the development of an antitoxin. Early in 1894, Roux published a paper telling how he had treated rabbits suffering from the first stages of diphtheria with antitoxin. His treatment had been successful. Further than that, he found that when antitoxin was used before animals were exposed to the disease they were not susceptible.

As an assistant to Pasteur and as an independent investigator, Roux proved himself to be a man of great ability. Not long before the death of Pasteur, Roux became an assistant director of Pasteur Institute, and in 1904 he was made the director. He died in November, 1933, at the age of eighty.



ÉMILE ROUX

The picture shows Roux at the Pasteur Institute at the time he was carrying on his experiments with antitoxin for diphtheria. The simplicity of the apparatus and the laboratory are evident. (*The Bettmann Archive*)

Emil von Behring, the German whose investigations were given impetus by the work of Roux and Yersin, was born in Hansdorf in East Prussia, in 1854. After attending the Gymnasium of Hohenstein, he was graduated from the Army Medical School in Berlin, in 1880. For the next seven years he served in the army.

At this time iodoform was used very widely for dressing wounds. Von Behring wondered why the substance was effective. Although he accepted the current belief that it destroyed bacteria, he found that it also acted upon substances given off by bacteria. This was a new idea. Not only must bacteria be killed, if possible, but substances must be found to neutralize the toxins they formed.

Von Behring continued to experiment in laboratories at Bonn and Berlin. The work of Roux and Yersin fitted in well with his ideas. These men had proved that the toxins given off by bacteria produce the symptoms of specific diseases. As little as one half a cubic centimeter of the toxin from diphtheria bacilli would kill a guinea pig in forty-eight hours. Using the same kind of experimental animals, von Behring and Kitazato, a Japanese who studied under Koch (see page 199), found that when very small quantities of the toxin were introduced into the body of a guinea pig an immunity to diphtheria was built up. In time they realized that this introduction of small quantities of toxin into the animal caused a reaction to be set up in the cells of the animal. The cells themselves formed a substance that neutralized the poison. This substance is known as antitoxin.

The years 1890-1894 mark a period when the most feared of children's diseases lost much of its terror. If antitoxin was produced in the bodies of animals, why could it not be produced there and then introduced into the body of a person ill of the disease? Experimentation proved that this could be done. Paul Ehrlich, another investigator, found that the horse was an excellent animal for this purpose because antitoxin in large amounts could be produced in its body. Before the end of 1894, diphtheria antitoxin was being manufactured in Europe on a commercial scale and put on the market. A phenomenal decrease in the death rate from diphtheria was noticed when antitoxin was used within a few hours after the symptoms of the disease appeared.

In 1895 von Behring became a professor in the University of Marburg and director of the Hygienic Institute

there. Under his supervision large laboratories were developed. These became known as "Behringwerk." Here, during the World War, great quantities of tetanus antitoxin were prepared for use in the army. It had been found that the bacteria causing tetanus (lockjaw) also produced a toxin and that, as in the case of diphtheria, an antitoxin could be produced. Tetanus is apt to follow wounds in which there are particles of dirt. Since the war the use of tetanus serum has rapidly increased, and deaths from lockjaw following wounds have correspondingly decreased.

At the same time that von Behring was perfecting his diphtheria and tetanus antitoxins, he was working out a method by which to immunize children. Toxin-antitoxin, so widely used in this country, was developed from his investigations. This contains the toxin of the bacteria and a sufficient amount of antitoxin to neutralize it partly. Injected into the body of a child, it stimulates the cells to produce enough more antitoxin to neutralize the poison and cause immunity.

Von Behring and Roux shared the Nobel Prize (see page 153) in 1901, for their work on diphtheria. In the same year the German was raised to the nobility. This honor gave him the right to use the honorary *von* before his name. In 1917 Emil von Behring died of pneumonia.

The same conditions which had spurred European workers to find a way to produce antitoxin existed in this country. In 1894 hundreds of children in New York City alone were dying of diphtheria. But the newspapers were giving accounts of antitoxin being successfully used in Europe. Why should American children die for want of this new substance? Something should be done and done

at once, and William Hallock Park became one of the active men in this historic campaign against diphtheria.

William Hallock Park was born in New York, in 1863. He received his degree in medicine from Columbia University, in 1886. During 1889-1890 he studied in Vienna. When he returned to New York, he began to practice as a specialist in diseases of the ear, nose, and throat. At the same time, he carried on a study of the diphtheria bacilli which attracted the attention of Dr. Herman M. Biggs, a professor at Bellevue Hospital Medical College in New York. Dr.



WILLIAM H PARK

Diphtheria antitoxin was first produced in the United States largely because of Dr Park's activity in the public health field (*Keystone View*)

Biggs also held an important post in the City Health Department. Through his influence Dr. Park was appointed as a bacteriologist in the department and in 1894 was made Director of the research laboratory

In 1894 Park asked his friend, Dr. Biggs, who was going to an International Medical Congress in Budapest, to find out what he could about the new substance, antitoxin. In Paris Biggs talked with Roux, and was so much impressed that he cabled Park to start producing antitoxin at once. That was easier said than done, for horses were needed, and the city laboratory had no money to buy them. An appeal to the public was made through a

newspaper, and enough money was raised to buy sixty horses. In this way antitoxin came to be used in the United States. Since then toxin-antitoxin and toxoid have been developed as immunizing agencies.

In December, 1935, Dr. Park retired from the New York City Board of Public Health. So that he might still be in the service of the city when the William H. Park Research Laboratories were completed, he was given a six-months leave of absence before his retirement became permanent. After his retirement he continued to work in the laboratory as an advisor. He died in April, 1939.

When Dr. Park received the Roosevelt Medal in 1935 on the seventy-seventh anniversary of the birth of Theodore Roosevelt, an editorial in a medical journal spoke of him as a "crusader for child life, consulted by half the world, and held in affectionate regard by every physician so fortunate as to know him. . . ."

Dr. Park did not confine his research work to diphtheria. He made important contributions to the understanding of typhoid, tuberculosis, tetanus, and infantile paralysis.

Among Dr. Park's writings are *Bacteriology in Medicine and Surgery*, *Pathogenic Micro-organisms*, and *Who's Who among the Microbes*. In the two latter books Anna Williams collaborated with him.

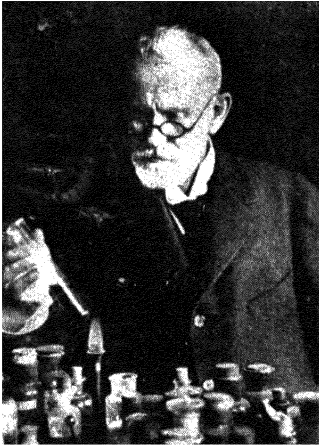
It has been mentioned that Paul Ehrlich found that the horse was an excellent animal in which to produce antitoxin in large quantities. The contribution of that bit of knowledge to the crusade against diphtheria would itself be important enough to make his name known, but Ehrlich made other contributions to medicine which are of very great importance.

Paul Ehrlich was born near Breslau, Germany, in 1854. On both sides of the family he had several relatives who were interested in science and medicine. While in the University of Strasbourg, Ehrlich decided to study medicine. During his second year he read a pamphlet on lead poisoning. It stirred his imagination. He wanted to carry on a series of investigations of his own. Since lead was expensive, he used fuchsin, an aniline dye. Bacteriologists should be thankful that lead was expensive and fuchsin cheap, for the technique of using dyes for staining cells grew out of Ehrlich's experiments.

As a university student, Ehrlich seems to have been allowed to do about as he chose, and he chose to carry on his own research work. In 1877, when it was time to take the examinations for his degree, Ehrlich was worried. He need not have been, for he was already recognized as a brilliant worker, and his degree was given to him.

When Robert Koch discovered the tubercle bacilli (see page 197), Ehrlich was working in his laboratory. The bacilli could be seen on the slides, but that was about all. By the use of aniline dye Ehrlich brought these minute organisms into such prominence on the slide that Koch could show them to anyone who looked through the microscope, Ehrlich's interest in tuberculosis proved very costly to him, for he became infected, and for a year and a half he was forced to stop his researches.

After he had recovered from this disease, Ehrlich turned to experiments on the toxin and antitoxin already mentioned. He attacked the problem of natural and acquired immunity and became a leading authority. In 1904 he published *Collected Studies on Immunity*. The



PAUL EHRLICH



EMIL VON BEHRING

Ehrlich's interest in dyes gave the microscopist new techniques and the physician new methods for treating diseases (*The Bettmann Archive*)

The investigations of von Behring led to the production of antitoxin on a commercial basis. The method he worked out by which children are immunized against diphtheria was of vast importance (*The Bettmann Archive*)

same year he came to the United States and gave a series of lectures. While he was in this country, Chicago University gave him an honorary degree. Two years later he became connected with the George Speyer Haus in Frankfurt on the Main as a research worker in chemical therapy.

While working with dyes, Ehrlich had noticed the different effects they had on tissues. This made it possible to have slides in which the different kinds of tissues or cells are distinguishable by their colors. These experiments raised a question in Ehrlich's mind. Since some dyes were absorbed by cells, could he find some chemical substance which would kill the parasites in the blood without destroying the body cells?

He attacked this problem. Ehrlich was an untiring worker and at last he found that solution 606 killed the organisms causing syphilis. This does not mean that he tried 606 solutions in a haphazard fashion, as the doctors in the time of King Charles compounded their medicines. Ehrlich worked systematically, trying a formula, changing it a little in accordance with the results, trying again, and so on. At last, after hundreds and hundreds of animals had been used, he met with success. The amount of suffering that has been relieved by the use of 606, now called "salvarsan," is too great to measure.



SIMON FLEXNER

Dr. Flexner is well known for his work on infantile paralysis. (*Science Service*)

Mechnikov (see page 278) and Ehrlich both worked on the problem of immunity. The Russian attacked it from the point of view that the phagocytes could destroy germs. Ehrlich, as a chemist, sought substances to counteract the bacterial toxins and to kill the parasitic organisms in the body. In 1908 they shared the Nobel Prize (see page 153).

Although his research work took an enormous amount of time, Ehrlich wrote 212 books and papers between 1877 and 1914. After many months of ill health, caused in part by diabetes, Ehrlich died in August, 1915.

Today in this country the death rate from diphtheria is very low among young people. However, there is another

disease, most prevalent in the late summer months, which has not yet been conquered. This disease, infantile paralysis, is being studied from all angles. What causes it? How is it spread? How may it be prevented? What is the best treatment for a person afflicted with it? Parts of the answers of these questions have been discovered. The name of Dr. Simon Flexner stands out among many who have worked on the problems connected with infantile paralysis, more technically known as poliomyelitis.

Simon Flexner was born in Louisville, Kentucky, in 1863. He received his degree in medicine from the University of Louisville and then studied at Johns Hopkins and in universities in Germany. From 1891 to 1899 he taught pathological anatomy at Johns Hopkins. From there he went to the University of Pennsylvania.

In 1903 he became director of the newly established Rockefeller Institute. Among the workers he chose for this new venture was Hideyo Noguchi (see page 233). At the time Flexner joined the staff of the institute, cerebro-spinal meningitis was causing many deaths in New York City. Flexner turned his attention to that and developed a serum which is still considered the best remedy for the disease. Dr. Flexner has been honored by scientific societies in all parts of the world. He retired as director of the Rockefeller Institute for Medical Research in 1935.

Today antitoxins, toxin-antitoxins, and serums play an immeasurable part in the treatment and prevention of many kinds of diseases. No such control of diseases would ever have been possible if the germ theory of disease in the last half of the nineteenth century had not changed the entire conception of their causes.

Hints for Further Reading

- “Dr. Flexner and the Rockefeller Institute,” *Scientific Monthly*, LXI (Oct., 1935), 373-376.
- GOODMAN, HERMAN, “Ehrlich,” *The Medical Times*, LII (Aug., 1924), 175-177.
- “In Honor of W. H. Park,” *Science*, LXXXIV (Sept. 18, 1936), 261-262.
- PARK, WILLIAM H., “Half-mast on the Pasteur Institute” (re: Emile Roux), *Scientific Monthly*, XXXVII (Dec. 1933), 570-574.

Blood Will Tell

MECHNIKOV AND LANDSTEINER

TH**ERE** is a common expression, "Blood will tell." Years ago when it was first used, it meant something very different from what it can be interpreted to mean today. Today an examination of the blood will tell whether a person is anemic, whether he is absorbing pus from some infected area, whether definite bacteria and protozoa may have found their way into his body. Furthermore, a sample of blood from one person will show what type of blood can successfully be used with it for a transfusion, if that should be necessary.

The functions of the blood are varied. It carries food and oxygen to the cells and removes waste products. By means of blood hormones are circulated from the point of manufacture through the body. Antibodies and fibrinogen circulate in the blood stream. It is difficult to comprehend how so many different purposes are served by it.

Two distinct types of blood cells are visible under the microscope, the red corpuscles and the white, or colorless, corpuscles. The difference in shape and color indicates at once that a difference in function is to be expected. Study of the red corpuscles has shown that the red color-

ing matter, the hemoglobin, is an iron compound which readily takes up oxygen when exposed to it. However, the oxygen can be separated from it where it is needed at the cells, and the red corpuscles return to the lungs with a load of carbon dioxide. The white or colorless corpuscles are not so impressive when first seen, but they are remarkable, nevertheless, in their functions.

After bacteria were found to be almost everywhere, how could it be explained that everyone was not ill all the time? The body must have some natural way to protect itself. What was this way? Ilya Mechnikov discovered in the colorless corpuscles at least part of the answer.

Ilya Mechnikov was born in Kharkov, Russia, in 1845. His father had been a member of the Russian guard; the name "Mechnikov" means sword-bearer. His mother had considerable money, but this his father spent in gambling and entertaining. Then the family moved to a farm which had been given to the Mechnikov family by Peter the Great. Ilya's mother and an uncle managed the farm and the many serfs who were inherited with it. Although the father spent part of his time at this farm, he does not seem to have had an active part in managing it.

An incident that occurred when he was five made an impression on Mechnikov that he could never shake off. His mother and uncle were taking the children to a resort some miles away. While they stopped at noon for lunch, the coach was surrounded by a mob of peasants. The horses were led away, and the threatening peasants demanded a ransom. After insisting that he did not have enough money to meet their demands, the uncle offered to ride to the home of a relative and borrow some. The

unsuspecting peasants let him go alone. He rode to an encampment of soldiers and returned with an armed force. The horror of the brief but bloody conflict remained in Ilya's mind, and from that moment he had a great fear of crowds and violence of any sort.

When Ilya was eight years old, an older brother, Leo, was in such poor health that he left school and returned to the farm, bringing a tutor with him. The tutor found a willing pupil in young Ilya, who quickly learned the names of all the plants in the neighborhood. Usually when children give shows or other performances, the actors receive the pennies, but Ilya was so anxious to display his knowledge that he paid his brothers and sisters to listen to him give lessons on natural history.

In time Ilya became a pupil at the Lycée, a school corresponding to our high school. He was not satisfied with the instruction he received there, so he attended lectures at the university whenever he could. He spent most of his time studying. Music and debating upon philosophical subjects were his chief means of recreation. He was determined to study protoplasm, and after one professor had told him he was too young, he finally persuaded a physiologist to give him private instruction. He borrowed a microscope and began studying the *Infusoria*, minute organisms found in stagnant water.

Mechnikov was sixteen when he made his first appearance in print. He wrote a critical analysis of a text on geology. The criticism was of enough merit to be published in a journal at Moscow.

His family's resources were not large when Mechnikov finished his course at the Lycée, but by their making sacrifices enough money was saved for him to enter the

University of Würzburg in Germany. Because he did not know that the vacation period in this university was different from that in Russian universities, he arrived six weeks before the term began. Young, homesick, not able to speak German, and coldly received by the Russian students he found there, Mechnikov returned home. The trip would have been a complete failure if he had not bought a copy of Darwin's *Origin of Species* (see page 121). This made a deep impression on him. Upon his return home he entered the University of Kharkov.

For several years after finishing his work at the university, he taught first in Odessa and then at St. Petersburg. The death of his first wife and a serious eye trouble temporarily unbalanced his reason, and he became very melancholy. One day while he was taking a walk, his attention was attracted by some insects. The adults of this species only live a few hours. Their life history did not fit into Darwin's idea of the survival of the fittest in the struggle for existence. Mechnikov became absorbed in his thoughts about them, and his interest in science was reawakened. Since he was not able to use a microscope, he made a trip into the Kalmuk steppes to take comparative measurements of the people belonging to the Mongolian and Caucasian races. Upon his return he again took up his profession of teaching.

In 1875 he married a woman much younger than he. He had taught her in classes and continued to direct her work in biology after they were married. Mme. Mechnikov was entirely in sympathy with her husband's work and wrote his biography, which appeared after his death.

Until 1880 Mechnikov had done no work on infectious diseases. The summer of that year he spent at a place in



I IYA MECHNIKOV

This Russian scientist's theory of the activities of the phagocytes solved some of the problems of immunity (*Underwood and Underwood*)

the country belonging to his wife's family. The grain crops in the vicinity were being destroyed by a beetle. Mechnikov became vitally concerned with the destruction of this pest. When examining dead beetles, he found that they usually had fungus growths on their bodies. If he could infect living beetles with this, he might reduce their numbers. He set to work. In laboratory experiments he met with success. Soon a wealthy landowner offered him the use of his fields for the purpose of verifying his experiments on a large scale. Mechnikov could not remain there to finish the work, but he planned the procedure and left an entomologist in charge. The results were very encouraging to the landowner, and Mechnikov himself in later years considered that his interest in infectious diseases began at this time.

The desire to study protoplasm, which he had had as a boy, continued. In the course of his work on low forms of

animals, he found that the transparent larvae of starfish made excellent microscopic material. In them he saw wandering cells moving as amoebae do by the flow of protoplasm. One day an idea flashed into Mechnikov's mind that these wandering cells might have some points of similarity with the colorless corpuscles in human blood. He knew, for instance, that when a sliver is embedded in a person's finger, the matter formed around the sliver has a large number of colorless corpuscles in it.

In describing his feelings when the idea first came to him that he might be on the verge of an important discovery, Mechnikov said that he was so excited he went to the seashore and walked up and down trying to think of a way to test it. The idea began to crystallize. He returned home. In the garden there was a small tree which had been decorated the day before as a Christmas tree for the children. The Mechnikovs had no children of their own, but since the death of Mme. Meknikov's parents, they had been taking care of her young brothers and sisters.

Some roses had been used in decorating the tree. From these Mechnikov pulled some small thorns. Then with great care he inserted them under the skin of the transparent starfish larvae. He could not sleep that night because he was so anxious to know whether he was correct in his assumptions. Early in the morning he was at his microscope. He saw what he had hoped to see. The thorns were surrounded by the wandering cells. Further experimentation with carmine and other substances proved that the colorless corpuscles surrounded and digested foreign particles. From this they were named "phagocytes" or "eating-cells."

With the discovery of the function of the phagocytes, part of the mystery of immunity was solved. For the next twenty-five years Mechnikov devoted his life to trying to convince people of the importance of the phagocytes. His first published works on his theory appeared in 1883–1884. Three years later, while attempting to make converts to the theory that phagocytes protect the body by destroying harmful bacteria, he visited Koch (see page 197) who received him coldly. In Paris, however, he found Pasteur (see page 194) not only cordial but receptive to the phagocyte theory.

In the fall of 1888 Mechnikov went to Paris to live. He became connected with Pasteur Institute and after the death of Pasteur succeeded him as director of the institute.

For many years Mechnikov studied the physiological changes that take place as a person grows old. He concluded that hair turns grey because the color bodies are destroyed by phagocytes. It had been found that enormous numbers of bacteria inhabit the intestines. He studied the effects of these and decided that this intestinal flora might be the cause of a slow chronic poisoning that would bring on the symptoms of old age. Mechnikov restricted his own diet to food that would be free from harmful organisms. On the other hand, he used large quantities of sour milk in his diet because of the beneficial bacteria contained in it.

Mechnikov died in Paris of a heart attack in 1916, when he was seventy-one years old.

After the discovery of certain chemical substances in the blood, the phagocyte theory was modified somewhat, but the fact remains that these amoeba-like cells are

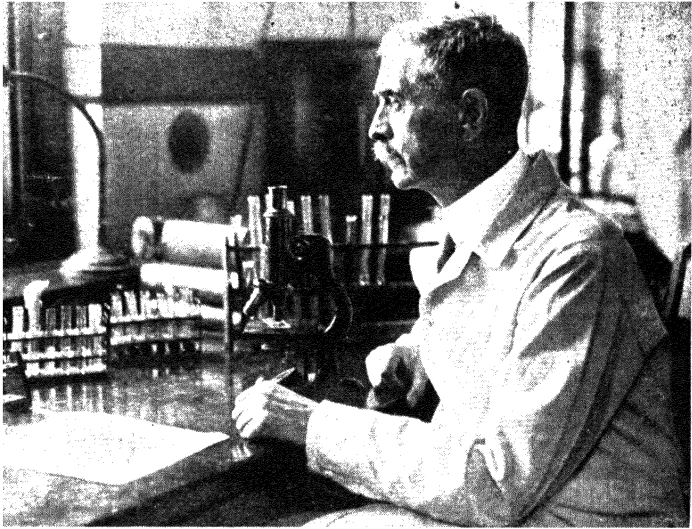
natural protection against disease. Because they multiply when certain infections take place in the body, they are important today in the diagnosis of internal conditions. For example, if a person has some of the minor symptoms of appendicitis, a sample of blood is examined. The average number of colorless corpuscles in a cubic millimeter of blood is 6,000. Suppose the number in the sample was 12,000 to 15,000. A surgeon would feel justified in operating even if the usual symptoms were not acute.

In recent years it has also been discovered possible to classify blood by type so that transfusions of blood may be made with little danger to the patient. Before 1900 the success of a blood transfusion could not be predicted. Sometimes a patient would die very soon after the transfusion. Apparently there was something antagonistic to the body of the patient in this foreign blood. What it was and how to select the donor of blood were not then known.

In a footnote to an article written in 1900, Karl Landsteiner made the first reference to the fact that blood may be divided into types.

Extensive experimentation was carried on with the result that Landsteiner was able to identify three types of blood, and some of his pupils discovered a fourth. These four types are now called "O," "A," "B," and "AB." The type of blood is inherited and follows definite laws so that it is possible to predict the blood type of a child, if that of the parents is known.

The discovery of the four types of blood and the test for them is of great importance. When a transfusion is necessary, a simple test will tell to which type the patient's blood belongs. It is known what types will not



KARL LANDSTEINER

Landsteiner and his assistants eliminated much of the risk in giving blood transfusions when they found a way to distinguish the types of human blood (*Brown Brothers*)

cause a harmful reaction. In large hospitals a list is kept of people who are willing to sell blood for transfusions. The list shows the type of blood and the results of the tests that prove the donor has no disease which might be transferred to the patient by the blood. The importance of blood transfusions is indicated by the fact that about ten thousand are given each year in New York City, and that there are about two thousand commercial donors registered.

Criminologists were given a new tool when the blood types were discovered, for samples of blood can now be tested to prove whether the blood is from a human being, and if it is, to which of the four types or thirty sub-types

it belongs. Scientists interested in the relationships of animals are also making use of blood tests. Landsteiner and Dr. Charles Philip Miller, also of Rockefeller Institute, compared the blood of apes and monkeys with that of human beings. Their findings strengthened the belief, held by most zoologists, that man did not evolve from any species of primate known today.

Karl Landsteiner was born in Vienna, in 1868. He received a degree in medicine from the University of Vienna in 1891. From 1909 to 1919 he was a professor of pathology at the university. His study of blood types was begun in Vienna. During this same period, he successfully transmitted the disease, infantile paralysis, to monkeys. The work of Landsteiner, Flexner, and Lewis served as a foundation for further study of the disease and made serums possible.

After spending three years as a pathologist in Holland, Landsteiner came to the United States in 1922. Here he joined the staff of the Rockefeller Institute for Medical Research. In 1930 he was awarded the Nobel Prize in medicine (see page 153). In 1939 Rockefeller Institute put into force a ruling that members of the staff must retire from active administrative duties at the age of sixty-five. Landsteiner, then seventy, was affected by this ruling.

In addition to the articles Landsteiner has written about the blood groups, he has published many papers on immunology. In the latter field he ranks among the most important scientists of today.

Probably there are several ways, unknown today, in which blood tests of the future will be of great importance so that diagnosis of diseases may be made while they are

in early or incipient stages. The contributions of Mechnikov and Landsteiner to a more complete understanding of the functions of the blood are in themselves important, and there is no doubt that there are many surprising things that the blood has not yet told.

Hints for Further Reading

“Dr. Karl Landsteiner’s Discovery of Blood Groups,”
Science, LXXII (Nov. 7, 1930), Supplement, p. x.

“Karl Landsteiner” (in German), *Les Prix Nobel en 1930*,
102.

LANDSTEINER, KARL, “Serological and Allergic Reactions
with Simple Chemical Compounds” (abstract),
Scientific Monthly, XLIII (Oct., 1936), 379–380.

MACFIE, RONALD C., *Romance of Medicine*.

ZINSSER, HANS, “The Award of the Nobel Prize in Medi-
cine to Dr. Karl Landsteiner,” *Scientific Monthly*,
XXXII (Jan., 1931), 93–96.

Conquerors of Pain

LONG, MORTON, AND SIMPSON

IT IS estimated that without the use of anesthetics nine out of ten operations that are performed on human beings today would be impossible. Pain affects the entire body, and even if the patient were strapped to the table and held down by strong men, as he was in the days before anesthetics, he could not be kept quiet enough to permit the many delicate operations that are successfully accomplished in modern surgery.

Attempts to relieve pain have been made for thousands of years. The medicine men or priests in primitive tribes performed strange rites that were supposed to lessen pain by driving out the evil spirit believed to cause it. Gradually men learned from experience that, when certain plants were eaten, the senses were dulled and pain was less keenly felt. It is difficult to identify positively the plants that were first used, but by the time Homer sang of Ulysses, stupefying drinks were not uncommon. The great historian Herodotus in the fifth century A.D. wrote of a vapor produced from a plant that was inhaled by the Scythians, a people living in Asia Minor. Mandragora, or mandrake, was one of the plants most commonly used



A SURGON IN THE SIXTEENTH CENTURY

Instead of cauterizing the stump of a limb after an amputation the surgeon tied the blood vessels. Anesthetics were unknown (*The Bettmann Archive*)

in the early centuries of the Christian era. Galen (see page 179) mentioned that it could be used to dull sensation. The use of alcoholic drinks to produce a state of intoxication during an operation was not uncommon.

In the last quarter of the eighteenth century a new method for causing insensibility without the use of herbs or alcohol aroused the curiosity of hundreds of people in Europe, and this curiosity spread to the United States. A German, Franz (or Friedrich) Mesmer (1733–1815), claimed that he could cure people of diseases by stroking their bodies with magnets, and that he could make them insensible to pain during an operation. Mesmer's claims were investigated. He was driven first out of Vienna and then out of France, but his name is perpetuated in the term "mesmerism," now more commonly spoken of as hypnotism.

On the vaudeville stage, hypnotism is often featured, and there it is sometimes little more than a trick. However, it is possible for a hypnotic state to be induced in some people by persons who know how to do it. Hypnotism raised a flurry of excitement, but its use did not substantiate the claims of Mesmer. As a means of preventing pain during operations, it is almost negligible today. Its use is confined largely to experimental work in the study of mental activities. But indirectly at least, as will be seen later, the interest aroused by Mesmer had a connection with the early use of ether as an anesthetic. People clamored to be mesmerized, but were not willing to try ether.

As a chemical substance, ether was known in the middle of the sixteenth century under the name of sweet oil of vitriol. In 1730 it was called "ether." Unfortunately, the word "ether" is used by physicists with an entirely different meaning, and the presence of the two words in the language has led to some confusion. The ether used in surgery is a volatile liquid made by the action of strong sulphuric acid on alcohol.

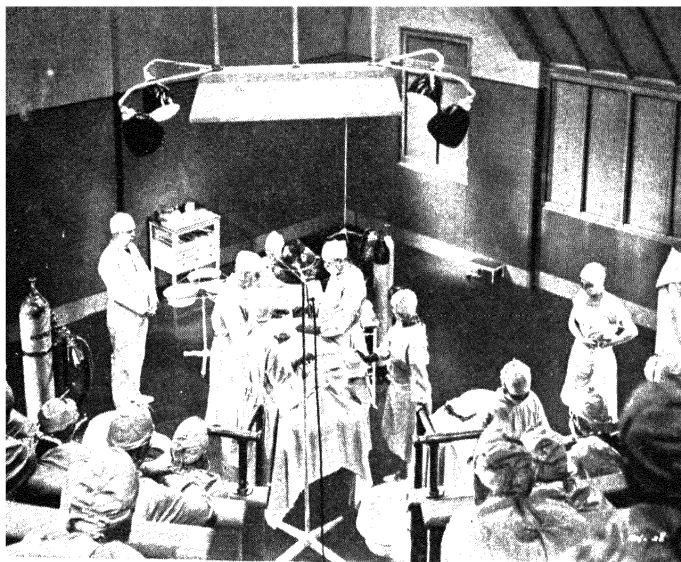
Ether was first used in England in the treatment of tuberculosis and asthma. In fact, the Medical Pneumatic Institute was organized as a place where patients might come to inhale this substance. The institute was not a success from the point of view of curing sufferers, but an indirect result of its existence is of importance. Sir Humphrey Davy was at one time connected with the establishment, and he began to experiment with nitrous oxide, popularly called laughing gas.

By the beginning of the nineteenth century he had found out that this gas relieved headaches, and he even

went so far as to have a wisdom tooth pulled after he had inhaled some of it. His personal experience led him to make the prophecy that it could be used to relieve the pain of surgical operations.

Besides its use as a headache cure, nitrous oxide was known for a number of years chiefly for its peculiar effect on the nervous system of the person who inhaled it. A few whiffs of it might make a person laugh hilariously and become talkative. It was not uncommon for a man who knew about this gas to lecture about it and take a tank of it with him so that he could demonstrate its effects before his audience. In 1821, a lecturer who lived in Utica, New York, took a tank of nitrous oxide to the near-by city of Rome and gave a lecture on its effects. After the lecture he found that a young man, eager to see what would happen to him if he inhaled the gas, had gone into a back room where the tank was and helped himself. He was found unconscious. It seems strange that no one who knew about this incident put the knowledge into practical use and tried nitrous oxide as a general anesthetic.

While demonstrations of nitrous oxide continued to be popular at public entertainments and at private parties, ether began to vie with it as a means of producing a state resembling intoxication. It was only a step from this worthless use of ether to a practical use, but it took courage to administer enough of the substance to cause complete insensibility. It is not surprising when one considers how many people were familiar with the effect of small doses of ether that within a period of four years two men, hundreds of miles apart, should have administered it for operations.



A MODERN SURGERY

In such a room every possible aseptic and antiseptic measure is taken to protect the patient (*Keystone View*)

After a careful study of all the circumstances, it is now conceded that, in 1842, Crawford W. Long, of Georgia, performed the first operation in which the patient was under the influence of ether. On the other hand, in 1846, William T. G. Morton administered ether at the Massachusetts General Hospital. Morton's use of ether received wide and immediate publicity and, therefore, came to the attention of the medical profession. Naturally, when Morton's claim of priority became known in the South, Long and his friends resented it, although Long had never attempted to publicize his achievement which had had no apparent effect on surgical practices. The compromise mentioned above was finally reached, by

which both Long and Morton are given a place of honor in the history of anesthetics.

Crawford Williamson Long was born in Danielsville, Georgia, in 1815. His father, James Long, named his son for his closest friend, William Crawford, who was minister to France when Napoleon was in power. When he was fourteen years old, Long entered Franklin College, now the University of Georgia. Special permission to enter at such an early age was obtained from the president of the college, who was a friend of the boy's father. He was graduated in 1835. The next year he taught in the academy at Danielsville.

His medical career began when he read medicine in the office of Dr. George R. Grant. This was followed by a year in the Medical Department of Transylvania University at Lexington, Kentucky. Since the only way for him to go to Lexington was on horseback, he started off on the lonely trip of several weeks, with his belongings in a saddlebag.

For his last year Long went to the University of Pennsylvania, where he received his degree. There he studied under some of the greatest surgeons of the day. Next, he went to New York where he spent eighteen months as a hospital interne. He was so skillful in surgery that he was advised to enter the Navy as a surgeon, but at his father's wish he returned to Georgia and settled in the small town of Jefferson. As a matter of fact, he bought out the practice of Dr. Grant with whom he had begun his studies. Dr. Grant later became a well-known physician in Memphis.

Jefferson at this time was a small town 140 miles from the nearest railroad. With unimproved roads and the long

distances that he had to travel with horses, the doctor's life was anything but an easy one. In the biography of her father, Frances Long Taylor gives a very graphic picture of life in Georgia at this time.

Long had been interested in the effects caused by the inhalation of nitrous oxide and ether while he was a medical student. After he settled in Jefferson, this interest was revived when some friends, who had seen a lecturer demonstrating laughing gas, asked him if he had any of it that they might try. He had no gas, but he mentioned the fact that he had inhaled ether and told them of its effects.

In spite of the fact that Long had been taught that ether was dangerous, he believed it could be used during operations. Among his patients was James Venable, who had two small tumors on the back of his neck. Venable hesitated to have them removed because he dreaded the pain. Dr. Long knew that Venable had inhaled ether for its exhilarating effects, and he suggested that he believed the operation could be performed without pain, if ether were used. One thing made Long confident. While under the influence of small amounts of ether, he had received bruises which he did not feel until the effects of the ether had worn off. Venable consented to try ether, and the operation was performed on March 30, 1842.

The ether was put on a towel and held loosely over the patient's nose and mouth. When he did not respond to the prick of a pin, Long began the operation. The charge was two dollars for the operation and twenty-five cents for the ether.

Dr. Long continued to use ether whenever he had an opportunity. However, these opportunities were few.



STATUE OF CRAWFORD W LONG

This statue in Statuary Hall in Washington commemorates Long's use of ether as an anesthetic in 1842.

There were not many accidents in the agricultural section where he lived. Besides that, some people were afraid to lose consciousness; others had religious scruples against anything to alleviate pain. Furthermore, the fame of Mesmer had reached the United States, and remarkable tales were spread about the efficiency of mesmerism for operations. Dr. Long himself had little faith in mesmerism.

After Morton used ether in Massachusetts, the controversy already mentioned broke out. Dr. Long became so sensitive on the subject that he did not want anyone in his household to mention the word anesthesia. In 1864, when a raid was threatened on Athens, where the doctor was living, he sent his family to a plantation off the main road. As his daughter, then a young girl, was leaving the house, he entrusted her with a glass jar containing among other things a roll of papers which he considered to be documentary proof of his discovery of the efficiency of ether as an anesthetic. He made the girl promise to bury the jar as soon as she reached the plantation. This she did. The threat of the raid passed, and the jar was unearthed and taken home again.

Dr. Long practiced medicine about forty years. He died in 1878. Since his death, several tablets and other memorials have been erected in his honor. Among them is a statue in Statuary Hall in Washington, D. C., which was unveiled in March, 1926.

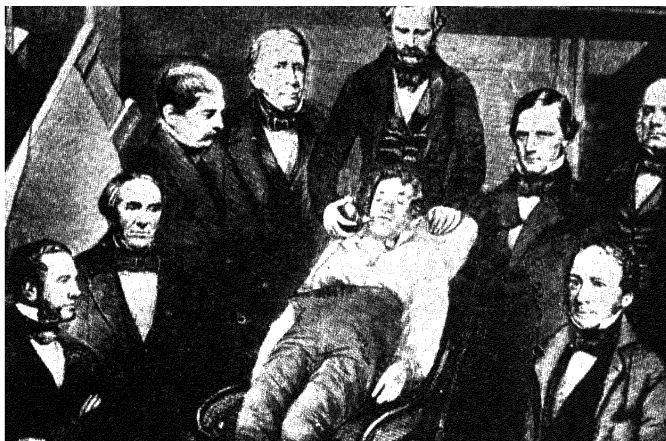
In Massachusetts, the use of ether was also connected with nitrous oxide. Horace Wells, (1815-1848) a dentist, attended a lecture where the effects of laughing gas were demonstrated. He was so much impressed that he had the gas administered to himself so that a tooth could be pulled. Satisfied that it could be used in surgery, Wells

tried to interest surgeons, but a public demonstration turned out unsuccessfully. However, he used the gas in his dental work.

For three years Wells had an associate, William T. G. Morton, who was born in Charlton, Massachusetts, in 1819, and who had studied dentistry in Baltimore. After they dissolved partnership, Wells moved to Hartford, Connecticut, in 1843. The following year Morton enrolled in Harvard as a medical student. As it was customary at this time for a young man studying medicine to associate himself with an established physician, Morton entered the office of Dr. Charles Thomas Jackson as his assistant.

In 1845, Morton was visited by Wells, who came to Boston hoping to interest someone in producing nitrous oxide for use as an anesthetic. Wells and Morton discussed the subject at length, but Morton felt that he did not understand chemistry well enough to start manufacturing the gas. He went to his superior, Dr. Jackson, with some questions about nitrous oxide. Dr. Jackson's curiosity was aroused, and he wanted to know why Morton was so much interested in the gas. The young man explained his interest, and Jackson pointed out that ether, which was easier to obtain, had effects very similar to those of the gas he and Wells considered using.

Morton began to experiment with ether. He caught flying insects and big green caterpillars and tried ether on them. The family dog, Nig, was also used as an experimental animal. By September, 1846, he had enough confidence in the substance to inhale a sufficient quantity to make himself unconscious for several minutes. Since he suffered no ill effects, he determined to



MORTON ADMINISTERING ETHER

William T. G. Morton administered ether for an operation at the Massachusetts General Hospital in 1846. The surgery, one of the best at that time, seems very crude compared to a modern surgery (*The Bettmann Archive*)

try it again and have someone pull a tooth while he was unconscious. This was unnecessary, for a man with a bandaged face appeared in his office and wanted to be mesmerized so that Morton could extract an aching tooth. Morton convinced the man that he had something better than mesmerism and gave him ether. The extraction of the tooth occurred on September 30, 1846. Morton was so delighted with the use of ether that he went to see Dr. John C. Warren of the Massachusetts General Hospital. Warren gave him permission to try ether in the hospital.

On October 16, 1846, Morton arrived at the hospital and before a large number of people administered the ether with complete success. The following day, ether was

used for another operation, and on the seventh of November an amputation was performed without any pain to the patient. A new era in surgery had begun.

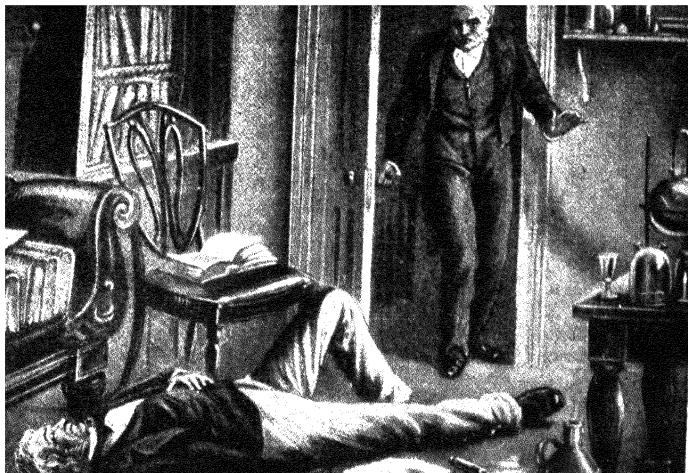
There is nothing to be gained by recounting the legal trouble that arose when Morton tried to patent the use of ether, or the bitter controversy about priority. Morton died in 1868. His death was hastened by the strain and unpleasantnesses connected with his legal difficulties and quarrels.

One would expect that surgeons would have used ether as soon as they heard of it. This was not the case. In spite of the publicity that followed its use in the Massachusetts General Hospital, more than a year passed before some of the large city hospitals tried it.

Dr. Henry Jacob Bigelow, who was one of the witnesses at the operation in Boston, took some ether to England. There, on the nineteenth of December, it was given to a patient before pulling a tooth.

Surgeons from the United States who served in English hospitals at the time of the World War noticed how much more frequently chloroform was used than ether as an anesthetic. One reason for this can be traced to the fact that ether did not gain popularity there in the early days of anesthetics, whereas chloroform did.

A Scotch doctor, Sir James Simpson, began the use of chloroform in England. He knew about ether; he had used it in 1847, but did not like its irritating effects. Early in his medical training Simpson was horrified by the suffering he saw in hospitals. From that time on, the desire to relieve pain was one of the greatest influences in his life. His search to find an anesthetic to his liking was carried on in an unusual way. He inhaled the fumes



EARLY EXPERIMENT WITH CHLOROFORM

An artist's conception of one of the episodes that led to the use of chloroform as an anesthetic (*Brown Brothers*)

from every substance that he thought might be used. It is a wonder that his health was not impaired, for on one occasion, at least, the fumes were dangerous. After he became acquainted with ether, he asked a chemist if he could not suggest a substance that would have a less disagreeable odor and, therefore, be less irritating. The chemist suggested chloroform.

Simpson procured some chloroform, but the liquid was so heavy that he did not think it would vaporize easily. However, a few evenings later, he and his two assistants were sniffing different substances as they frequently did in the evening. Mrs. Simpson and other people were present in the room. Chloroform was mentioned, and Simpson produced the bottle he had had for several days but which he had not opened. The three men, one

after another, inhaled the fumes, and one after another collapsed on the floor. Simpson had found what he was searching for. On November 15, 1847, the first public trial of chloroform was made at the Royal Infirmary. The results were very satisfactory.

The opposition to the use of anesthetics was more bitter in England than in the United States. Many people believed that pain was sent by God, and that no mortal had a right to alleviate it by making a person unconscious. Opposition gradually died down, and chloroform came into general use.

Sir James Simpson was born at Bathgate, Scotland, in 1811. Incidents in a single family sometimes show with striking effect how beliefs may change. Simpson's grandfather buried a cow alive because he thought that by doing this he could stop the spread of a disease that was killing his cattle. One of Simpson's uncles, when he bought a new farm, fenced off a corner of a field with a stone wall. This piece was given to the spirit of evil who, it was hoped, would be satisfied and leave the crops on the rest of the farm alone. Simpson, of course, outgrew such superstitions, but they lingered in the minds of many people. It is not surprising, therefore, that some curious reasons were given against the use of chloroform when it was first employed.

Simpson went to Edinburgh University and received his medical degree in 1832. His thesis for the degree was on the subject of inflammation and was written in Latin. Not long after this, theses in English were accepted from medical students.

Three years after receiving his degree, Simpson was appointed senior president of the Royal Medical Society

of Edinburg. This was a great honor for a twenty-four-year-old physician. In 1840 he became a professor in the University of Edinburgh. During the same year that he introduced chloroform as an anesthetic, he was appointed one of Queen Victoria's physicians for Scotland. Simpson was created a baronet in 1866. On his crest he had the rod of Aesculapius, the Greek god of healing, and the motto *Victor Dolore*, which may be translated as "conqueror of Pain." Sir James Simpson died in 1870 and was honored with a public funeral.

Ether, chloroform, and nitrous oxide are general anesthetics; that is, when they are administered, the patient is unconscious during the operation. Anesthetics which deaden pain in part of the body but do not cause unconsciousness are called local anesthetics. Novocain, so commonly used by dentists, is an example of a local anesthetic.

During the last half century the number of substances which have come into use to produce sleep, quiet nerves, deaden pain, and produce complete unconsciousness is almost unbelievable. In 1936 there were more than two hundred of these substances, and others have come on the market since. Many of these substances are so individual in their properties that they are only suitable for very specific purposes. Surgeons and the public are becoming less antagonistic to the use of new substances. Biologists are finding that the substances that affect only local areas, or a few nerves at a time, are making it possible to learn more and more about the nervous system.

The men who have learned to conquer pain by using chemical substances have saved untold numbers of lives and made existence bearable for millions of others.

Hints for Further Reading

GWATHMEY, JAMES T., *Anesthesia*.

LEBENSOHN, JAMES E., "The Story of Local Anesthesia,"
Hygeia, XII (Nov. 1934), 973-974.

MURRAY, ROBERT H., *Science and Scientists in the Nineteenth Century*.

"Ninety Years of General Anesthesia," *Literary Digest*,
CXXII (Oct. 24, 1935), 34-35.

TAYLOR, FRANCES L., *Crawford W. Long and the Discovery of Ether Anesthesia*.

Every Green Leaf Is a Chemical Factory

INGENHOUSZ, SACHS, WILLSTÄTTER, AND CONANT

FOOD is one of the necessities of all organisms. For this reason, the source of food is a subject that demands investigation. It is a well-known fact today that green plants alone are capable of manufacturing food from inorganic raw materials. It is an equally true statement that all the energy produced from the burning of wood and coal comes directly or indirectly from plants. What chemical processes go on in a green plant that makes it so different from an animal? This question cannot be completely answered, but since the beginning of the century a great deal has been learned about food making, or, as it is more technically called, the phenomenon of "photosynthesis." The word itself means "a putting-together by means of light."

Some of the problems connected with the understanding of photosynthesis were recognized several centuries ago. However, a number of circumstances existed that delayed an intensive study of the process. It would be natural to expect that the botanists would be the ones

who would want to know how food was made, but many of them were so busy classifying plants that they did not have time for anything else. Besides that, photosynthesis is very largely a problem in chemistry, and few botanists were trained chemists. As a matter of fact, the understanding and techniques of organic chemistry have only recently been developed to the point where they can be successfully employed in such a delicate study as that of photosynthesis.

One of the early experiments on the nutrition of plants was carried on by Jan Baptista van Helmont, who was born in Brussels, in 1577. Helmont studied theology in a Jesuit college and then turned to medicine. After he received his degree, a large income made it unnecessary for him to earn a living. He did practice medicine to some extent as a form of charity without charging his patients any fees, but most of his time was spent in writing and carrying on experiments in different lines. In his writings he showed the influence of Paracelsus (see page 179) and like him attempted to break down the authority of Aristotle and Galen (see pages 10 and 179). Jan Baptista van Helmont died in 1644.

While most of Helmont's work had little permanent effect on the development of science, it is worth while to notice that he carried on experiments in fermentation. His study of fermentation made him conclude that the gaseous substance produced during the process was the same as that produced when charcoal burns. In his mind this substance was different enough from air to deserve a name, so he called it "gas sylvestre." Previously, he had invented the word "gas" which he used in a general way to distinguish substances that were not visible, but which



THE LABORATORY OF JAN BAPTISTA VAN HELMONT

This picture shows an alchemist presenting Helmont with a "philosopher's stone." Many of the experiments Helmont performed were in the line of alchemy and so were of little permanent importance. His experiment with the willow tree, however, showed a real scientific attitude. (*The Bettmann Archive*)

differed from air. During his investigations he also concluded that digestion was a form of fermentation, although he had no understanding of the actual chemical processes involved.

One of his experiments on the growth of plants stands out as an early attempt to determine how plants are nourished. To Helmont, water was the most important substance on earth. He believed that all things were derived from it. In order to prove his point, he set up an experiment to demonstrate that plants were formed from water. Into a large receptacle, he put 200 pounds of dry earth. In this he planted a young willow tree that weighed 5 pounds. He watered it regularly with rain water during a period of five years. At the end of this time he found the tree weighed 164 pounds. He dried the earth and weighed that. When he found that the earth weighed only 3 ounces less than it had at the beginning of the experiment, he naturally came to the conclusion that the water was responsible for the great increase in weight of the tree. In one sense Helmont was right. The tree had used the water, but little did he suspect the part which the carbon dioxide in the air had played in combining with some of the water to form the sugars used by the plant for its growth.

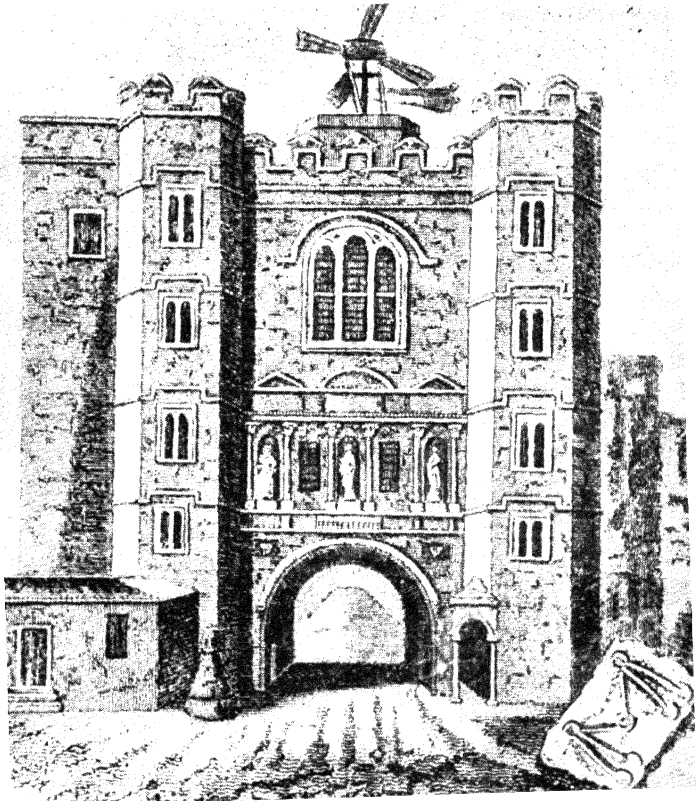
A little later Marcello Malpighi, an Italian (see page 42), and Nehemiah Grew, an Englishman (see page 164), independently observed small openings on the surfaces of leaves. These are now called "stomates," from the Greek word meaning "mouth." Malpighi rightly assumed that these openings had to do with the respiration of plants.

More knowledge about the the function of leaves was added by Stephen Hales, who was born in Beckesbury, England, in 1677. Like Helmont, Hales studied theology. After serving in several parishes he became the vicar of Teddington. Though busy with church affairs, Hales found time to be active in the Royal Society (see page 49). When an appeal was made to the society to investigate the high death rate in prisons, he was one of the committee to study the problem. A ventilator which he invented was installed in Newgate Prison. Before its installation seven or eight people died there every week of a disease called "jail fever." The death rate dropped to about two a month from this disease, after better ventilation was established. The ventilator was improved by other men, including Captain James Cook, the explorer, and was installed in the holds of ships.

Hales's interest in physics led him to carry on investigations with plants in a really scientific way. By using mercury gauges, he studied the pressure of sap in growing vines. Other experiments made him conclude that some part of the air was used by the plants in building up tissues. He was also of the opinion that sunlight played a part in this building. Of course, he had no definite knowledge of the actual role of carbon dioxide and sunlight in the manufacture of sugars. However, if nothing more, Hales showed his scientific ability by suggesting a possible relation of the two to the development of a plant.

In 1727 Hales published the results of his studies on plants in a book titled *Vegetable Staticks*. He died in 1761.

Events in the last half of the eighteenth century changed the entire future of chemistry and, therefore,



STEPHEN HALES'S INVENTION

A ventilator designed by Stephen Hales in 1752 materially reduced the death rate in old Newgate Prison (*The Bettmann Archive*)

some phases of the study of biology. Joseph Priestley discovered oxygen, and Antoine Lavoisier by his experiments removed the mystery from the process of combustion. The work of these two men and their contemporaries, among whom were Henry Cavendish (1731–1810) and Karl Wilhelm Scheele (1742–1786), freed chemists from

strange ideas and explanations that had come down from the early days of alchemy. How was the study of living things affected by this new conception of chemistry? For one thing, a possibility was now open to explain respiration and nutrition as chemical processes.

Oxygen is used by all organisms during respiration. Until this gas was isolated and recognized as a substance with definite chemical properties, no great advances could be made in understanding its use in organisms. In 1774 Joseph Priestley heated an oxide of mercury by focusing the rays of the sun on it with a lens, as a boy today would set match heads on fire. The oxide underwent a change in color, and Priestley found that the gas given off during the heating was different from air. This gas was named "oxygen" by Lavoisier.

Priestley carried on several experiments which might be thought of as crude beginnings of the experimental method of studying respiration and photosynthesis. He found, for example, that rats in a closed jar soon died. However, after green plants had been kept in this jar for some time, the air was changed so that rats could live in it for a little while. Curious to know why rats died in a closed container, Priestley made tests and found that the jar contained a large amount of carbon dioxide, then called "fixed air."

Joseph Priestley was not a scientist by profession; he was a minister with a hobby. Chemistry was that hobby. He was born at Fieldhead, Yorkshire, England, in 1733. He carried on his experiments because he wanted to know the how and why of things. He was a man of decided opinions and aroused so much feeling against himself by his political ideas that he thought it advisable

to come to America. He settled in Northumberland, Pennsylvania, and lived there until he died in 1804.

One hundred years after the discovery of oxygen, in 1874, a number of scientists met at Northumberland to hold a service of commemoration. As a result of this service, some of the men who were present developed the idea of forming a chemical society. This grew into the American Chemical Society, which today is one of the largest scientific societies in the world.

In spite of the fact that Priestley isolated oxygen, proved that rats gave off carbon dioxide and that green plants changed the composition of air confined in a jar, he did not understand the relationship between these facts. Antoine Lavoisier, by a series of brilliant experiments, was able to fit one fact with another until he explained combustion as a union of oxygen with another substance. He then recognized that the carbon dioxide given off during respiration was a product of oxidation within the body.

Lavoisier was born in Paris, in 1743. He was guillotined in 1794 by the Terrorists because of his political affiliations.

During early experimentation the different processes carried on in a leaf were not recognized. As in all living things, respiration is carried on in a green plant. Oxygen is used, and carbon dioxide is given off. But while food is being made in a green plant, carbon dioxide is used and oxygen is given off. It is not surprising, under these circumstances, that different experimenters obtained different results. If the plants were not in sunlight, no oxygen was given off. On the contrary, in sunlight the amount of oxygen was in excess of the amount of car-

bon dioxide These varying observations led to dispute and confusion. A Dutch physician, Jan Ingenhousz, should be given credit for clearing up some of the difficulties in interpreting the results of experiments on plants

Ingenhousz was born at Breda, Holland, in 1730 He studied medicine at Leyden and became particularly interested in smallpox In 1768, he was summoned to Vienna to combat an epidemic of smallpox which was raging. He met with so much success in his treatments that Maria Theresa gave him a yearly income This enabled him to spend all the time he wanted on his



JAN INGENHOUSZ

Ingenhousz made valuable contributions to the understanding of photosynthesis (*The Bettmann Archive*)

experiments with plants Priestley's experiments showing that plants change the composition of the air surrounding them had made Ingenhousz ask himself questions he wanted to answer by his own experimentation.

The results of Ingenhousz's experiments may be briefly summed up as follows: plants can change the composition of air if they are in the sunlight, for they exhale oxygen under these circumstances; sunlight does not have any effect on the composition of air containing a relatively large amount of carbon dioxide unless plants are present; during the night plants give off carbon

dioxide; an excess amount of carbon dioxide is poisonous to plants as well as to animals; and the leaves are the parts of the plant which give off both the carbon dioxide and the oxygen.

In 1796, Ingenhousz published *An Essay on the Food of Plants and the Renovation of Soils*. In this he stated the facts which are now expressed by the carbon and oxygen cycle in biology textbooks. Three years after the publication of this essay, Ingenhousz died while on a visit in England, where he was making a study of inoculation and vaccination as a means of producing immunity to smallpox.

During the year following the death of Ingenhousz, Jean Senebier (1742–1809) published a book called *Physiologie végétale*. Senebier, a native of Geneva, Switzerland, found time, while a pastor of a church and later as a librarian, to conduct experiments on the effect of light on plants. In his experiments he used double-walled bell jars. He filled the spaces between the walls with solutions of different colors and then put the jars over growing plants. He found that the red rays of the spectrum caused the greatest activity in the plants. His observations were of most importance at that time because they showed that it was the light and not the heat from the sun that was the necessary stimulus for growth.

The understanding of plant nutrition was greatly advanced by another native of Geneva, Nicholas de Saussure, who was born in 1767. Nicholas's father was a well-known geologist with an interest in botany. The son accompanied him on trips of exploration in the Alps and in this way received valuable training in observation. Later geology became secondary to his interest in physics and chemistry.

Saussure was among the first scientists to take full advantage of the quantitative and systematic methods that had been introduced into chemistry by Lavoisier. Applying these new methods to the study of plants, he conclusively proved many things that Ingenhousz had observed and made the findings very definite. It is one thing to say that a large amount of carbon dioxide is injurious to a plant, as Ingenhousz had said. It is another thing to say, as Saussure stated his facts, that when the carbon dioxide increase is greater than eight parts in a hundred, it is injurious to plants kept in the shade or in darkness. The exactness with which Saussure stated the results of his experiments showed a really scientific attitude in the modern sense of the word.

While carrying on further experiments, Saussure found that the carbon taken into a plant would not account for the increase in dry weight of the plant. He concluded that some water must have been changed so that it became a part of the substance of the plant. It is now known that the carbon dioxide of the air and water from the soil do unite to form a new compound which is stored in the plant tissues as starch. At the same time, Saussure maintained that, in spite of the fact that the mineral substances taken into the plant are comparatively small in amount, they are essential to its normal development. He also concluded that the nitrogen used by plants did not come from the air.

There was one point which Saussure misinterpreted. In much of his work he used plants with red leaves. He did not know that chlorophyll was present in such leaves, and, therefore, he came to the conclusion that it was not necessary in food making.

Many men might be mentioned who carried on experiments that added further information about the sources



JEAN BOUSSINGAULT

Boussingault, an agricultural chemist, showed the importance of soluble nitrates in the growth of plants (*The Bettmann Archive*)

of the raw materials of photosynthesis. Three men who made lasting contributions were Dutrochet, Boussingault, and Liebig.

Henri Dutrochet (1776-1847) was a surgeon attached to the French Army during a campaign in Spain in 1808 and 1809. Not long after this he retired from active practice and went to Touraine where he devoted himself to study and experimentation. Dutrochet made a thorough study of the phenomenon of osmosis, thus

contributing knowledge about absorption of water through the roots of plants. In a treatise he gave the first correct interpretation of the passage of gases through the stomates into the spaces in the leaves. He also stated that only cells containing chlorophyll could manufacture food.

Jean Baptiste Boussingault (1802-1887), a French agricultural chemist, and Justus von Liebig (1803-1873), working independently, showed the importance of soluble nitrates to the development of plants. Boussingault was educated in a school of mines. After finishing his studies, he went to South America to investigate the practicability of reopening abandoned mines there. He

stayed in Bolivia longer than he anticipated because he took part in the struggle by which this country gained its independence. When he returned to France, he became a professor of chemistry at the university in Lyons. In 1839 he was appointed a professor of agriculture. Bous-singault did a great deal of experimentation on the nutritive values of different foods for domestic animals. His two-volume *Traite d'economie rurale* was published in 1844. In his *History of Botany* Sachs says that Boussingault should be considered the founder of modern methods of experimentation on plants.

Liebig is well known as a chemist. His work made possible the intelligent use of fertilizers so that large areas of exhausted soil could be efficiently cultivated.

After it was determined what raw materials were needed by a plant, the next problem was to discover by what means and into what substances these materials were converted in the plant. Obviously the answer must be found by using chemical tests and the microscope. Julius von Sachs, a plant physiologist, conducted well-planned experiments along these lines. He studied the starch granules in cells. Starch had already been identified in cells by von Mohl, who has been mentioned for his study of protoplasm (see page 74). Starch is not the first product formed in leaves from carbon dioxide and water, but since it is not soluble, it is the first one that can be seen. Sachs studied starch granules in the chlorophyll-containing cells where it is made and in the tissues of stems and roots where it is conveyed for storage.

Although this work was important, today Sachs is perhaps better known in connection with his work on the reactions of plants to stimuli and as the author of a

history of botany dealing with the period from 1530 to 1860. Julius von Sachs was born in Breslau, in 1832.



JULIUS VON SACHS

Today Sachs is probably best known for his history of botany and his work on the reaction of plants to stimuli (*Science Service*)

His family was very poor, and if the poverty-stricken youth had not been helped by Purkinje, he could not have completed his education. It happened that Sachs and the sons of Purkinje were in the same school. In 1850, when Purkinje went to Prague, his interest in Sachs was sufficient to have him come there to work as an assistant and draughtsman. This help made it possible for Sachs to be graduated from the University of Prague in 1856. For a time he taught in a school of forestry at Tharand. From there he went to Bonn, and in 1868 he was called to Würzburg. He stayed there for the remainder of his life although he was offered professorships elsewhere. He died in 1897.

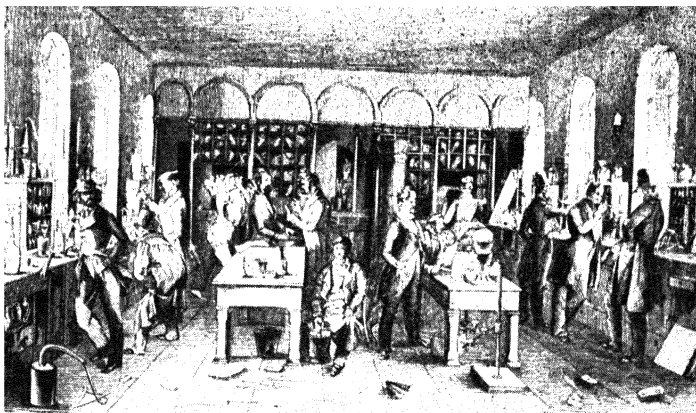
The textbooks in botany written by Sachs were the best of those published in the nineteenth century. Besides *The History of Botany*, two of his books were *The Handbook of Experimental Physiology of Plants* and *Textbook of Botany*. In reading histories of science, one finds Sachs quoted again and again.

Recent investigations in photosynthesis lose some of their significance unless one realizes the changes in

scientific thought that followed the first synthesis of an organic compound. This compound was urea, and it was produced by Friederich Wöhler in 1828. Until this time it was believed that substances in living organisms were different from those in dead matter, like sand and rocks. It was possible to analyze the substances found in living organisms, but it was believed that it was impossible to produce them from nonliving matter. In 1828, Wöhler warmed a compound known as ammonium cyanate. To his surprise he found that the resulting substance was identical with urea, a nitrogenous waste given off by the body.

This simple experiment caused a revolution in chemistry and resulted in the development of organic chemistry. If one substance found in living things could be made in the laboratory, why not others? Attempts at synthesizing all kinds of substances began and still continue to the present moment. In chemistry the word "synthesize" means "to put together" two or more substances to form a compound. Thus water is synthesized when an electric spark is passed through a chamber containing a mixture of oxygen and hydrogen.

It is a curious fact that to Wöhler the preparation of urea was only a remarkable chemical accomplishment from the theoretical point of view. Since the World War, the preparation of urea has become of great practical importance. Contrary to what might have been expected, army surgeons found that wounds which were not dressed until maggots of flies had developed in them frequently healed faster than wounds more promptly treated. Investigation of this seemingly contradictory situation proved that a substance given off by the maggots



THE LABORATORY OF JUSTUS VON LIEBIG

This picture was published in a German newspaper in 1848 (*The Bettmann Archive*)

helped in the healing process. This substance suggested the use of urea, which is now made from ammonia and carbon dioxide and used with excellent results in wounds where pus is forming.

Wohler and Liebig were close friends and conducted many investigations together. The work of these men and the students who found places in their laboratories made a lasting mark in the science of chemistry. Wohler died in 1882. He had been born near Frankfort on the Main in 1800. Although a doctor of medicine, he did not practice his profession but became a professor of chemistry.

It often happens that when a professor goes from one university to another he takes a pupil or an assistant with him. When Liebig left the University of Munich, he was succeeded by Adolf von Baeyer whose name is noted among chemists for the production of synthetic indigo.

Emil Fischer, who was working with him, followed him to Munich to continue his chemical researches. The work of Fischer gives a striking example of the way in which organic chemistry became a tool that could be used in solving the biological problem of how plants manufacture food.

Emil Fischer was born in Rhenish Prussia, in 1852. About 1875 he discovered a substance, phenylhydrazine, which made it possible for him to synthesize some sugars, such as grape and fruit sugar, from inorganic substances. This same substance proved to be an effective reagent in testing for sugars in other substances and in isolating them. As has been mentioned, starch is not the first product of photosynthesis. Sugars are formed before starch, but sugars are soluble and do not form grains in the tissues which can be detected by the use of the microscope. The work of Fischer, therefore, made it possible to gain considerable information about the presence and kinds of sugars to be found in plant tissues.

During his lifetime Fischer held professorships in several universities. In 1892 he became professor of organic chemistry in the University of Berlin, and in 1902, he received the Nobel Prize (see page 153) in chemistry. This was the same year in which Ronald Ross received the prize in medicine for his work on malaria (see page 216). Emil Fischer died in 1919.

Baeyer attracted other chemists besides Fischer to his laboratory in Munich. Among them was Richard Willstätter. When the Research Institute at Berlin was opened in 1911, Fischer was the principal speaker, and he showed the assembled scientists a sample of pure chlorophyll prepared by Willstätter. In 1915 Willstätter re-

ceived the Nobel Prize in chemistry for his study of the colors in plants. It may seem odd that a person should be given such an honor for the study of colors, but this is a matter of great importance in understanding the chemical functions of an organism. For example, Willstätter analyzed the blue coloring matter of cornflowers and the red coloring matter of roses. The cornflower, a garden plant in Europe, is valued for its beautiful blue-colored flowers. It might be expected that the blue and the red pigments would be of entirely different chemical composition; but no, Willstätter found that the same pigment is present in each. The difference in color is due to the fact that the pigment in one is in an acidic medium and in the other in a basic medium. More surprising than that, he found that the green coloring matter in plants, the chlorophyll, and the red coloring matter in human blood, hemoglobin, are chemically very much alike.

It has been said that we owe a large part of the present knowledge of chlorophyll to Willstätter. What did he find out? For one thing, he discovered that the chloroplasts, the tiny green bodies in plant cells, are of a mixture of proteins and other substances with four pigments. These pigments are called "chlorophyll-a," "chlorophyll-b," "carotin" which is orange-red in color, and "xanthophyll" which is yellow. Carotin is the substance which gives carrots their color. It is believed that this substance when acted upon by an enzyme is changed into vitamins.

Willstätter's investigations have not been confined to the pigment substances. In 1933, when he was awarded the Willard Gibbs Medal by the Chicago Section of the American Chemical Society, he talked on enzymes. He



RICHARD WILLSTATTER

The medical profession is familiar with Willstatter's name in connection with anesthetics. The botanist knows him as the chemist who extracted chlorophyll in a pure form. In the picture Willstatter is shown as very much pleased with the Willard Gibbs Medal awarded to him. (*Wide World*)

stated that every animal and plant cell is ruled by enzymes, which are the most delicate chemical reagents in the world. He believes that it is these enzymes which select and change the food substances brought to the cell in such a way that the cell may continue to live.

Along a different line, Willstätter has worked with substances which deaden the senses, such as cocaine, and has made possible the production of synthetic anesthetics. In connection with Carl Duisberg, he produced tribromethanol, commercially known as avertin. This compound is now widely used in hospitals as a basal anesthetic.

Richard Willstätter was born in Karlsruhe, Germany, in 1872. He was educated in that city and at Nuremberg and Munich. In 1912 he became the director of organic research at the Kaiser-Wilhelm Institut. At the beginning of the World War, he entered the aviation service but was told by government officials to return to his laboratory and continue his investigations. Besides the Nobel Prize and the Willard Gibbs Medal, Willstätter has been the recipient of many honors. The Davy Medal of the Royal Society was presented to him in 1932.

Another German scientist who should be mentioned in connection with photosynthesis is Otto Warburg, a director of the Kaiser-Wilhelm Institut. He was born in Freiburg, in 1883. He studied chemistry and medicine and has been particularly interested in respiration.

In 1919 Warburg devised a method of determining the rate of photosynthesis in one of the uni-cellular green algae. His experiments were conducted with so much exactness that he could determine how much light was necessary to cause a molecule of carbon dioxide to be

changed in a cell during photosynthesis. He was awarded the Nobel Prize in chemistry in 1931.

When one considers the quantitative exactness that has come into scientific work since Helmont carried on his experiments in terms of pounds and ounces, one readily understands why it is difficult for a person who is not a trained scientist to follow some of the experiments. Organic chemists, who are working on substances found in living things, have very definite objectives. First, they isolate the substance in a pure form. Then they analyze it to find its exact composition. Finally, they try to make the compound, synthesize it, in the laboratory. The synthesis is, in a way, the final test of their accuracy in analyzing the substance. If they can make the compound out of other substances, they have proved the correctness of their analysis, and they may be able to determine the exact arrangement of the atoms in the molecules of the compound.

Chlorophyll was extracted in a pure form by Willstätter. Its chemical composition is known. The arrangement of the atoms within the molecules has been studied very intensively by Hans Fischer, a German, and James Bryant Conant, now the president of Harvard University.

Hans Fischer was born in Hoechst on the Main, Germany, in 1881. He studied in several universities and received a degree in medicine from the University of Munich in 1908. Since 1921 he has been a professor of organic chemistry in a technical school in Munich. Hans Fischer spent fifteen years before he finally prepared porphyrin, a substance closely related to chlorophyll, although not identical with it. A chlorophyll molecule is believed to have a nucleus of porphyrin plus other atoms.

Hans Fischer began his research work by studying the pigment in bile, a secretion of the liver. From this he turned to chlorophyll and hemoglobin, and in 1931 was awarded the Nobel Prize in chemistry for his work in the field of biochemistry.

James Bryant Conant is a world authority on the chemistry of chlorophyll and has worked out a possible molecular structure for this substance. As might be expected, because of the close connection between the two substances, he has done much research on the hemoglobin of the blood.

When Conant was made president of Harvard, an article about him stated that he was one of the first important organic chemists to have been trained entirely in this country. This statement is significant because it indicates that the influence of the great German organic chemists was strong enough until the end of the first decade of this century to draw the most serious students of chemistry to that country.

James Conant was born in Dorchester, Massachusetts, in 1893. Even while a student in the Roxbury Latin School, he showed unusual ability in chemistry. He was graduated from Harvard in 1914 and received his Ph.D. in 1916. One of the professors under whom he studied was Theodore William Richards, a Nobel Prize winner in chemistry. Dr. Richards later became his father-in-law.

For two years during the World War, Conant was connected with the Chemical Warfare Service, with the rank of major. Before the war many important medicines containing arsenic were imported from Germany. When this supply was cut off, Conant developed methods for making these medicines in the United States. He was

also in charge of the research work done on mustard gas. After the war he returned to Harvard as an associate professor and in 1925 was made a full professor of organic chemistry. His textbooks in this field are widely used.

The choosing of Dr. Conant to be president of Harvard in 1933 came as a surprise to many people. He was unusually young for the presidency, and he was not particularly well known outside scientific circles. However, it was recognized at Cambridge that he was an excellent administrator in the Chemistry Department. Dr. Conant has proved to be a very efficient president, but among his friends there are some who wish that he had stayed in the field of organic research, where he had already received many honors.



JAMES B. CONANT
Before he was made president of Harvard University, Conant did some brilliant research work on chlorophyll and hemoglobin (*Wide World*)

The problems of the nutrition of plants are not yet entirely solved, in spite of the great advances in knowledge in the past fifty years. Chlorophyll must be synthesized before the chemists will be satisfied. This is only one of the problems that still baffle the research workers. Although this green substance is essential for the manu-

facture of food, the chlorophyll content of a cell does not change during the process and the ratio of chlorophyll-a and chlorophyll-b remains constant. The actions of enzymes enter into the problem, and much work must still be done on them.

There are other phases of plant nutrition that are receiving definite attention at the present time. It will be remembered that the dual functions of the leaf, respiration and food making, caused the early experimenters much trouble. It has been found that there seems to be a definite relationship between the rates of respiration and photosynthesis. Further work is needed on this point. It has been known for some time that sugar is formed before starch, but there is still doubt about the chemical changes that occur from the time the carbon dioxide and water enter the cell until they have united to form sugar.

The stomates of a leaf have naturally been the subject of much study since they were described by Malpighi and Grew. It is estimated that a medium-sized sunflower leaf has about thirteen million stomates. They are not openings that remain constant in size day after day. The guard cells on either side change the size of the openings in response to internal and external stimuli. What causes the thirteen million stomates in a leaf to open and close? Part of the answer seems to be osmotic pressure within the guard cells, which changes in relation to the amount of sugar or starch present in the guard cells themselves. The rest of the answer has not yet been found.

Research on plant nutrition is going on in other lines. Lamps have been developed to speed up the process of photosynthesis and thus hasten growth. Balanced

chemical solutions have been substituted for soil. These experiments have met with so much success that it is hinted that "water culture" may replace truck farming in crowded areas around cities.

Green plants still continue to be the only organisms which can make inorganic substances into food for themselves and animals. Every leaf is an amazingly delicate and intricate chemical factory.

Hints for Further Reading

"The Award of the Willard Gibbs Medal to Dr. Richard Willstätter," *Science*, LXXVII (April 21, 1933), 385-386.

BREUER, F. W., and FRANK C. WHITMORE, "Richard Willstätter, Willard Gibbs Medalist for 1933," *Scientific Monthly*, XXXVII (Oct., 1933), 377.

CONNORS, C. H., and V. A. TIEDJENS, *Chemical Gardening for the Amateur*.

HARROW, BENJAMIN, *Eminent Chemists of Our Time*.

"The Healing Effects of Urea," *Science*, LXXXIV (Aug. 14, 1936), Supplement, 8.

LEVENE, P. A., "The Award of the Nobel Prize in Medicine to Doctor Hans Fischer," *Scientific Monthly*, XXXII (Feb., 1931), 191-192.

MACDOUGAL, D. T., *The Green Leaf; the Major Activities of Plants in Sunlight*.

MIRSKY, A. E., "Professor Otto Warburg, Recipient of Nobel Prize in Medicine," *Scientific Monthly*, XXXIV (March, 1932), 283-287.

"Otto Heinrich Warburg," *Les Prix Nobel en 1931*, 79.

SACHS, VON, JULIUS, *The History of Botany 1530-1860*.

SCOTT, FLORA M., "The Botany of Marcello Malpighi, Doctor of Medicine," *Scientific Monthly*, XXV (Dec., 1927), 546-553.

SPOEHR, HERMAN A., *Photosynthesis*.

THWING, CHARLES F., "Harvard and Its New President" (re: James Conant), *Review of Reviews*, LXXXVIII (Dec., 1933), 40+.

WILLSTÄTTER, RICHARD, "A Chemist's Retrospects and Perspectives," *Science*, LXXVIII (Sept. 29, 1933), 271-274.

Calories and Vitamins

RUBNER, BENEDICT, MCCOLLUM, AND EVANS

A YOUNG crow must be furnished with at least one half of its own weight of food every day if it is to live. It must have more than that to develop properly. Could you eat half of your own weight of food every day? Perhaps you think you could, if you were allowed to select the kinds of food you liked best. However, if you saw this amount of food placed on a table, you would realize that you had a difficult task ahead of you.

Why do young birds need so much more food than young human beings? For one thing the rate of oxidation in the body of a bird is much more rapid than it is in a human being. One proof of this is evident in the higher body temperature of a bird. Energy is produced during this process of oxidation. To answer the question in a little different way, we may say a young bird needs more calories per day than a young human being.

Everyone has heard people talk about counting calories. What do they mean when they say they are watching their calories? Some people who talk so glibly about these heat units have no idea what the word "calorie" really means: A calorie is a unit by which a

quantity of heat is measured. It must not be confused with a degree on a thermometer. A thermometer will indicate at what temperature a kettle of syrup is boiling, but it will indicate nothing about the quantity of heat in the syrup. This unit for measuring heat is spelled with a small "c" or with a capital "C." The difference in the size of the letter indicates a difference in the size of the unit. A calorie is the amount of heat required to raise a gram of water one degree on the centigrade thermometer. This amount of heat is so small that it is not practical to use when considering the oxidation of foods. A Calorie refers to the amount of heat used to raise a kilogram (a thousand grams) one degree on the centigrade thermometer. The root of the word is from a Latin word meaning heat.

Attempts to measure heat were unsuccessful for many years, because heat was thought to be a kind of matter that was given off from a burning or hot substance. About 1783 Lavoisier (see page 306) and Laplace (see page 82) designed a piece of apparatus, called "Laplace's ice calorimeter," in which the amount of heat given off was measured in terms of the rapidity with which ice melted. Lavoisier was especially interested in determining the heat as well as the amount of waste products given off by the human body. It is said that he was carrying on an experiment for this purpose at the time he was taken to the guillotine.

Liebig, the chemist, whose work has been mentioned in connection with photosynthesis (see page 314), carried on experiments in the middle of the nineteenth century to determine how much protein food is used by a person. Carl von Voit (1831-1908), one of his pupils,

continued in this line and proved that the amount of nitrogen given off in the waste products from the body is equal to the amount taken into the body in protein food during a given period of time. During his experiments, Voit realized that if he were to find out how much of other foods was being used, he would have to measure the amount of carbon dioxide given off. Most of the carbon contained in foods leaves the body in the form of carbon dioxide.

Voit interested a physicist, Max Joseph von Pettenkofer, in his problem. They built a room large enough for a man to live in. It was completely sealed and ventilated by a current of air forced through it. The amount of air was measured by a gas meter that was run by a water wheel. After the man entered this chamber, samples of the ingoing and outgoing air were taken continuously and analyzed to determine the quantity of carbon dioxide given off. This experiment furnished definite information about the oxidation of foods containing carbon.

Carl von Voit had a pupil named Max Rubner, who became interested in the heat values of foods. While he was working in Voit's laboratory, he showed that 100 grams of fat have the same heat value for the body as 232 grams of starch. Later, when Rubner was a professor at Marburg, he was able to calculate how much heat energy was developed in the body from definite amounts of all the nutrients that undergo combustion in the body.

In order to test his figures by an actual experiment, he built an animal calorimeter large enough for a dog. This small chamber was supplied with air as Voit's had been. In addition, a very important new feature was

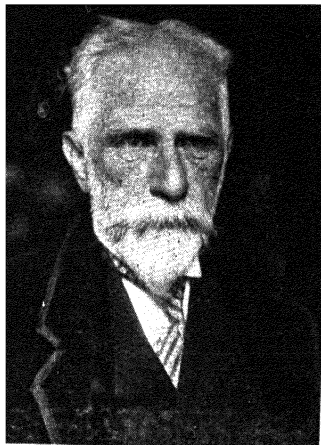
added. The chamber was surrounded with water so that the heat given off by the dog's body could be measured.

By his work Rubner proved that the laws of conservation of energy, which the physicists had found in non-living matter, apply to living organisms as well. The only source of energy that living animals have is from chemical changes within their bodies.

Max Rubner was born in Munich, Germany, in 1854. After studying under Carl von Voit in Munich, he spent a year in Leipzig. In 1885, he became a professor of hygiene at Marburg University and six years later succeeded Robert Koch (see page 197) as professor of hygiene at the University of Berlin. Under his direction a new laboratory of hygiene was established there. Rubner was made professor of physiology at the university in 1909 and, when he was seventy years old, was made emeritus.

Rubner visited the United States in 1912 and was the guest of Graham Lusk at his camp in the Adirondack Mountains. Lusk tells, in a tribute written about Rubner at the time of his death, that the German scientist brought with him a barometer, a hygrometer, and a pedometer. The first two instruments indicate his interest in weather conditions. The pedometer was to keep track of the number of steps he took, for since 1892 he had kept a record so that he could draw a curve to indicate the relation between his age and his activity.

Rubner had another interesting hobby directly connected with his work on foods. He collected all the old menu cards of dinners that he could find. By studying these, he learned how the diet of people changed during



MAX RUBNER

Rubner's work proved that the laws of conservation of energy apply to living as well as nonliving matter. The source of all energy in living animals is in the chemical changes within their bodies (*Keystone View*).

Atwater was a pioneer in America in the study of metabolism. After ten years of experimentation his famous calorimeter, large enough for a man to live in, was developed (*Ewing Galloway*).



WILBUR O. ATWATER

the course of years. Up to the time of his death he maintained an active interest in the nutritional problems of the people.

Max Rubner died in 1932. The Calorie values of protein, carbohydrates, and fat which he established are international standards today.

The influence of these German investigators was transferred to the United States by Wilbur Olin Atwater. He was born in Johnsbury, New York, in 1844. His first three years in college were passed at the University of Vermont. He spent his senior year at Wesleyan University, in Connecticut, where he received his bachelor's degree in 1865. Four years later he received his Ph.D.

from Yale. He specialized in chemistry, and his thesis for his doctorate was on the composition of several kinds of Indian maize.

He spent some time abroad, at Leipzig and Berlin. After his return to the United States he taught in colleges in Tennessee and Maine before returning to Wesleyan. In 1888, when the Agricultural Experiment Station was organized at Storrs, Connecticut, Atwater was appointed its director. He held this position until ill health made it impossible for him to be active. Atwater realized that if the agricultural stations were to be very efficient there must be co-operation between them. He was instrumental in having an office created in the Department of Agriculture to have charge of the stations, and he was the first person to hold this office. After several years of ill health, W. O. Atwater died in 1907.

Atwater was a student in Voit's laboratory when Rubner was working there. When the time came for him to carry on his own experiments in this country, Atwater, like Voit, called in a physicist to advise him about the construction of a calorimeter. This man was E. B. Rosa of the National Bureau of Standards, formerly a professor at Wesleyan University. The calorimeter was built at the Connecticut Agricultural Experiment Station. The United States Department of Agriculture and other agencies helped finance the development of the calorimeter. It took about ten years of experimentation before a satisfactory construction was completed. After Atwater's retirement, Francis G. Benedict continued the work. Later Lusk, the pupil of Rubner, added improvements in the construction of calorimeters.

The calorimeter at Storrs was large enough for a man to live in comfortably. One of the special features of the room was a stationary bicycle. On this the occupant of the room pedaled at different speeds. The purpose of the experiment was to show the difference in heat developed when a person was quiet, and when exercising mildly or violently.

Benedict has continued in the field of nutrition and metabolism. Since 1907 he has been director of the Nutrition Laboratory of Carnegie Institution. Benedict has overcome some of the inconveniences in the use of a room calorimeter by designing a helmet that can be used in the study of metabolism. This makes it possible to make tests under many environmental conditions and during a wider range of physical activities.

The high temperature of birds has been mentioned. Lower in the scale of vertebrates we find the so-called cold-blooded animals, such as the snakes. Recently Benedict has conducted many experiments for the purpose of explaining the relation of metabolism to the temperature of these animals. Among other points of interest, Benedict has found that the temperature of snakes is normally a little below that of the environment. His findings are contrary to the familiar statement that the temperature of a cold-blooded animal is about a degree higher than the environment.

Early in the use of the calorimeter in this country, an attempt was made to determine what happened to alcohol taken into the body. Alcohol is a substance which is easily oxidized, but unlike most foods it causes intoxication when used in quantity. Benedict has done consider-

able work on alcohol, and the subject is being intensively studied at the Nutrition Laboratory.

Francis G. Benedict was born in Milwaukee, Wisconsin, in 1870. He was graduated from Harvard in 1893 and received his master's degree in 1894. The following year he received his Ph.D. from the University of Heidelberg in Germany. Before becoming connected with the Nutrition Laboratory, he taught at the Massachusetts College of Pharmacy and at Wesleyan University.

The statements in every biology book concerning the Calorie requirements of an individual are based on the conclusions of Voit, Rubner, Atwater, Benedict, Lusk, and their associates. By consulting a table it is possible to learn just how many Calories are considered most efficient according to the age, sex, occupation of the individual, and the climate in which he lives. Furthermore, it is possible to find out what ratio of protein, carbohydrates, and fat is best.

Recently it has been estimated that the average American eats fifteen times his weight of food every year. That amounts to about 2,190 pounds, figuring average weight to be between 150 and 160 pounds. This amount of food will produce 730,000 Calories, or as much heat as can be produced in the burning of a tenth of a ton of coal.

There is no doubt that counting Calories has become a fad with some people, and that manufacturers of food products have capitalized on this fad in their advertisements. However, there are advantages to be gained by knowing something about efficient diets for people in good health. Furthermore, special diets are often as



FRANCIS G. BENEDICT

For many years Benedict has been making improvements in the apparatus and techniques used in the study of nutrition. (*Brown Brothers*)

important or more important than medicines in treating people who are ill.

It is not enough to know the heat value of foods and the ratios of carbohydrates, proteins, and fats that an individual needs. Vitamins have come into the first rank of importance. It is only about twenty-five years since the first vitamin was isolated, but the effects caused by lack of vitamins have been known for hundreds of years.

Diseases caused by lack of vitamins are called "deficiency diseases." Scurvy, one of these deficiency diseases, was known to Hippocrates, in the fifth century B.C. He described symptoms of a disease occurring among the soldiers in camps that was undoubtedly a form of scurvy. In the records of the Crusades during the thirteenth century, the disease is definitely described. Before extended voyages on the sea became common, scurvy appeared most frequently where a number of people lived on a restricted diet, as in encampments of soldiers and in besieged towns.

During the sixteenth, seventeenth, and eighteenth centuries, when long voyages of exploration were at their height, scurvy became so prevalent that it was known as the "calamity of sailors." Sea air was thought by some to cause the disease. Others believed that salt meat should be blamed.

Navigators sailing from different countries of Europe were all faced with the same very serious problem: how to keep their crews free from scurvy. Men were not only incapacitated, but the death rate was very high. In the sixteenth century the Dutch navigators recognized the necessity of fresh fruits and vegetables and, accordingly,

provisioned their boats as well as was possible, since there was no adequate means of refrigeration.

During the early part of that century, Jacques Cartier, the French explorer, learned a remedy from the American Indians which was of value in combating the disease. Cartier and his party spent a winter in an Indian village near the present site of Montreal. Twenty-six of his men died of scurvy during the winter, and the others would probably have died if they had not followed the advice of the Indians who told them to drink tea made of pine needles.

The voyages of Captain James Cook in the eighteenth century were important for more reasons than increasing the knowledge of the world's geography and claiming territory for England. The plants collected on one of the voyages by Banks, the botanist, proved important to Robert Brown and other naturalists in England who studied them (see page 59). Then, too, Cook became actively interested in the prevention of scurvy. On the first voyage he lost so many men that "he swore that if his own life was spared he would devote all his intelligence and energy to combating scurvy." On the second voyage, after spending several months at sea in the region of the Antarctic Circle, he landed on New Zealand. At once he had the buds and needles gathered from a tree that was like the black pine of North America. By fermenting these with molasses and malt, he brewed a liquor which benefited the men as much as fresh vegetables would have done.

More than twenty years before Cook's first voyage, a naval surgeon, James Lind, had advised that lemon juice be rationed to the men on long sea trips. He also recog-

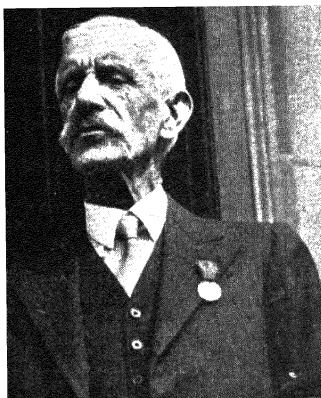
nized the importance of green vegetables. His advice was not put into general practice at once. But by 1795 the importance of lemon juice was recognized, and an order made the rationing of it compulsory on all ships in the British navy.

Why fresh fruits and vegetables prevented scurvy was not known. The fact that they did was enough for the navigator and his crew, but the scientific curiosity of men interested in a serious study of nutrition was aroused.

The experiments of two men, one working in Java and the other in England, furnished the clue to the cause of scurvy and other deficiency diseases. Christian Eijkman, who was born in Holland, in 1858, went to the Dutch East Indies as a military surgeon when he was twenty-five years old. While a director of the hygiene laboratory on the island of Java and a teacher in the medical school, his attention was directed to a deficiency disease prevalent in that locality.

Eijkman found that chickens fed exclusively on polished rice developed beriberi, a disease similar to that afflicting people in countries where polished rice is the principal article of diet. In human beings the disease is often called polyneuritis, and paralysis, or partial loss of the control of muscles, is one of its effects. Eijkman found that chickens did not develop beriberi if some unpolished rice was fed to them. In the prison on the island, many men had symptoms similar to those of the unhealthy chickens. Since the diet of the prisoners consisted chiefly of polished rice, Eijkman had unpolished rice substituted. In many cases, the men's health showed a marked improvement.

At the time of his early experiments, Eijkman did not interpret his findings correctly. This is not to his discredit in view of the fact that nothing whatever was known about vitamins at the time. Since one of the symptoms of beriberi is loss of muscular control, he was led to think that it was a form of intoxication, and that in some way rice hulls counteracted the toxic effect in the body. This early, incorrect interpretation of the disease makes no difference. The important fact had been demonstrated that there was something present in the hulls of rice necessary for adequate nutrition.



SIR FREDERICK G. HOPKINS

Hopkins was one of the first to recognize the presence in food of the substances now called vitamins (*Wide World*)

Eijkman's experiments in Java were carried on in 1897. In England, a few years before this, Frederick Gowland Hopkins was coming to the conclusion that the quality of food served to patients in the hospitals was of as much, if not greater, importance than the quantity. During 1906 and 1907, while he was conducting experiments on rats fed on a highly purified diet, he found that they became unhealthy and developed symptoms of deficiency diseases. Small quantities of butter fat were added to the food. An amount so small as to be negligible in terms of proteins or fats and oils had a curative effect.

As Eijkman had recognized the fact that there was something present in unpolished rice that prevented beriberi, in the same way Hopkins realized that there was something in butter fat that had a definite effect on the health of his rats.

Since he had no specific knowledge about this substance or substances, Hopkins used the term "accessory food factors." This long expression was replaced by the word "vitamin." The word was coined by the Polish biochemist, Casimir Funk (1884—). At the time the word entered the scientific vocabulary, it was believed that vitamins were nitrogenous substances necessary for life. This was implied in the word itself which was at first spelled "vitamine." "Vita" is derived from a Latin word meaning life, and "amine" implies a compound containing nitrogen. Further investigation proved that vitamins did not necessarily contain nitrogen. By this time the word was so well entrenched in the scientific vocabulary that another word could not easily be substituted. A slight change was made in the spelling, however, and the final "e" was dropped.

In 1929, Eijkman and Hopkins shared the Nobel Prize (see page 153). Eijkman had returned from Java to Holland in 1898, on a leave of absence. After he arrived in Holland, however, he was offered a professorship in the University of Utrecht, which he accepted. He died in 1930.

Sir Frederick Gowland Hopkins was born in Eastbourne, England, in 1861. He received his education in science and medicine at the University of London. At the invitation of Sir Michael Foster, he went to Cambridge University in 1898 to develop the teaching

of physiology in terms of chemistry. In 1914 a special chair of biochemistry was created there, and he was given the professorship. About ten years later, as the study of biochemistry had continued to grow in importance, a special department was created for it. Under Hopkins's direction this has become a large and very active department.

Hopkins's name is well known for research in other lines besides the vitamins. The work of Hopkins and W. M. Fletcher on the formation of lactic acid in muscles became the starting point for the recent studies of Hill (see page 402) on reactions of muscle cells. The experiments of Eijkman, Hopkins, Funk, and others gave specialists in nutrition new problems to solve.

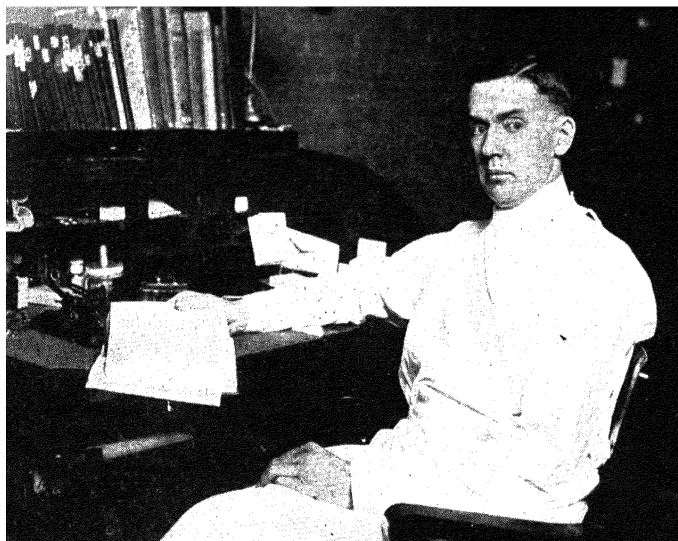
Among the scientists the name of Elmer McCollum became closely connected with the increasing knowledge of vitamins. Elmer Verner McCollum was born near Fort Scott, Kansas, in 1879. He was brought up on a farm and enjoyed the life there.

After graduation from the University of Kansas, he received a scholarship at Yale and continued the study of chemistry. In 1907 he was offered a position teaching agricultural chemistry at the University of Wisconsin. This was one of four offers he received from agricultural experiment stations. He went to Wisconsin because experiments on the nutrition of calves were being carried on there. McCollum decided to use rats for his laboratory animals. In 1912, after he had become an associate professor of biochemistry, he discovered the accessory food factor now called "vitamin A." Twenty years after its discovery, it was obtained in a pure form by another investigator.

Vitamin A protects animals and man from an eye disease, xerophthalmia, and from night blindness. A lack of it also retards growth. Night blindness is common in Labrador and Newfoundland where the variety of food is very limited. Since the beginning of this century, there have been several striking proofs of the importance of vitamin A. In 1904 a food shortage in Japan resulted in an alarming amount of eye disease in the children of the poorer classes. During the World War, when the diets of the people in Austria and Rumania contained almost no milk or animal products, xerophthalmia increased rapidly. If unchecked, the cornea and lens of the eye are destroyed so that permanent blindness results. Fortunately, the children in Central Europe were brought to the attention of the American Red Cross. Cod-liver oil was supplied to them, and the sight of those who were in the early stages of the disease was restored.

A few years after the discovery of vitamin A, McCollum was able to recognize vitamin B. It was lack of this vitamin that caused beriberi in Eijkman's chickens. Recently the pure vitamin has been prepared from rice hulls.

In 1917 McCollum went to Johns Hopkins as a professor of biochemistry. Five years later he announced that it was vitamin D in cod-liver oil that made it important in the prevention and treatment of rickets. Later it was shown that the irradiation of foods with ultraviolet light produced vitamin D. The importance of this vitamin to growing children has proved to be so great that in some communities cod-liver oil is provided free to children under two years of age in needy families.



ELMER V. MCCOLLUM

McCollum discovered the presence of vitamins A, B, and D in foods
(*Broken Brothers*)

Since fish have more vitamin D than other organisms, the question arose as to the origin of this substance. Experimentation showed that sargassum weed contained oils that acted like vitamin D in curing rickets in experimental animals. Sargassum weed is free from animal life where it originates, but when pieces that were drifting along the Gulf Stream were examined, a large population of small animals were found on them. Since these small animals, shrimps, mollusks, and other forms are the food of larger fish, it would seem that there is a definite connection between the oils in the sargassum weed and vitamin D in fish. This theory is given added weight by the report that codfish taken in the White Sea have less

vitamin D in their livers than those taken where they come in contact with the Gulf Stream which carries plant and animal life with it.

McCollum has not confined his studies of nutrition to the vitamins. In his opinion there are thirty-seven chemicals that must be present in the body if it is to function properly. Eight of these substances are metals: calcium, copper, iron, magnesium, manganese, phosphorus, potassium, and sodium. If all these thirty-seven chemicals are necessary, then there is a possibility of the same number of deficiency diseases or conditions that would not be considered normal. For example, when rats are fed on a diet completely lacking in manganese, the female rats will not build nests or take care of their young. When magnesium is lacking, the rats become ill-natured. They will bite at the sides of their cages and show great irritability. If a change is not made in their diet, they eventually have convulsions and die.

The relationship between iodine and the thyroid gland has been proved, and iodine is successfully used in the treatment of some forms of goiter. There is evidence to support the idea that the proper functioning of some of the other ductless glands depends on mineral substances. The behavior of rats when on a diet lacking magnesium would indicate that there is a relation between this metal and the adrenal glands, popularly called "the glands of courage." For many years it has been known that iron is one of the elements in hemoglobin, the coloring matter of the red corpuscles. The ease with which hemoglobin unites with oxygen makes it possible for oxygen to be carried from the lungs to the farthest cells in the ends of the toes. Recently, copper has also been found necessary

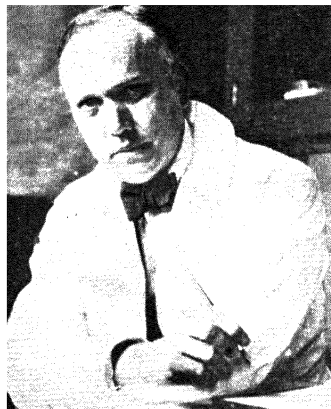
for the efficient functioning of the red corpuscles and has been added to medication for anemia.

McCollum wrote *Book of Chemistry for Medical Students* in 1916. With Nina Simmonds as co-author, he wrote *Foods, Nutrition, and Health*. This book has gone through many printings. In it the authors give reasons for the increase of deficiency diseases as the diet of a people has changed. One of these reasons is pride. White flours and polished rice cost more than flours from whole grains and unhulled rice; therefore, they became associated with wealth. When a man rose in the economic scale, white bread supplanted black bread on his table. Since the hulls of the kernels are richest in vitamins, as a man amassed wealth his food became poorer in these substances.

A short time before McCollum announced the discovery of vitamin A, another investigator, Alex Holst, had detected a substance which would prevent scurvy. That scurvy was a deficiency disease was being doubted by some scientists. One reason for this doubt was the fact that people who were using canned vegetables and fruit juices to prevent scurvy were not finding them effective. After the scurvy-preventing substance, vitamin C, was studied, the reason why canned vegetables and juices were not efficient became apparent. Vitamin C is destroyed at the temperatures used in the ordinary canning of foods if the foods are open to the air.

In the same year that McCollum discovered vitamin D, Herbert McLean Evans and his assistant, Katherine S. Bishop, discovered vitamin E. Herbert Evans was born in Modesto, California, in 1882. He was graduated from the University of California in 1908 and four years

later received his medical degree from Johns Hopkins University For the next eighteen years he taught anatomy at this university and then returned to the University of California



HERBERT M. EVANS

Evans and his associates discovered and isolated vitamin E (*Science Service*)

Evans was primarily a physiologist and not a chemist He was interested in the reproduction of rats. During the course of his experiments, he found that rats fed on a certain diet did not reproduce normally The substance lacking in the diet he first called "X" This was later changed to vitamin E In 1935, Evans and two other workers obtained the substance in a pure form If the vitamin is as important as it seems to be in preventing sterility in animals, commercial breeders will undoubtedly profit by its use

Further experiments on rats led Evans to use hormones (see page 368), which he injected into the animals When he used a hormone from the pituitary gland, he found that the offspring of the treated rats developed into abnormally large animals.

During the years from 1918 to 1929, Evans investigated the chromosomes of the cells in the human body He determined that they were forty-eight in number

Since 1930, Evans has been a lecturer in biology and a director of the Institute of Experimental Biology in

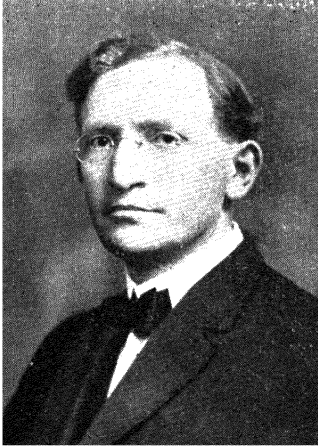
Berkeley, California. He has published many papers on physiology and reproduction. His work is considered of such importance that the Rockefeller Foundation has granted his institute \$20,000 a year for a number of years so that Evans can proceed with his experiments.

The five vitamins discussed so far have been obtained in pure forms. In 1916, Dr. Joseph Goldberger announced that he had discovered another vitamin, now called "G." At the time Goldberger began his studies, pellagra was so common in the South that an appeal was made to the United States Public Health Service for help in studying its cause and prevention. The general opinion was that pellagra was a parasitic disease carried by an insect. After visiting hospitals and homes for orphans where the disease was common, Goldberger was impressed by the fact that the attendants and nurses did not have the disease. He suspected that it was caused by some lack in the diets of the inmates.

Goldberger was so sure he was on the right track that, through the co-operation of the Governor of Mississippi, he obtained twelve convicts who were willing to take part in an experiment. Freedom was promised them if they survived the tests to be made on them. After several weeks on a restricted diet planned by Goldberger, seven of the convicts showed symptoms of pellagra. A change of diet cured them.

Immediately there arose a difference of opinion about the reason that a changed diet had cured these men. Some authorities maintained that the diet on which the men lived had been so low in iron content that this was the cause of the disease. The results of experiments by scientists using dogs did not agree with those obtained

by Goldberger Although in the United States the disease is commonest in the South, it does occur in the North



JOSEPH GOLDBERGER
Goldberger is most widely known for his investigations in connection with pellagra (*Brown Brothers*)

In one of the hospitals in New York City, a definite relation between chronic alcoholism in the patients and the occurrence of the disease has been noted Until vitamin G can be obtained in a pure form, there will continue to be uncertainty about it

Goldberger died in 1929. The substance he believed to be the pellagra preventive was first called "vitamin P-P" (pellagra preventive) After his death the American Society of

Biochemists changed it to vitamin G in his honor.

During the intensive advertising campaigns that made people vitamin-conscious, many lost sight of the fact that by a little study in the discrimination and the choice of ordinary foods one can easily procure all the necessary vitamins Fortunately a careful choice of foods is now becoming a common practice.

Proper nutrition is important to the health of the individual for his own personal comfort But nutrition is also a factor in the progress of the world If the population of a country has its health undermined by deficiency diseases, it will not have an equal chance with a properly nourished population.

There are plenty of food fadists everywhere who have been so extreme in their ideas that they have prejudiced many people against the scientific study of nutrition. However, they cannot lessen the importance of this study. Investigations in three lines of research put the study of nutrition on a scientific basis.

When Harvey discovered the circulation of the blood (see page 38), he made it possible for later scientists to explain how the nutrients, vitamins, and hormones are carried to the cells in the body. Priestley (see page 305) and Lavoisier (see page 306), by their studies of oxygen and oxidation, pointed the way to the understanding of the oxidation of foods in the body. Voit, Rubner, Atwater, Benedict, and others interested in the caloric value of foods based their conclusions on a previously discovered property of oxygen, the readiness with which it unites with other substances. When Wöhler prepared the first organic compound, he led the way for the study of vitamins by such men as Eijkman, Hopkins, Funk, McCollum, Holst, Evans, Goldberger, and a number of other men interested in the analysis and synthesis of organic compounds.

What the effects of the uses of pure vitamins will be remains to be seen. The present wide use of insulin, discovered by Banting in 1922 (see page 390), demonstrates how important a new substance may become in a short time. The first vitamin to be obtained in a pure form was vitamin D. That chemical achievement took place as recently as 1931. It is too soon to predict the part that vitamins will play in the nutritional problems of the future.

Hints for Further Reading

- BENEDICT, F. G., "Reptiles Used in the Study of Human Physiology," *Scientific Monthly*, XXXIV (May, 1932), 421-428.
- "Biochemistry and Medicine" (re: F. G. Hopkins), *Science*, LXX (Dec. 20, 1929), 610.
- "Christian Eijkman" (in German), *Les Prix Nobel en 1929*, 78.
- DARBY, H. H., and H. T. CLARKE, "The Plant Origin of a Vitamin D," *Science*, LXXXV (March 26, 1937), 318-319.
- "Frederick Gowland Hopkins," *Les Prix Nobel en 1929*, 79.
- FUNK, CASIMER, *The Vitamines*.
- HOPKINS, FREDERICK G., "Discovery and Significance of Vitamins," *Smithsonian Institution Annual Report* (1935), 265-273.
- , "Some Chemical Aspects of Life," *Smithsonian Institution Annual Report* (1934), 129-152.
- LUSK, GRAHAM, "A Tribute to the Life and Work of Max Rubner," *Science*, LXXVI (Aug. 12, 1932), 129-135.
- MCCOLLUM, ELMER V., and NINA SIMMONDS, *Food, Nutrition, and Health*.
- "Nobel Prizes for Pioneers in the Field of Vitamin Research," *Scientific Monthly*, XXX (Feb., 1930), 186-189.
- WILLIAMS, R. R., "Who's Who in the Beri-Beri Vitamin Field," *Science*, LXXIX (May 4, 1934), 410.

Tropisms and Regeneration

I.OEB, JENNINGS, AND SPEMANN

REACTIONS to stimuli are an indication of life. From the one-celled amoeba to the highest form of life, living organisms react to internal conditions and to conditions in the environment.

In the human being even a seemingly simple reaction is complicated. Suppose as you step off a curb, an automobile horn is blown near you. You jump back to the curb. What happened in that fraction of a second? The sound of the horn made your eardrums vibrate; this set in motion the three small bones in the middle ear. They in turn caused the fluid in the cochlea of the inner ear to move in such a way that an impulse was sent along the auditory nerve to the brain. In the brain, this impulse was associated with the idea of an automobile and danger. If you saw the automobile as well as heard the horn, the reactions were more complicated. Light reflected from the surface of the car formed an image on the retina of the eye. Here a reaction occurred that caused an impulse to be carried along the optic nerve to the brain. This image was also associated with the idea that it is safest to get out of the way of an automobile.

As a result of the reception of the sound or the image, or both, you jumped. Millions of cells were involved in this motion. A momentary change in respiration and circulation resulted. If the car missed you by a couple of inches only, fear caused the adrenal glands to secrete a substance that had further effect on the rate of your heart beat and the amount of oxygen used.

In getting out of the way of the automobile, you performed what might seem to you a simple act of self-preservation. It was all over in the fraction of a second. To explain in detail what happened would necessitate considerable knowledge of chemistry, electricity, and the laws of mechanics.

Even after pages of formulas had been written, the explanation would not be complete, for the smallest units taking part in the reaction would be the cells, and they are made of protoplasm which possesses the property of irritability. Exactly what irritability is no one has yet satisfactorily explained. It is a mysterious property which makes living matter different from nonliving matter, as the terms are generally understood.

In their attempts to explain reactions to stimuli, scientists have made intensive studies of simple animals and plants. These make responses according to the substances or conditions that cause the reactions. These responses are termed "tropisms." Tropism means "a turning," and it may be toward or away from the stimulus. Thus, there are positive and negative tropisms.

Chemotropism or chemotaxis is the response to some chemical substance, such as food, oxygen, an acid, or an alkali. An amoeba or a paramecium may be watched under a microscope approaching food or moving away

from a drop of acid. Neither of these animals has a nervous or muscular system. The protoplasm of the cell itself is irritable and has the power of motion. An amoeba changes its direction and gets away from an unsuitable substance by sending out pseudopodia on the side away from the substance. If, on the other hand, the substance is food, the amoeba surrounds it by sending out pseudopodia in the direction of the food. A paramecium backs up when it comes in contact with some unsuitable condition, changes its direction, and goes forward again. It continues this avoidance reaction until it has moved far enough away so that it no longer comes in contact with the unsuitable condition.

Phototropism is a response to light. Everyone has seen a plant on a window sill with its leaves turned toward the light at the expense of the symmetry of the plant. This is a common example of positive phototropism. Amoebae and paramecia avoid strong light. Earthworms, also, are negatively phototropic. They have no eyes, but specialized cells are stimulated by light, and the earthworm retreats to its dark burrow.

The effect of light on some animals is not obvious without experimentation. Jacques Loeb, whose experiments on lower animals more than once startled his fellow workers, did some interesting work on phototropism. Caterpillars of *Porthesia* climb towards the tips of branches of trees as soon as they emerge from winter nests. Sometimes they arrive before the buds are open. Since no one believed that the caterpillars could see these buds, their migrations up the twigs were credited to some wonderful instinct. Loeb proved that it was light that caused them to climb. They are positively phototropic to such an

extent that they move toward light, even if starving and if food might be reached in some other direction.

In the stories of the superhuman logger, Paul Bunyan, there is a Mountain That Stood On Its Head. On the slopes of this inverted mountain, the trees grew with their tops pointed downward and their roots firmly fastened in the soil above them. If the mountain had been bare rock, the idea would not be so humorous to the reader. But trees growing in that upside-down position create an absurd mental picture, even before the reader is told of the difficulties of the loggers in cutting them down. Anyone knows that trees would not grow that way. However, few people stop to think that the reason they do not lies in the irritability of the growing tips of the trees. Roots are, normally, positively geotropic, causing downward growth. The tips of the stems are negatively geotropic, causing upward growth.

Protoplasm also reacts to electrical impulses. This reaction, galvanotropism, perpetuates the name of Luigi Galvani, one of the early experimenters with electricity. Galvani accidentally discovered that electricity caused contractions in the muscles of a dead frog. Any boy who has built a "shock machine" knows how his arm muscles twitch when he takes hold of the pieces of metal connected with the terminal wires. Galvanotropism is made use of in a novel apparatus by which fishermen catch worms. Two metal poles are pushed into the ground a few feet apart. A current is passed through them. The angle worms react so violently to this unexpected shock that they seem to pop out of their holes. Even single-celled animals react to currents of electricity which are not strong enough to kill them.

Recently, measurements have been made of the electricity produced in a human brain. These show that in higher animals galvanotropism is of importance in relation to electricity produced within the body as well as to that which comes from the external environment.

There are other tropisms, such as thermotropism, the response to temperature, and thigmotropism, the response to contact. Loeb experimented on a hydroid form of animal life which produces rootlike structures and stemlike structures. He found that when he kept these animals in a dish of water that was undisturbed and in such a position that more than one part of the animal touched the bottom of the dish, the rootlike structures developed at the places of contact.

Tropisms are the simplest kinds of responses caused by the irritability of protoplasm. Two scientists who have added much to the understanding of this irritability are Jacques Loeb and Herbert Spencer Jennings. Frequently they worked on the same materials and obtained the same results. While their purposes in carrying on investigations were often the same, the individuality of the workers was shown in the methods of attack and the interpretations of the results.

Loeb tried to prove that all reactions could be explained by the laws of physics and chemistry. As an ideal he wished to express life in terms of formulas and equations. This mechanistic conception of life brought forth bitter opposition. Fortunately for him, Loeb lived in the nineteenth and twentieth centuries when freedom of thought was allowed and physical persecution had passed out of fashion.

Jacques Loeb was born in 1859, at Mayen in the Rhine Province in Germany. His ancestors had migrated from Spain at the time of the Inquisition. His father's sympathies with France were so strong that he insisted that Jacques speak French when he talked to him. At school, of course, the boy spoke German.

At sixteen, Jacques was left an orphan. He went to work in a bank in Berlin, but soon left that and returned to school. He was graduated from the Gymnasium at the head of his class. Even before he entered the University of Berlin, his originality of thought was recognized, and he was warned not to become too liberal.

The activities of animals, explained as instincts, aroused his curiosity as did the problem of free will. As courses in Berlin University and Munich did not help him find answers to his problems, he went to Strasbourg, where he studied under Friedrich Goltz, a specialist in work on the brain. Acting on the advice of Goltz, Loeb studied for a degree in medicine, which he received in 1884.

The thesis Loeb prepared at this time was attacked by other brain specialists. Loeb felt this keenly. However, his disappointment at the reception of his work was lessened by a letter of approval from William James, the American psychologist. In later years when Loeb was an outstanding man in his field, he always had time to encourage some younger man. He said that this interest resulted from his own appreciation of the kindness James had shown him.

Two years after receiving his degree, Loeb became an assistant professor of physiology at Würzburg. Here a



JACQUES LOEB

Loeb encouraged many young men at critical points in their scientific careers, just as he had once been befriended by William James at a turning point in his life (*Fiving Galloway*)

strong friendship sprang up between Loeb and Julius Sachs, who was carrying on original investigations in plant physiology. Sachs has been mentioned in connection with his study of starch granules in plants (see page 311). It was his experiments on tropisms and the growth of plants that particularly impressed Loeb. At this time Loeb was discouraged with the results he was getting from his work on responses in higher animals. He watched Sachs and decided that he would experiment with lower animals in the same ways that Sachs was experimenting with plants. This change to lower forms brought him success.

In the winter of 1889-1890, Loeb went to Naples. The Zoological Station in Naples was the mecca of American and European biologists. Here Loeb's interest in America was aroused by two American men. This interest was increased in the spring of 1890 when he met Anne Leonard, a young American woman who had been studying in Zürich. In October of that year he came to America and married Miss Leonard. They soon returned to Naples where Loeb continued his experiments on lower animals.

Loeb had inherited enough money to live on, if he were very careful of his expenses. It was not enough to supply any luxuries for himself and his wife. He did not wish to return to Germany and seek a professorship there because of his hatred for the militaristic policy of that country. Since he knew of no position in America, he thought he would become an oculist, devoting part of his time to that profession and the remainder to research. For six weeks, he attended the optical clinic of a friend in Zürich. Then, because his mind was haunted by

unfinished problems, he gave up, declaring, "I cannot live unless I continue my scientific work."

To Loeb, his scientific work meant more than the personal satisfaction he might gain from some discovery. W. J. U. Osterhout, a close associate, writes of him, "He believed that the ills of mankind spring wholly from ignorance and superstition and are curable only by the search for truth." Loeb felt a great responsibility—he must discover truth in his experiments. Realizing this, one can understand why he felt he must go on experimenting. On the other hand, his family must not be permitted to suffer from his enthusiasm.

Quite in the approved storybook fashion, when he could not make up his mind what to do, Loeb received a letter from Bryn Mawr College offering him a position in America. He accepted, but his stay at this college was short, for in 1892 he was asked to join the staff of the new University of Chicago. When the fall term began, the outlook was not very promising at Chicago. An apartment house had been leased for the sciences, and each department was assigned one floor. The lack of equipment and these makeshift laboratories would have been unbearably discouraging for some men, but Loeb's sense of humor came to his rescue. Five years later a physiological laboratory was formally opened, with Loeb as head of the department.

In 1902 he accepted a position in the University of California. He felt that the climatic conditions in California would make it possible for him to have marine forms during the entire year. A laboratory was built for him at Pacific Grove. He stayed in California until 1910.

In that year he became connected with the Rockefeller Institute for Medical Research in New York.

It will be remembered that Malpighi (see page 44) once said that he had begun with the highest forms of life and worked down to simple ones, and that if he could have lived long enough he would have investigated the nonliving mineral substances. L^oeb followed much the same procedure. He once said he had lived his life backwards.

He had begun his research work on the human brain, worked down the scale of animals, studied regeneration in plants and, finally, while connected with the Rockefeller Institute, made some brilliant investigations in the field of colloid chemistry with substances that are not quite alive but have some of the properties of living matter.

Probably the one experiment that caused the greatest surprise to both the scientifically and unscientifically minded was made known in 1899. Loeb was experimenting with the eggs of sea urchins. A sea urchin is an invertebrate animal belonging to the phylum *Echinodermata*, of which the starfish is also a member. Normally, it reproduces sexually: that is, a sperm cell enters an egg cell. Loeb tried putting unfertilized eggs in different solutions. One day he saw that the eggs in one solution formed a membrane about themselves just as if they were fertilized by sperm cells. But development ceased at this point. He kept on experimenting. He removed some eggs after the membrane had been formed and put them in a different solution. He watched them. The egg cells divided. Development continued. Before long the unfertilized eggs had developed into the larval stage of the

sea urchin. Fellow scientists were greatly interested. The experiment was news in the papers.

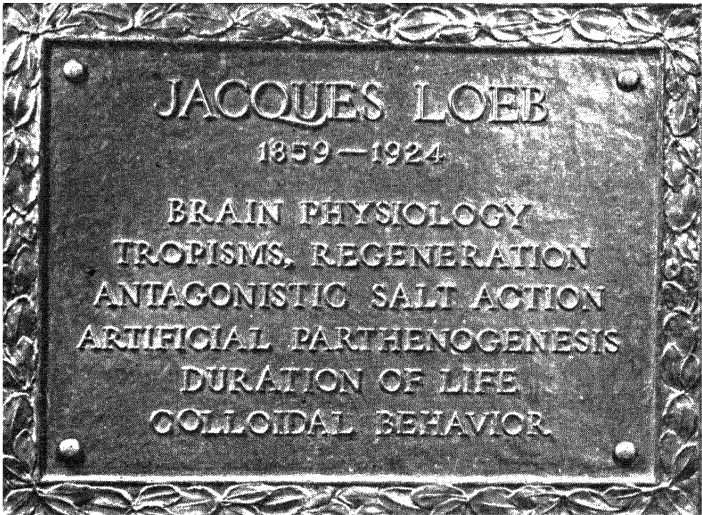
Further experiments by Loeb and others proved that this "artificial parthenogenesis," as it was called, could sometimes be produced in eggs of sea urchins by merely pricking the eggs with a needle.

Regeneration was another subject that interested Loeb, as it has many other scientists. What happens within a plant or animal that makes it possible for a new part to grow after an injury? In his work on regeneration, Loeb turned to plants and used those of the genus *Bryophyllum*.

In 1924, when he was very tired and overworked, Loeb was persuaded to go to Bermuda on a short vacation. Here he always enjoyed seeing the plants that were his laboratory material in the North growing in their wild state. Unfortunately, he had a heart attack while there and died. His ashes were brought to Woods Hole, Massachusetts, a place which he loved.

He had worked in the Marine Biological Laboratory there every summer since 1892, except during the eight years in California. At Woods Hole and at the Rockefeller Institute commemorative plaques were placed. These tablets list the directions of his experimental work: brain physiology, tropisms and regeneration, antagonistic salt action, artificial parthenogenesis, duration of life and colloidal behavior. The leaves of *Bryophyllum* are represented around the border of each tablet.

Loeb was constantly trying to explain life: that is, the irritability of protoplasm, in terms of chemistry and physics. He has many followers today in experimental methods and in thought. He himself distrusted all but the most simple kinds of apparatus and showed great



COMMEMORATIVE PLAQUE TO JACQUES LOEB

On this plaque are listed the different fields in which Loeb made important contributions. The leaves around the border are of *Bryophyllum*. Loeb used this plant for some of his study of regeneration. (Courtesy Rockefeller Institute for Medical Research)

ingenuity in devising apparatus to fit his needs. His work on tropisms, on the functions of the nervous system, and on regeneration added much knowledge to the "how and why" of the behavior of living things, especially of low animal forms.

Herbert Spencer Jennings, another scientist who has made a thorough investigation of the behavior of lower animals, was born in Tonica, Illinois, in 1868. His father was a physician who kept himself informed about the newest developments in science. Along religious lines he was a free thinker and was affectionately called the "village infidel" by his patients, who respected his

ability as a doctor, but did not approve of his ideas on religion.

Herbert Jennings was graduated from the University of Michigan in 1893, and shortly after that became a graduate assistant at Harvard. His ability was quickly recognized, and the fellowship he received made it possible for him to continue his studies in Europe where he spent some time at the Naples Zoological Station.

From 1897 to 1909, Jennings experimented and collected material on the reactions of lower organisms. The results of this twelve years of work were brought together in his book, *Behavior of the Lower Organisms*. During the time he was gathering material, he held positions at several colleges. In 1906 he went to Johns Hopkins University to deliver a lecture. As a result he was called there, and in 1910 he became director of the Zoological Laboratory at that university.

About the time that Jennings became connected with Johns Hopkins, he turned his attention to the study of heredity, to which field he has since made valuable contributions in his studies and writings. In his student days, Jennings lived for a time in the home of Charles Benedict Davenport, one of the leading authorities in



HERBERT S. JENNINGS

The binocular microscope, which Jennings is using here, is especially well adapted for studying living species of the lower organisms (*Science Service*)

the world on heredity in human beings. Undoubtedly, the association with Davenport did much to interest Jennings in this field.

Few American scientists are as well known for their philosophical writings as is Jennings. *Prometheus*, *The Biological Basis of Human Nature*, and *The Universe and Life* are three thought-provoking volumes that have made his name known outside strictly scientific circles.

In *The Behavior of Lower Organisms*, Jennings reports his experiments and those of other workers on a large number of invertebrates. For stimuli he used chemical substances, such as food, acids, and alkalis. He also used electricity, light, and so forth. He found that the responses of some of the simplest organisms as well as those of the higher ones depend on the internal conditions of the animal. A hungry hydra, for example, will move by a series of slow motions after it has explored the water around it with its tentacles and not found food. The movement of a hydra on the surface of some substance resembles a slow-motion picture of somersaults. The hydra bends over until the tentacles are in contact with the substance to which it is attached, then the base is released, it straightens up, bends the base over until it finds the surface, and then rights itself. In this way it slowly explores a region until it either comes to a place where there is food or it starves.

Jennings found that some forms, such as starfish, react as if they had memory. For a time certain actions become a habit. When a person teaches a dog to shake hands with his right paw, words and usually a reward are employed. The training process is repeated over and over, each time with a repetition of the same words.

A bit of food or a pat on the head may be the reward. Jennings taught starfish to use particular arms in righting themselves when they had been turned upside down. Words are nothing to a starfish. Jennings's procedure was to fasten some of the arms of the starfish so that only certain ones could be used in the activity of righting itself. After repeating this procedure a number of times, he found that the starfish, when all its arms were free, used only those that had been free during the training period.

Jennings and Loeb both found that lower organisms exercised what might be termed choice. In one of his experiments, Loeb used a sea anemone, an animal with a cylindrical tubelike body. It fastens itself by the base to some hard surface. The mouth opening of the animal is surrounded by tentacles. When food comes in contact with these tentacles, it is seized and carried to the mouth. Loeb used particles of meat and filter paper soaked in beef juice. These were alternately put in contact with one or a few tentacles. After about ten trials, the tentacles carried the meat to the mouth, but not the filter paper. This training, however, did not have any lasting effect. The choice that was learned was entirely gone within a few days.

In his work Jennings showed that all lower organisms show symptoms of fatigue after they have responded for a certain time to a stimulus. He also found that a reaction similar to fear was shown in some of the forms which contracted when a shadow fell on the surface of the water above them.

The work of Loeb, Jennings, and others on the reactions of the lower organisms has settled an important point. Organisms which do not possess nervous systems

react to different stimuli and in different ways to the same stimuli, according to their internal or physiological conditions.

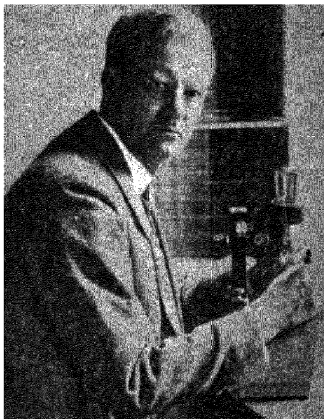
The unexplained irritability of protoplasm manifests itself in the processes of regeneration of lost or injured parts of an organism, as well as in responses to stimuli in the environment of an organism. The successful grafting of tissues from one part of an organism, or from one organism to another, also depends on this same irritability. In the past few years, experiments by Hans Spemann have cleared up some questions about this particular characteristic of protoplasm and brought up other questions that have no answers as yet.

Like Loeb, Spemann knew Sachs, the botanist (see page 311), who influenced the experimental methods of both. Loeb artificially fertilized the eggs of an invertebrate. Spemann by mechanical and chemical stimuli was able to make the eggs of a vertebrate, a frog, develop without normal fertilization by sperm cells.

Loeb was very much interested in regeneration, particularly in low form plants. Spemann has obtained some remarkable results in grafting animal tissues. The process of grafting is closely related to regeneration.

Spemann, who is a master of micro-surgical technique, transplanted pieces of tissue from one developing embryo newt to another. From a very young embryo of a newt, Spemann removed a piece of tissue that would normally have developed into part of the brain. In its place, he put a piece of tissue that would have become skin, if it had been undisturbed. What happened? The transplanted tissue became brain.

Not satisfied with this, Spemann removed a piece of skin from the head region of an early stage of an embryo toad. This he transplanted at the corresponding place on the head of an embryo newt. Toads and newts are both amphibians, but they belong to different orders. This transplanted skin developed into the suckers and horny jaws of the toad, which are quite unlike the parts of the mouth of a newt.



HANS SPEMANN

Spemann's experiments in grafting tissue from one embryo to another have led to interesting conclusions about the development of tissues (*Keystone View*)

From the results of many experiments along these lines, Spemann concluded that at a very early stage in the development of an embryo, a given piece of tissue may have the potential ability of developing into more than one kind of tissue. This was proved by transplanting tissues in animals of the same or closely related species. On the other hand, the tissue will develop characteristics of its own species if it is transplanted in another animal quite unlike it. The influences determining the development of tissues, Spemann calls "organizers." What these organizers are or how they exert their influence is not known. The problem is one that will require much research by the biologist and the biochemist before the answer is found.

This experimenter on embryonic tissues was born at Stuttgart, Germany, in 1869. His father was a publisher, and Spemann entered the publishing business in 1888. After two years, he decided to continue his education and went to the University of Heidelberg, where he remained two years. The following year he attended the University of Munich and in 1894 went to Würzburg, where he became a pupil of Sachs. In 1895 he received his doctorate in zoology. He became a professor in Freiburg in 1919, and his work has attracted students in embryology from all parts of the world. The Nobel Prize was awarded to him in 1935.

Spemann's best-known book is *Experimental Research in the Field of Evolutionary Physiology*. He has visited the United States to deliver lectures at Chicago and Yale.

The work of Loeb, Jennings, and Spemann is a striking example of the fact that new knowledge in the field of biology usually does two things. It partially answers old questions, and at the same time it raises new questions to challenge the biologist. For example, more is known about the irritability of protoplasm than was ever known before, and yet no one knows why it is irritable.

Hints for Further Reading

CONKLIN, EDWIN G., "Professor Hans Spemann, Nobel Laureate in Physiology and Medicine," *Scientific Monthly*, XLII (Feb., 1936), 191-194.

DE KRUIF, PAUL H., "Jacques Loeb," *American Mercury*, V (July, 1925), 273-279.

GEISER, SAMUEL W., "Herbert Spencer Jennings," *Bios*, V (March, 1934), 3-18.

"Hans Spemann" (in German), *Les Prix Nobel en 1935*, 56.

JENNINGS, HERBERT S., *Behavior of the Lower Organisms*.

———, *The Biological Basis of Human Nature*.

"Nobel Prize Goes to German Doctor," (re: Hans Spemann), *New York Times* (Oct. 25, 1935), 15.

OSTERHOUT, W. J. V., *Biographical Memoir of Jacques Loeb* (pamphlet). Washington: National Academy of Sciences, XIII (1930), 318-401.

SPEMANN, HANS, "The Mode of Operation of the Organizer" (abstract), *Scientific Monthly*, XLIII (Oct., 1936), 378-379.

"Work of Professor Spemann," *Science*, LXXXII (Nov. 1, 1935), Supplement, 8.

Chemical Messengers

KENDALL, BAYLISS, STARLING, AND BANTING

ON HER trip through Wonderland Alice ate a little currant-trimmed cake. What happened? She grew so tall that her head bumped the ceiling. When Lewis Carroll published his famous book in 1865, no one knew what factors controlled the size of a person. No one can be like Alice, nine feet tall for a time and in a few minutes only two feet high. However, by increasing or decreasing the hormones in the body of the animals, experimental animals are raised that are giants or dwarfs compared to the normal animals of their species.

There are other hormones in the body besides those that control the growth of an organism. More than a dozen hormones are known to be present in the human body, and each has a specific effect on the body. What, then, are hormones? They are definite chemical substances produced in the bodies of both plants and animals.

In higher animals, such as man, hormones are secretions of glands. Glands in general may be divided into those with ducts, and ductless or endocrine glands. The glands with ducts allow their secretions to escape to the

surface of the body as in the case of sweat glands and tear glands, or to the inside of the alimentary canal as in the case of the gastric glands in the wall of the stomach. Since the food in the blood stream is carried to all living cells, it is apparent that those cells which make up a gland must have the peculiar ability to select from it substances that form the secretion. In some animals the secretions of special glands with ducts are used as a means of defense by the animal. Although a skunk eats the same food as other animals, gland cells in its body can synthesize the vile-smelling liquid, a sulphur compound, that is effectively used against its enemies.

The secretions of the glands with ducts are more apparent, but the secretions of the ductless glands are of vital importance. These ductless, or endocrine, glands produce hormones that enter the blood stream as it passes through them. These hormones, often called "chemical messengers" or co-ordinators, are then distributed throughout the body where they definitely affect growth, metabolism, reactions of the nervous system, and the contraction of the muscles. In fact, it is by means of the effects of these hormones that a complicated organism like a person is able to maintain life within itself. Twelve endocrine glands have been studied in the human body. Each produces at least one specific hormone. Each hormone has definite effects on the body.

Goiters are caused by an abnormal condition of the thyroid gland. This gland has two lobes, one on either side of the windpipe or trachea. References to goiters are found in the writings of the Greeks and Romans. The gland was known to Vesalius. (see page 34) and other anatomists of his time. However, the effects of the

thyroid secretions on the mental and physical health of a person were not understood until recently. Thyroxine, the hormone secreted by this gland, affects the rate of metabolism in the body. When the amount of thyroxine is far below normal, growth in children may be affected, and at the same time the brain does not develop. Such underdeveloped individuals are called "cretins." Iodine is one of the elements found in thyroxine; for this reason, in localities where there is a deficiency in iodine, a large number of persons have goiters.

Although the ashes of seaweed and sponges which are rich in iodine were used centuries ago in China for treating goiters, modern knowledge of the thyroid does not extend back farther than the last half of the eighteenth century. In 1891 G. R. Murray, an Englishman, used an extract of thyroid from sheep for the first time in treating a patient with an abnormal thyroid.

When the possibility of the treatment of goiters by the use of thyroid extracts from sheep was proved, the curiosity of chemists was aroused. What chemical substance in the gland made it beneficial? Several men attacked the problem. It was the good fortune of Edward C. Kendall to obtain the first crystals of thyroxine, the thyroid hormone.

Edward Calvin Kendall was born on March 8, 1886 in South Norwalk, Connecticut. At Columbia University he majored in chemistry. His training was very thorough, and he received his Ph.D. in 1910. During the following year he was a research chemist for Parke, Davis and Company, manufacturers of medicines. While in the employ of this company, he carried on investigations on the thyroid gland. In 1911 he went to St. Luke's

Hospital, New York City, and continued this work there. Since early in 1914 he has been head of the biochemistry department at The Mayo Foundation Graduate School, which is connected with the University of Minnesota. In 1925 Columbia University awarded him the Chandler Medal for his contributions to science.

A description of how this thyroxine was obtained, is too technical to be given here, but one point is of interest. At a certain stage in the experiment that was being carried on, the alcohol in which some thyroid products were dissolved was unintentionally entirely evaporated. More alcohol was added, but the dry material did not completely dissolve; a white residue remained in the vessel. The liquid was filtered off and the white substance was nearly thrown away. In his book, *Thyroxine*, Dr. Kendall does not say why it was not thrown out. Fortunately, it was analyzed and found to be rich in iodine. Further experimentation was done on it, and on December 25, 1914, crystals of thyroxine were obtained. Spurred on by this success, he tried to isolate more of it. For over a year these attempts brought very unsatisfactory results.

One factor which contributed to the failure was the lack of iodine in the glands of animals during the winter months. At the time this fact was not known. However, the work went on, and by the spring of 1917 seven grams of the thyroxine crystals had been produced. It was estimated at this time that the cost of producing a gram of thyroxine was about \$350. Other investigators took up the problem of producing it synthetically. Ten years later Charles R. Harington, of Cambridge University, and George Barger made thyroxine crystals in the

laboratory. Tests were made with this synthetic preparation, and the results were as satisfactory as when the thyroxine from the glands of animals was used.

Disturbances of the thyroid gland are detected by a metabolism test. An apparatus is used by which the amount of carbon dioxide produced by a person during a given number of minutes may be measured. If the rate of metabolism is above normal, more oxygen will be used up and more carbon dioxide will be exhaled. On the contrary, if the rate of metabolism is below normal, less oxygen will be used and a smaller amount of carbon dioxide will be exhaled.

While the effects of disturbances in the thyroid may not be noticeable until some time after the changes in the gland have begun, the adrenal glands, situated above the kidneys, have an immediate effect on the behavior of the individual. The adrenal glands produce two hormones, epinephrin and cortin. Since the discovery of epinephrin, the substance has been made for commercial use and is sold under the name of adrenalin. This has proved to be of great benefit as a stimulant in heart diseases and in patients suffering from shock after an operation or an accident.

The hormone epinephrin is frequently spoken of as the "courage hormone." When extremely frightened, people often perform feats of strength which they could not possibly perform under usual circumstances. This is explained by the fact that fright or anger causes an increased supply of epinephrin to be poured into the blood. This, in turn, causes a larger amount of the food stored in the liver to enter the blood stream and increases the rapidity of the circulation of the blood. The result is



EDWARD C. KENDALL

The first crystals of thyroxine, the thyroid hormone, were obtained by Kendall on December 25, 1914 (*Brown Brothers*)



WALTER B. CANNON

Cannon did pioneer work in showing that different emotional reactions disturb normal functioning of the body (*Brown Brothers*)

that more food is made available to the cells, and oxidation is increased. Therefore, a person who has no marked muscular strength might carry a surprisingly heavy object from a burning building under the excitement of the fire, or he might knock out a large antagonist when angry. The adrenal glands are also responsible for the so-called "second wind" of athletes.

It is a well-known fact that after a fright or severe emotional strain a person's digestion may be upset. Walter Bradford Cannon when studying the effects of adrenal secretions performed some interesting experiments with a cat. To the food of this cat, Cannon added a preparation of bismuth. Bismuth preparations are

used when it is desirable to study the stomach and intestines by using the X ray, because these preparations will show up darker than the tissues. As soon as food enters the stomach peristaltic motion begins. Peristaltic motion may be thought of as a series of wavelike contractions in the muscles of the digestive tract. This motion, occurring in the gullet, stomach, and intestines forces the food along the alimentary canal. This motion also causes the food to become thoroughly mixed with digestive juices and has the mechanical effect of reducing the size of the food particles. After the cat had eaten the meal containing bismuth, it was X rayed. Normal motion was observed. A barking dog was brought into the laboratory. The observers then noticed that the action of the stomach slowed down.

This experiment would have proved nothing about internal secretions, but Cannon was able to produce the same results when, instead of frightening the cat, he injected a very small amount of adrenalin into the animal. The indigestion that follows fright or nervous excitement can, therefore, be explained by the fact that the normal activities of digestion are interfered with when an increased amount of the adrenal hormone causes the blood to be diverted from the digestive tract to the voluntary muscles and lessens the action of the involuntary muscles of the tract.

Walter Bradford Cannon, who made these experiments on the cat, was born at Prairie du Chien, Wisconsin, in 1871. He was educated at Harvard and in 1906 was made a professor of physiology there. Among his writings is a book explaining the changes in the body that are caused by pain, fear, hunger, and other sensations.

Another hormone, cortin, secreted by the adrenals also increases the rate at which some body functions are carried on. Cortin is even more effective than adrenalin in relieving shock, but its cost at present prohibits its extensive use. It was first isolated in 1934 by Edward C. Kendall, already well known for his work on thyroxine (see page 371).

One of the most versatile organs in the body is the pancreas. It is both a ductless gland and a gland with a duct. The pancreatic juice, manufactured here, is poured into the small intestine through a duct. How it happens that the pancreas secretes its digestive juice shortly after the food has reached the small intestine from the stomach was a puzzle for a long time. Most physiologists believed that a nervous reaction was responsible. Two experimenters set out to prove or disprove this idea. These men were Sir William Maddock Bayliss and Ernest Henry Starling.

Before Cannon used the X ray to see what was happening in the alimentary tract of a cat, these Englishmen had studied peristaltic motion (see page 374). About the same time a pupil of Pavlov (see page 395) had proved that when an acid was introduced into the upper part of the small intestine, the pancreas became active and poured a digestive juice into the intestine.

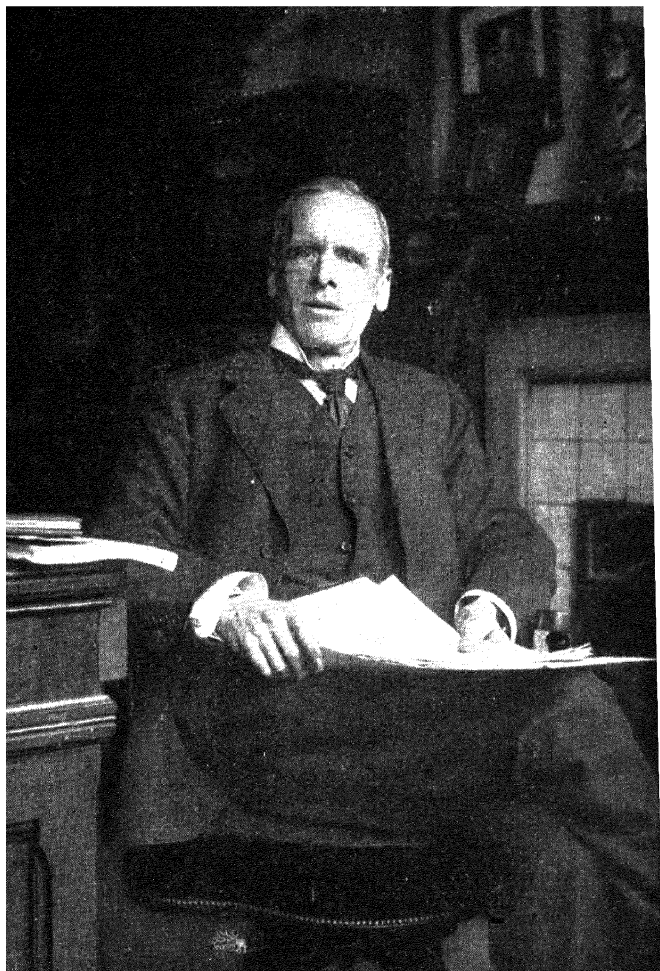
With this information and their own experiments on the intestinal tract as a starting point, Bayliss and Starling set out to solve the problem: What makes the pancreas secrete digestive juice at the proper time; that is, after the food has passed from the stomach into the intestine? Dr. C. J. Martin, who was present on the day the answer was found, described the experiment in the *British Medical Journal*.

A dog under the influence of an anesthetic was used for the experiment on the digestive tract. The lower end of the stomach opens into a section of the small intestine known as the duodenum. The duct coming from the liver and pancreas opens into this section. In the experiment on the dog, a section of the intestine beyond the duodenum was tied off, and all the nerves connected with it were dissected out. After this was done, a small amount of hydrochloric acid was introduced into the tied-off section. To the surprise of those witnessing the experiment, pancreatic juice began to flow into the duodenum. Dr. Martin wrote he remembered that Starling said, "Then it must be a chemical reflex."

As there were no nerves to carry an impulse to the pancreas, it was obvious that some substance must be taken to it by the blood. Further experimentation proved that when the partially digested food, made slightly acid by the hydrochloric acid in the gastric juice, reaches the small intestine, cells in its lining produce a substance, now called "secretin," which enters the blood stream. This secretin stimulates the pancreas and causes it to pour pancreatic juice into the intestine.

Starling first called this substance a "chemical messenger." Later the word "hormone," from the Greek meaning "I stir up," came to be used for the many regulative substances secreted by the ductless glands. Bayliss and Starling were pioneers in the study of secretions of ductless glands and opened up a wide new field of research concerning chemical reactions within the body.

Ernest Henry Starling was born in 1866, in Bombay, India, where his father was a clerk to the Crown. He was educated in England. After studying medicine in Guy's



ERNST H. STARLING

Starling did pioneer work on the secretions of ductless glands. Secretin, now known as one of the hormones, he called a "chemical messenger"
(*Courtesy The University of London*)

Hospital and in Germany, he practiced for a while; but physiology was his chief interest. Fortunately, he secured scholarships that made it possible for him to give up his practice. About 1893 he spent some time in Pasteur Institute. Ilya Mechnikov (see page 277), who was working there, had recently discovered the fact that colorless corpuscles in the blood have the ability to destroy bacteria by engulfing them. Starling and his wife translated into English the lectures of Mechnikov on the relation between colorless corpuscles and inflammation in body tissues.

Under Starling's direction, the physiology laboratory at Guy's Hospital became the best laboratory of its kind in London. In 1899 he was made a professor at University College, where, ten years later, an Institute of Physiology was opened. The scope of the institute was later widened to include pharmacology and biochemistry. Its importance was then recognized, and it received financial aid from the Rockefeller Foundation. Starling was made a research professor of the Royal Society (see page 49) in 1923.

During the World War, Starling directed research work on mustard gas in England and later was sent to Salonika as a chemical adviser. He resigned from this service, in which he held the rank of a lieutenant colonel, and returned to England in 1917, where he became adviser to the government on foods.

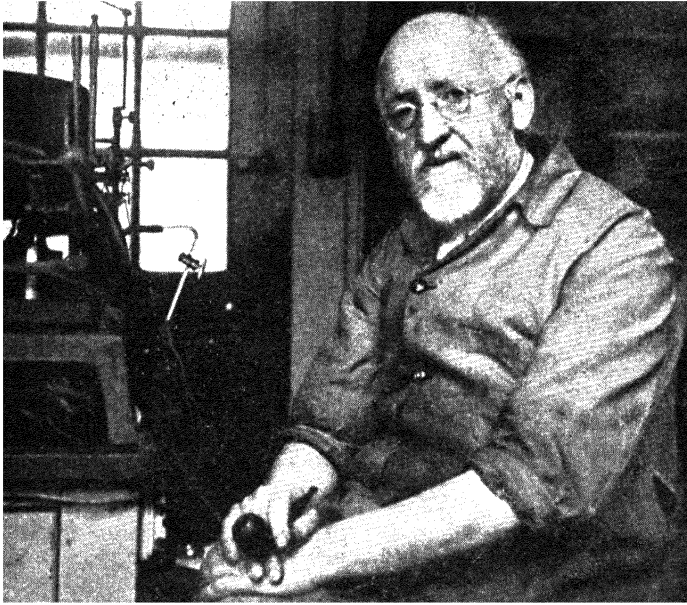
Starling was particularly interested in the physiological processes that he believed could be explained in terms of physics and chemistry. This interest led him to experiment on the action of the heart, the intestinal tract, the kidneys, and lymph. It has been said that Starling contributed more new knowledge about the action of the

heart than anyone had done since Harvey made his observations in the early part of the seventeenth century (see page 38). Starling's writings include *Elements of Human Physiology* and *Principles of Human Physiology*. The first book went through eight editions. The *Principles*, published in 1925, has been translated into Spanish. Starling died off the coast of Jamaica in 1927, while on a sea voyage.

Closely associated with Starling in many of his investigations was William Bayliss. Although Bayliss and Starling differed in ability and in their attitude toward their research problems, on the whole, these men complemented each other. Starling was more forceful. He wanted to test his ideas at once and became annoyed with the details that had to be taken care of. Bayliss was a man with a calmer temperament. He was more critical in his judgments, and he had a great deal of mechanical and technical ability.

Sir William Bayliss was born in Wednesbury, England, in 1860. As a child he was frail; therefore, he was educated at home. In 1881 he entered University College with the idea of studying medicine. He changed his plans a few years later and went to Oxford to study physiology. After Starling went to University College, he and Bayliss began their "scientific partnership." The bond between the men was strengthened by the fact that Bayliss married Starling's sister.

Although the names of Bayliss and Starling are most frequently met together, Bayliss is well known for his own study of colloid substances. This study made possible a clearer understanding of the process of osmosis in cells. During the World War, Bayliss made important practical



SIR WILLIAM BAYLISS

If one knew nothing about the man, this picture would suggest the mechanical and technical ability which made Bayliss a great investigator. (Courtesy *The University of London*)

use of his knowledge of colloids. In association with Walter B. Cannon, he proved that wound shock was caused by poisons formed in the injured tissue. Transfusions with salt solutions did not bring about the expected results. Bayliss added a colloid, gum arabic, to the salt solution before the transfusion and found the results more satisfactory. During the later stages of the war the gum-saline solution was used in many cases of wound shock with marked success.

Bayliss was knighted in 1922. His death occurred two years later. He was the author of several books on bio-

chemistry and a book on physiology which was revised by his friends during his last illness.

In 1929 a sum of money was raised in England to provide a Bayliss and Starling Studentship. This studentship, or scholarship, is given to students who show ability in the field of physiology and biochemistry. It is expected that persons who benefit by this scholarship will devote themselves to research work.

The experiments of Bayliss and Starling made it possible to understand some of the factors controlling the secretions of the pancreas. It was in connection with the disease, diabetes, that much further knowledge of the pancreas as a ductless gland was gained.

The symptoms of sugar diabetes are described in the earliest medical writings. The loss of weight, great thirst, and the passage of large quantities of urine led to much speculation by physicians as to its cause. In 1657, at a meeting of the Invisible College, afterward the Royal Society, Dr. Thomas Willis, a close friend of William Harvey, startled the group by saying that he had tasted the urine of a diabetic patient and found it sweet.

In order to gain a more complete understanding of the problems that had to be solved before all the functions of the pancreas could be understood, the work of Claude Bernard should be considered. Bernard is frequently given credit for being the founder of experimental medicine because he produced diseases in his animals by chemical and physical means. For example, he artificially produced diabetes in a dog by puncturing its brain in the part known as the *medulla oblongata*.

Claude Bernard was born in Saint-Julien in France, in 1813. His father owned a small vineyard and was not

well to do. A priest helped Claude with his education. Later he attended a Jesuit school and then entered the college at Lyons. He left the college before earning his degree and became an apprentice to an apothecary. He spent his spare time writing; but when he took a play to a critic in Paris, he was advised to study medicine so that he would be sure of a living. He received his degree in medicine in 1843 from the Collège de France. As a student he came to the notice of François Magendie, who is noted for his work on nerves. At the death of Magendie, Bernard succeeded him as a professor at the college. A number of years later he held a professorship at the Jardin des Plantes. For a dozen years or so before he died, Bernard's health was poor. He died in 1878. It is believed that the dampness and coldness in the rooms where he carried on many of his early experiments undermined his health.

Bernard has been the subject of many bitter attacks because of the experiments he performed on living animals. The subject of vivisection is an old one, and no one who uses living animals can expect to be free from all criticism. Bayliss, for example, was attacked in magazines by the anti-vivisectionists until he was forced to take his case to the courts. As in all controversial matters, reason as well as emotion must play a part. No normal human being enjoys the suffering of an animal, and it is safe to say that scientists, as a rule, are normal human beings in this respect. However, it must be remembered that a dead animal cannot serve in the place of a live one when one wants to observe the functions that are the manifestation of life itself. On the other hand, the influence of the anti-vivisectionists has led to a more humane treatment



CLAUDE BERNARD IN HIS LABORATORY

Bernard is often called the "Founder of Experimental Medicine," because he produced pathological conditions in animals by chemical and mechanical means (*The Bettmann Archive*)

of experimental animals. Anesthetics are generally used whenever they will not react unfavorably and interfere with the purpose of the experiment. The vigilance of the anti-vivisectionists has undoubtedly kept many unscrupulous and abnormal people from inhumane acts.

Vivisection can only be justified if it is necessary for a better understanding of the functioning of the human body. If all the knowledge about the human body that has been gained by vivisection were to be suddenly obliterated, the ability to cure many diseases would be no greater now than it was in the time of Aristotle (see page 5).

As far as the experiments of Bernard are concerned, it must not be forgotten that many of his experiments were performed before ether and chloroform were used as anesthetics. If a necessary operation on a human being

were performed today as it would have been in the first half of the nineteenth century, everyone would say that it was very barbarous. Humane treatment of animals could not be expected before men could make their own sufferings less severe.

Bernard's fame is based on many lines of work. For one thing, he proved that the pancreatic juice has a threefold effect on food: it acts upon starch, upon protein, and upon fat. His study of the liver which has special bearing on diabetes began in 1843, when he injected a solution of cane sugar into the veins of an animal and found that it appeared later in the urine of the animal. However, when sugar was treated with gastric juice before it was injected, it did not appear in the urine. While trying to determine what happened in the two instances, he discovered that the liver had a modifying effect on sugar. Further knowledge of the function of the liver was gained when he found that sugar was present in the veins coming from the liver of an animal that had been living on a protein diet of meat. By 1857 he had isolated glycogen, sometimes called "animal sugar." Diabetes results when this glycogen in the blood does not undergo oxidation and is, therefore, of no use to the cells.

Another major line of Bernard's research led him to the discovery of the vasomotor nerves. These nerves control the amount of blood going to the different parts and organs in the body. Blushing, for example, results when the nerves controlling the small blood vessels in the skin cause the vessels to dilate and allow more blood than usual to flow through them.

While studying the nerves, Bernard tried the effects of different substances. Among them was curare or urare,

a substance used by the natives of South America to poison their arrows. The drug had been brought to Europe in 1595, by Sir Walter Raleigh. Bernard proved that this substance acts on the nerves and renders them incapable of being excited, but does not affect the muscles in the same way. The knowledge of this property of the substance has been used to advantage by recent investigators, among whom is Archibald Vivian Hill (see page 408).

Bernard and Pasteur were once invited to attend some festivities at the court of Louis Napoleon, then Emperor of France. The Emperor, who encouraged scientists and showed a personal interest in their work, talked with Bernard for more than two hours. The material results of the conversation were the establishment of two laboratories for physiological study, one at the Sorbonne and the other at the Jardin des Plantes where Bernard was a professor.

Claude Bernard died in Paris, in 1878. He was the first scientist to be honored with a public funeral at the expense of the state.

Bernard's most important experimental work was done before he was fifty years old. He never lost his popularity as a teacher, and his books have an unusually fine literary quality. His *Lessons in Experimental Physiology Applied to Medicine* became a standard work. In his writings Bernard did more than merely state the facts he observed. His methods were explained and his attitude toward experimental physiology was so well expressed that one finds quotation after quotation from his writings in books dealing with medicine and biology.

One quotation that sums up Bernard's attitude and points a way for other experimenters is worth giving:

“Put off your imagination, as you take off your overcoat, when you enter the laboratory; but put it on again, as you do your overcoat, when you leave the laboratory. Before the experiment and between whiles, let your imagination wrap you round; put it right away from you during the experiment itself lest it hinder your observing power.”

The investigations that finally culminated in the production of insulin for the treatment of diabetes illustrate the necessity of both imagination and correct observation, as Bernard advised. After his work the next important discovery in connection with diabetes was made by Paul Langerhans in 1869, when he discovered that besides the cells in the pancreas which secrete digestive juice, there were others, the function of which he could not determine. By the beginning of the twentieth century it had been concluded from the study of the pancreases of people who had died of diabetes that these cells, now known as the “islets of Langerhans,” were always diseased when diabetes occurred.

After the discovery of the sugar content of the urine, the natural thing was to try to eliminate from the diet sugar and sugar-producing foods, such as starches. This lengthened the life of the patient, but the extreme weakness that was felt made the effort of keeping alive hardly worth while. After the conclusion was reached that there was a connection between diabetes and the islets of Langerhans, pancreatic preparations were tried, but with little real success.

In October, 1920, Dr. Frederick Banting, then living in London, Ontario, read an article in a medical journal that gave him a clue to the treatment of diabetes.

It had been discovered previously that the removal of the pancreas of a dog caused it to develop diabetes. In this article Banting read that Moses Baron had observed that when the duct leading from the pancreas to the small intestine was closed the cells secreting the digestive juice deteriorated, but the islets of Langerhans were unharmed. As long as these islets continued to function, diabetes did not occur.

A possible experiment flashed into Banting's mind. As he had neither the equipment nor the finances to carry out his experiment, he went to Professor John James Rickard Macleod at Toronto University and asked him for the privilege of a laboratory, for ten experimental dogs, and an assistant. He was given the dogs, and Charles H. Best became his assistant.

From some dogs they removed the pancreases. In other dogs, they tied off the duct from that organ so that the digestive juice-producing cells would deteriorate. Several weeks were allowed to pass. Then came the test. A deteriorated pancreas was removed from a dog. It was crushed and a little salt water was added. The mixture was filtered and a little of it injected into a dog so near death with diabetes that he could not stand on his feet. The effect was miraculous. Urine tests showed that the sugar was rapidly disappearing. At the end of an hour the dog was able to stand up.

But Banting's joy was short-lived. The dog died the next day. Nevertheless, Banting was on the right track, and he and Best kept on. He soon discovered that the effect of the pancreatic substance, now called "insulin," was not lasting, but that his diabetic dogs could be kept

alive by repeating the injections. Tying off the pancreatic ducts, waiting six to eight weeks for the degeneration to occur, was not, however, a practical way to get insulin.

Another article came to Banting's attention, in which the author said that in the pancreas of a newborn baby, the islets of Langerhans were well developed, but those secreting the digestive substance were not. At that time one of Banting's favorite dogs was dying of diabetes. In a lecture a number of years later, Banting told an audience that the affection he had for his dog made him anxious to try anything. As there was no insulin in the laboratory, he went to a slaughter house where cattle were being butchered. He obtained the pancreases of nine embryo calves and from these extracted the life-giving hormone.

Before long it was found that, if alcohol were used instead of salt and water, insulin could be prepared from the pancreases of cattle of any age.

After experimentation on human beings, insulin became a commercial product. Today there are thousands and thousands of people living happy and useful lives because Banting realized what were the effects of the pancreatic hormone, and because he was able to extract the hormone before it was destroyed by the digestive substance also produced in the pancreas.

Insulin is not a cure for diabetes. Like other hormones it controls in its own way certain functions of the body. It will be remembered that Claude Bernard found that after digestion excess amounts of starches and sugars are stored in the liver as glycogen. When needed, this glycogen is carried to the muscle cells where it is turned back into sugar. The combination of oxygen and this



SIR FREDERICK G BANTING

This bust of Banting was erected at a summer camp for diabetic children near Cleveland. It is significant that six healthy-looking youngsters are grouped around the pedestal. The use of insulin makes it possible for them to enjoy life as active children. (Courtesy Dr. Henry J. John)

sugar, a form of slow oxidation, causes energy to be released. This energy is the source of all bodily activity. When the hormone from the pancreas is not present in the blood, oxidation cannot occur, and sugar diabetes results.

During the past few years insulin has found new uses in the treatment of diseases. By inducing what is known as insulin shock, patients with some kinds of mental troubles have been helped. The use of insulin in the treatment of common colds is still in an experimental stage.

Sir Frederick Banting, the discoverer of insulin, was born on a farm near Alliston, Ontario, in 1891. He was educated in the Alliston High School and received his medical degree from the University of Toronto in 1916. During the World War he served overseas as a captain in the Medical Corps. He was so severely wounded that the doctors who attended him thought the amputation of his arm was necessary to save his life. He refused to consent to the operation and recovered. The Military Cross was awarded him for valor in service.

After the War he started to practice in London, Ontario. He had so few patients that to take up his time he obtained a post as demonstrator of physiology at the Medical School of the University of Western Ontario. While preparing a lecture to be given before a class, he read the article by Moses Baron that started him on the way to the discovery of insulin. After discussing his ideas with friends who gave him little encouragement, he sold his surgical instruments and went to Toronto where he began his experiments on dogs.

In 1923, Banting and Macleod were awarded the Nobel Prize (see page 153). Banting shared his part of the

money with Best. Macleod shared his with his assistant, James Bertram Collip. In 1923 the Canadian government granted Banting an income of \$7,500 a year so that he might devote all his time to research work. He is at the head of the Banting Institute of the Department of Medical Research of the University of Toronto. He was knighted a few years ago.

The fatality from diabetes among children had been very high. There are now many summer camps in the United States where diabetic children live happily because there is such a thing as insulin. In 1932, at a summer camp near Cleveland, a very beautiful statue was unveiled in honor of Dr. Banting. (A picture of this statue is shown on page 389.)

The study of hormones has thrown light on many branches of biology. Normal growth and normal mental development are proved to be dependent on some hormones. Internal reactions, the co-ordination of the work of organs, are brought about by these "chemical messengers." Even the temperament of a person and his ability to work are largely dependent on internal secretions. The internal chemistry of an individual should not be ignored in studying his reactions to stimuli. In cases where improper functioning of ductless glands has changed the quantity or quality of the hormones, both physical and mental disorders have resulted.

Hints for Further Reading

FOSTER, MICHAEL, SIR, *Claude Bernard*.

GARRISON, FIELDING H., *An Introduction to the History of Medicine*.

MARTIN, C. J., "Ernest Henry Starling, C. M. G., M.D., F.R.S.," *British Medical Journal*, I (May 14, 1927), 900-906.

"Memorial to Professors Bayliss and Starling," *Science*, LXIX (Feb. 1, 1929), 131.

"William Maddock Bayliss—Physiologist," *Science*, LX (Nov. 14, 1924), 448-449.

Nerves and Muscles in Reactions

PAVLOV, HILL, SHERRINGTON, AND ADRIAN

IN THE body of a living human being there is never an instant that reactions of nerves and muscles are not going on. Even when a person is lying down, relaxed, or asleep, countless muscles and nerves are active in the walls of the blood vessels, in the heart, in the brain, and in other organs of the body. How do impressions caused by stimuli travel from one part of the body to another? What happens when muscles contract to cause the activities of the organs and the motion of the arms and legs? These are some questions that have occurred to men for thousands of years.

Galen may have had some strange ideas about the curative power of herbs and about the circulation of the blood (see page 37), but he was far ahead of his time in understanding the nervous system. He even distinguished between the sensory and motor nerves. It would be possible to trace the gradual acquisition of knowledge about nerves from the time of this famous physician to the present. But in the last seventy-five years so much

progress has been made in the study of reactions that it is more important to know how the modern electro-chemical theory of reactions came into being.

When writing about a line of research that has extended through centuries, one can pick out men who have contributed outstanding bits of knowledge and trace the effects of this knowledge through succeeding years. If the names of all the men who have worked on reactions in higher animals during the past fifty years were listed, the list would be very long indeed. Furthermore, not enough time has elapsed since the newer methods have been used to prove conclusively which men have made the most valuable contributions. When writing about investigations in biology in very recent times, several problems present themselves. For one thing, many men have been carrying on investigations along the same lines of work at the same time. In the second place, their findings cannot be evaluated until more experimentation has been done. In scientific circles, recognition of a brilliant piece of work may come immediately, or many years may pass before its real significance is apparent. Recognition may be limited to a group of fellow scientists or, as in the case of the Nobel Prize (see page 153), it may be international.

The choice of Pavlov, Hill, Sherrington, and Adrian for discussion in this chapter is based upon two factors. Each has made valuable contributions to the study of reactions and each has been a Nobel Laureate.

Ivan Petrovitch Pavlov was born in Ryazan, Russia, in 1849. His father was a priest. As a boy, Ivan was sensitive because he was left-handed. Because he wanted to compete with other boys of his age, he went through regular exercises to develop his muscles.

It was expected that Pavlov would be a priest like his father, and he was sent to a theological seminary. Fortunately, the teachers in this school were liberal minded. They did not care if a boy were not equally good in all subjects. If he showed particular ability in some line, they did not nag at him to raise all his marks to the same standard. This attitude made an impression on Pavlov that he remembered all his life. At the seminary his interest in the natural sciences was aroused. When he was twenty-one, he entered the University of St. Petersburg where he studied science for four years. He then entered the Military Medical Academy at St. Petersburg, now Leningrad. During the summer of 1877, he went to Germany where he studied and worked with Rudolf Heidenhain, who was a physiologist and cytologist.

After his return to Russia, he was made an assistant in the Medical Academy from which he received his degree in 1883. The following year he returned to Germany and studied with Carl Ludwig. The influence of Ludwig can be seen in Pavlov's later work. Ludwig's special investigations were on the salivary glands and the nerves controlling them, on the functions of the heart, and the circulation of the blood. He explained the secretions of the glands and the action of the heart in terms of physics and chemistry. In other words, he used the scientific methods of the physicists and chemists, and he believed that living matter was governed by the same laws as nonliving matter. Ludwig's techniques and his conclusions had a world-wide influence in making biology a more exact science.

While working with Ludwig, Pavlov studied blood pressure and the nerves controlling the heart. He stayed

two years in Germany and returned to Russia where he held different positions in the Medical Academy until he was made a full professor.

Pavlov's first independent investigations were on digestion. He used dogs for his experimental animals and from the first insisted on the same conditions of cleanliness and care during and after operations that would be given to human beings. It was the work on digestion that won him the Nobel Prize in 1904. However, he is best known today for his work on reflex actions. Until the work of Bayliss and Starling (see page 375) became known, Pavlov believed that the digestive tract was controlled entirely by nerves. The recognition of secretin as the stimulus of the pancreas made it necessary for him to give up his theory of nervous control. It is to Pavlov's credit that he quickly accepted the secretin explanation of pancreatic action. At the same time, his work on digestion never absorbed him as much as it had before, and he turned more and more to the investigation of reflex actions.

Reflexes are generally considered the simplest acts of higher animals; for example, drawing the hand away from a hot object is a reflex action. No conscious thought is involved in the process, and the sensory impulses go only as far as the spinal cord. Pavlov divided reflexes into two groups, natural and conditioned. The reactions he grouped as natural reflexes are often called "instincts." The conditioned, or acquired, reflexes are reactions that result from the experiences of an individual; they are conditioned or changed from natural reflexes.

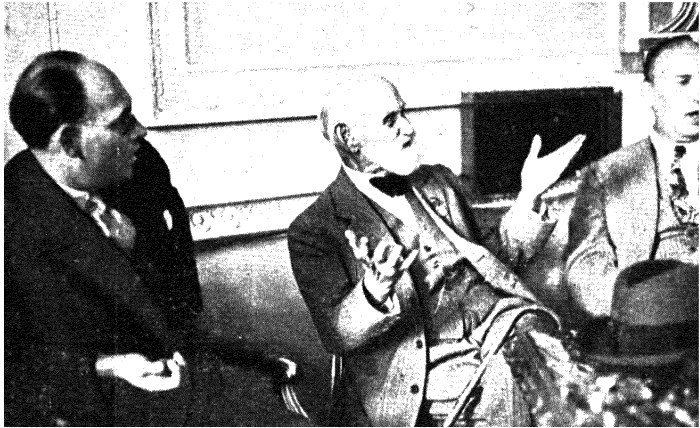
Pavlov had noticed that the sight of food caused an increase in the secretion of saliva in his dogs. This

gave him a starting point for a series of well-planned experiments. In one a metronome was used. This is an instrument that ticks audibly, and the interval between the ticks can be regulated. A dog was put in a room where there was nothing to distract its attention. After a short time the metronome began to tick. This was a new sound to the dog and was not associated with anything else. When the metronome had ticked a few seconds, a plate of food, that had been out of sight, was swung down to the floor. The dog ate the food, and the observer outside the room pulled the plate out of sight again.

The ticking of the metronome followed by the appearance of food was repeated at intervals, until the idea of the ticking was so closely associated in the dog's mind with food that the salivary glands became active at the sound of the metronome. This is an example of a conditioned reflex. The metronome would never have caused the saliva to flow, if it had not in some way made the dog know that food would appear.

In other experiments, squares of black and white cloth were used as signals. If feeding always followed the black cloth, the sight of it after several repetitions would cause the saliva to flow, while white cloth would not. A series of experiments along this line was repeated in which grey cloth of lighter and lighter shades was used. To the surprise of the observers it was found that the dogs could distinguish between grey and white, even when the grey was a very light shade.

From these experiments and many others, Pavlov explained how reflexes are conditioned in the process of learning. In other words, some types of learning are based entirely on the association of two or more things which



IVAN PETROVICH PAVLOV

The great Russian scientist is shown while attending an International Neurological Congress in London. At the time the picture was taken Pavlov was eighty-six years old (*Keystone View*).

are quite unlike. The work of Pavlov and of several Americans along this same line forms the basis for some methods now used in the education of young children.

While carrying on these experiments on conditioned reflexes, Pavlov noticed that all the dogs did not learn with the same degree of ease. Some of them became very excited during the experiments and developed nervous disorders. This led him to study nervous differences in human beings, and at the time of his death he was carrying on experiments in a clinic with patients who were mentally unbalanced. He hoped that he could help them build up new reactions, and that in this way their minds would become more nearly normal.

Everyone who visited Pavlov's laboratories was impressed by the care taken of the experimental animals and

the high standards maintained in all the work. Wherever Pavlov went, he impressed people by the charm of his personality. He had a keen sense of humor. A. V. Hill tells of an amusing incident in connection with Pavlov's visit to Cambridge University to receive an honorary degree. The students of physiology who were familiar with his work on digestion bought a large toy dog. To this, they fastened rubber and glass tubing and all sorts of pieces of apparatus like those Pavlov had used during his experiments on digestion. They hung this decorated animal on strings between the galleries where the ceremonies were being held. Pavlov was given his degree with all the solemnity fitting the occasion; then the dog was lowered in front of him. Pavlov was delighted with the stunt. He took the dog off the string and carried it back to Leningrad where it stayed for a number of years in his study.

The high regard for Pavlov in Russia was made evident by the fact that he was allowed to say about what he pleased, even when his ideas were opposed to the policies of the government. His work was never seriously interfered with. In fact, Lenin thought Pavlov's work of so much importance that he ordered that his five hundred dogs should have food at a time when the people themselves were having foodless days. A few years before his death, Pavlov was given a pension, and his laboratory received a large endowment.

Pavlov received early recognition for his work on digestion, but his work on reflexes was not well known beyond the boundaries of Russia until about ten years after he had begun his experiments. He turned to the study of reflexes in 1902, but the news of his research did not reach England until shortly before the World

War. The first book in English to give a clear account of conditioned reflexes was *General Physiology* written by William Bayliss (see page 381) and published in 1917. However, when Pavlov's experiments did become known, he was honored by both the physiologists and the psychologists. He attended meetings of these two groups in England and in the United States. His son who acted as interpreter accompanied him on these trips. Grief over the death of the son contributed to Pavlov's own physical breakdown which ended in his death in 1936.

How important Pavlov's conclusions will seem in the future remains to be seen, but no one can question that he stimulated experimental biology in Russia to a very great extent, both by directing it into new channels of thought and by introducing new techniques.

The Nobel Prize in medicine in 1922 was divided between an Englishman, A. V. Hill, and a German, Otto Meyerhof. Hill has done a great deal of experimental work on the changes which muscles and nerves undergo when they are active. Meyerhof is an authority on the respiration of cells and the action of enzymes.

Archibald Vivian Hill was born in 1886. He was educated at Trinity College, Cambridge, and became a Fellow there. He was a professor of physiology in Manchester University in 1920–1923, and at University College in London in 1923–1925. Since 1926 he has been a Foulerton Research Professor in physiology of the Royal Society (see page 153). Several times Hill has come to the United States to give courses of lectures, and during 1927 he conducted experiments on athletes at Cornell University while he was a nonresident lecturer there. Hill's best-known book is *Living Machinery*. Unlike many

scientists, Hill writes articles which appear in popular magazines. He has the ability to write about technical matters in a way that can be understood by people who are not trained in scientific thinking.

Hill is interested in the energy produced in muscles: how it is stored, what changes occur during the activity of muscles, and what causes fatigue. At Cornell University, Hill had a running track equipped with an electric timing device, so that he could have a record of the speed of runners during short intervals of the race. The electrical apparatus consisted of a number of coils set up at regular intervals along the track. The coils were connected with galvanometers that recorded current when it was induced in the coils. Each runner had a piece of magnetized hack-saw blade attached to his waist by a tape. Neither the weight nor the size of this piece of metal was great enough to interfere with his speed, but it was magnetized sufficiently so that as a runner approached a coil, an electric current was induced in the coil. The maximum current was induced in the coil as the runner passed it.

An automatic timing device and other recording instruments made it possible to secure a very detailed and permanent record of a runner's performance. Examination of the record sheets showed, for example, the time elapsing between the signal and the start of the runner, and at what point on the track the runner reached his maximum speed. By combining the information gained from these running records with other information about respiration and the formation of lactic acid in the muscles, Hill came to some interesting conclusions.

Track coaches have believed for some time that the present records for running will only be broken by frac-

tions of seconds. Hill not only agrees with this belief, but gives reasons for it. A runner covering a hundred yards in record time does enough work to lift himself three hundred feet or more in the air. When muscles are active, that is contracting and relaxing, lactic acid is formed. This acid causes a condition known as fatigue, and the muscles cannot continue to respond rapidly. Muscles of a man running at top speed produce three or four grams of this acid per second. By the time he has come to the 100-yard line, he will have about an ounce and a half of this acid in his muscles. Since four ounces of lactic acid in the muscles is enough to stop a runner completely, it can be seen that an ounce and a half will slow him up considerably.

The use of oxygen by the muscle cells must also be taken into account. A runner takes in about three and one half quarts of oxygen per minute. He has stored in his tissues about thirteen quarts. A runner at top speed will use all of the sixteen and a half quarts available in a little over three hundred yards. If he does this, complete exhaustion occurs. This stored oxygen may be "borrowed" rapidly during short sprints; but during long runs, if a runner uses it too fast, he will be forced to stop. This "borrowed" oxygen is replaced when the exertion is over and the athlete rests.

Besides the chemical effect of lactic acid and the limiting factor of oxygen supply, the muscles themselves determine the speed of a runner. Under the same conditions of environment, a muscle that contracts slowly does a greater amount of external work than if it contracts rapidly. In the muscle substance itself, the protoplasm, resistance increases the more rapidly it contracts. This resistance acts like a brake. In one of his articles, Hill

suggested that if it were not for this braking system an animal might move its arms and legs so fast that they would break. As a matter of fact, muscles do tear sometimes and tendons break at the speeds and under the exertion to which they are subjected in the body of an athlete. When one considers that the protoplasm of a muscle cell is actually a jellylike substance and that the membrane covering it is extremely delicate, it is almost unbelievable what strength a collection of these cells in a muscle can have. Hill says, for example, that an isolated muscle from a frog can be made to lift a thousand times its own weight when it is stimulated to contract.

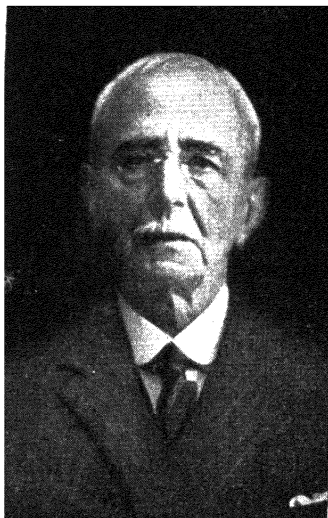
Since it is necessary to understand cell respiration in order to explain reactions in muscles, it might be well to mention the fact that Otto Meyerhof, who shared the Nobel Prize with Hill in 1923, and Otto Warburg, who received the prize in 1931, have done much to explain the chemical basis of respiration. Although some of their earlier conclusions have been modified, the fact remains that their studies of respiration contributed, directly and indirectly, to the knowledge of muscular activity.

Otto Warburg was born in Freiburg, Germany, in 1883. He studied chemistry under Emil Fischer in Berlin, where he received his degree in that subject in 1906. From there he went to Heidelberg to study medicine. Warburg is a director of the Kaiser-Wilhelm Institut.

Otto Meyerhof was born in Hannover, Germany, in 1884. He received his degree in medicine from Heidelberg University in 1909. He has been a director of the Kaiser-Wilhelm Institut of Physiology since 1929.

In the opening paragraphs of his *Chemical Dynamics of Life Phaenomena*, Meyerhof makes two important state-

ments The first one, which sums up the attitude of biologists toward respiration, is "Respiration is no mere



SIR CHARLES SHERRINGTON

Sherrington's work on the motor nerves is an outstanding accomplishment of scientific research in this century (*Courtesy Sir Charles Sherrington*)

external attribute of living matter it is a central life process, supporting the entire complicated machinery of the living being" The second statement, which indicates the direction which the biochemists are following in their work on respiration, is "If we desire to reduce the processes of life to physical and chemical terms, we must inquire as to what it is that distinguishes respiration from the chemical reactions of the inorganic world"

While the problems of muscular activity were being studied in relation to the chemical changes of respiration, Sherrington and Adrian were trying to solve the mysteries connected with the transmission of impulses along the nerves that cause muscles to react. These two men did not work together, nor did they use the same techniques. They are intimate friends, however, and in many respects the work of one complements the work of the other.

Sir Charles Sherrington was born in London in 1861. When he was twenty years old, he decided to study

medicine and entered Cambridge for that purpose. He received his degree in medicine in 1885. At this time there was a cholera epidemic in Spain. In spite of the highly contagious nature of the disease, Sherrington accompanied C. S. Roy, a pathologist, to that country to study the disease. The following year he went to Italy for the same purpose. He obtained specimens there to be examined and took them to Berlin, where he went to work in the laboratory of Virchow.

Rudolf Virchow (1821–1902) was active in many fields. Public health, politics, and pathology all claimed his time. His greatest work in pathology had been done by the time Sherrington reached Berlin. Sherrington stayed in his laboratory for two months and then, on Virchow's advice, went to Koch's laboratory (see page 197). Instead of going back to England at the end of a six-weeks course in methods used in pathological work, he stayed nearly a year.

After his return to England he held several positions and in 1895 became professor of physiology in the University of Liverpool, where he stayed until 1913. For the next three years he was a Fullerian Professor of Physiology, Royal Institution of Great Britain, and then went to Oxford. He was president of the Royal Society in 1920 and was knighted in 1922.

Sherrington's knowledge of the nervous system made his services valuable during the World War as a member of the committee studying tetanus. Tetanus affects the nervous system, and since the germs causing it are found in the ground, the danger of contracting it is great whenever dirt gets into wounds. Sherrington wanted to take a more active part in the war, but the university wished him

to continue his laboratory work. After hours, however, he gave his time to a hospital. During a vacation he even worked as a day laborer in a munitions factory.

The Integrative Action of the Nervous System, which Sherrington published in 1916, is considered a classic in the literature of physiology. It is sometimes said that Sherrington stands in the same relation to the work on the nervous system that Harvey (see page 38) does in relation to the circulatory system.

Edgar Adrian was born in England in 1889 and was educated at Cambridge, where he is now a Foulerton Professor of the Royal Society. Adrian's published writings include *The Basis of Sensation* and *The Mechanism of Nervous Action*.

The work of Sherrington and Adrian began a new era in the understanding of the nervous system. In the sections on reactions in biology textbooks, there is usually a diagram illustrating what is called the "reflex arc." One of the most common diagrams shows a lighted candle over which a finger is being held. An arrow along a line drawn from the skin of the finger represents the path of an impulse along a sensory, or afferent, nerve to the spinal chord. Another arrow pointing in the opposite direction indicates an impulse traveling from the chord along a motor, or efferent, nerve to a muscle. Such a diagram is useful because it indicates the directions of the impulses and the fact that the sensory and motor nerves have a connection in the spinal chord. Adrian's work has been particularly concerned with the sensory nerves; and Sherrington's, with the motor nerves.

Adrian showed, first of all, that a nerve impulse is electro-chemical in nature and passes along a neuron or

nerve cell. When the ending of a neuron is excited, as, for example, one in the skin of the finger held over a candle, an impulse travels along the neuron to the spinal chord. A common way of describing how this impulse travels is to compare it to a flame running along a fuse. To carry the analogy farther, the charred fuse back of the flame is different from the unburned fuse. As the impulse travels along the neuron, a change takes place in the cell so that for a brief time it cannot transmit another impulse. But cells are alive and different from a fuse. After a flame has passed along a fuse, another flame cannot follow. A nerve cell, however, recovers and is ready for another impulse. Therefore, if the stimulus remains at the nerve ending, impulses will follow one after another.

The intensity of sensation depends on the number of impulses sent along neurons. If one object feels warm and another hot, it is because the hot object starts more impulses per second than the warm one.

Sherrington's success in studying the motor nerves was made more certain when, between 1928 and 1930, he and his pupils were finally able to isolate a group of muscle fibers that was supplied by a single neuron from the spinal chord. They found that this one neuron was capable of carrying an impulse to as many as two hundred muscle fibers. Sherrington showed that strong muscular responses indicate more impulses per second are reaching the muscles, just as Adrian showed that the intensity of a sensation is determined by the number of impulses sent along the sensory nerves. Sherrington also showed that the impulses carried along the sensory nerves build up a "state of central excitation in the



ARCHIBALD V HILL



EDGAR ADRIAN

While he was in this country, Hill's interest in the energy produced in muscles led him to make a series of experiments with athletes at Cornell University (*Science Service*)

The work of Adrian on the sensory nerves together with that of Sherrington on the motor nerves has placed the study of reactions on a new basis (*Wide World*)

spinal chord or brain, which in turn starts impulses traveling from it to the muscles ”

Before reflexes were understood as well as they are today, each typical reflex was thought of in terms of a single reflex arc. Sherrington proved that reflexes are seldom as simple as they were supposed to be, for several arcs are concerned in most reflex acts. He considers that the function of the nervous system is to make an organism act as a complete whole, so that it is an integrated unit and not merely a collection of organs.

A. V. Hill has also worked on nerve activity. The work of Adrian and Sherrington caused him to change his mind somewhat about the nature of nerve impulses, as he had previously given more emphasis to the chemical rather than to the electrical nature of the impulses.

The activity of the nerves was the subject of an address given by him at a meeting of the American Association

for the Advancement of Science held during the Century of Progress, or World's Fair, in Chicago. In this he summarized the work of Adrian, Sherrington, and himself. He explained the phases or states of a cell from the period of inactivity following the discharge of an impulse, through the stage of recovery, and up to the time that it is ready to discharge another impulse. One might suppose that considerable time would be required for these changes. Of course, the time varies with different cells, but it may take less than a thousandth of a second. In other words, this means that a thousand or more impulses may travel along a neuron in a second.

The velocity with which impulses travel along a nerve fiber also varies in different organisms and in different fibers of the same organism. In man the rate of speed in the sensory nerves is approximately 100 meters, or 326 feet, per second.

A natural question is: how can such exact measurements be made? Electrical apparatus including amplifiers and photographic recording instruments is used. By this means the visual representations of the impulses may be projected on the screen of an oscillograph or put in a permanent photographic record for further study. Hill said, "We can even listen on a loud speaker to sensory impulses caused, for example, by gentle pressure on the toe of a cat."

Since Hill has always been interested in energy reactions, it is not surprising to find him making the statement that a single impulse traveling down a medullated neuron raises the temperature one ten millionth of a degree centigrade. That seems to most people too little to measure, but to the physiologist it is of great importance.

When we consider the chemical and electrical changes and the millions of cells involved, we can understand that even our simplest action is really a complicated process.

Hints for Further Reading

- BEILIN, ADOLPH, "Ivan Petrovich Pavlov, the Darwin of Physiology," *Hygeia*, XIV (July, 1936), 642-643.
- BRONK, DETLEV W., "The Nobel Prize in Physiology and Medicine: Professor Edgar Douglas Adrian," *Scientific Monthly*, XXXV (Dec., 1932), 571-572.
- FULTON, JOHN F., "The Nobel Prize in Physiology and Medicine: Sir Charles Scott Sherrington," *Scientific Monthly*, XXXV (Dec., 1932), 569.
- GRAY, GEORGE W., "Chemical Foundations of Mind," *Harper's Magazine*, CLXXIV (April, 1937), 509-519.
- HILL, A. V., "Are Athletes Machines?" *Scientific American*, CXXXVII (Aug., 1927), 124-126.
- , *Living Machinery*.
- , *Muscular Movement in Man*.
- , "A Tribute to Pavlov," *Science*, LXXXIII (April 10, 1936), 351-353.
- , "Wave Transmission As the Basis of Nerve Activity," *Scientific Monthly*, XXXVII (Oct., 1933), 316-324.
- "The Human Speed Limit" (re: A. V. Hill), *Literary Digest*, XCIII (May 28, 1927), 24.
- "The Nobel Prize in Physiology and Medicine for 1932" (re: Edgar Adrian and Sir Charles Sherrington), *Science*, LXXVI (Nov. 11, 1932), 427-429.
- "Otto Meyerhoff" (in German), *Les Prix Nobel en 1923*, 88.

Protozoa and Tissue Cultures

CALKINS AND GARREL

WHEN you read or hear about experimental animals in a biological laboratory, you are apt to think of frogs, cats, rats, dogs, and other fairly large creatures. The idea of Protozoa as experimental animals probably does not enter your mind. Nevertheless, Protozoa are important organisms from which many things about higher forms of life have been learned. More surprising than this is the fact that today parts of animals, tissues, and even organs, can be kept alive so that experiments on the living cells in them can be carried on.

A person may study Protozoa from several points of view. He may aim to identify as many as possible. He may be interested in how they cause diseases in other organisms, or he may study them as representative bits of protoplasm carrying on the vital functions.

When Antony van Leeuwenhoek (see page 55) first called the attention of naturalists to the tiny animals swimming under his lens, he opened the way for the special branch of biology known as protozoology.

After the discovery of Protozoa, two interesting theories about them were believed. Leeuwenhoek himself made a

statement that was accepted at the time. He said that it could not be doubted that these animals had organs like the higher animals. He was somewhat overawed at the necessary smallness of the organs, but since higher animals possessed organs, he could not comprehend life without them. Other naturalists, desirous of seeing the new creatures he had found, built microscopes and peered through them. Some, possessing a high degree of imagination, went so far as to indicate organs in their drawings.

In the eighteenth century, Felix Dujardin, who may not have had as much imagination as some of his contemporaries, believed that a one-celled animal could exist without organs. His description of the living stuff of Protozoa, called "sarcode" by him, did much to overthrow the idea of the necessity of organs. He also showed that the cilia of Protozoa, such as those of paramecia, were not comparable to the hair on higher animals but are the prolongations of the outer layer of the protoplasm of the organism. This position was further strengthened by the work of Max Schültze, who, it will be remembered, studied the properties of protoplasm (see page 77). His knowledge aided in the interpretation of the cell theory after Schleiden and Schwann had published their conclusions that both plant and animal tissues were made up of cells (see page 67).

At the time when the Protozoa first began to attract attention there was a widespread belief in spontaneous generation. Many people believed that all plants and animals could come into existence spontaneously. On the other hand, experiments had been performed which cast a doubt in the minds of some. One experimenter was

Francesco Redi (1626–1698), a contemporary of Leeuwenhoek. He was a court physician in Florence, Italy, who possessed an inquiring mind. It was commonly believed that as meat rotted it turned into the maggots of flies. Redi, by the simple method of tying pieces of cloth over some jars in which meat was rotting and leaving others open, proved that if flies did not lay eggs on the meat, no maggots appeared. However, this experiment did not keep him from believing that lower forms of life could arise spontaneously. So it was with many others: while they doubted spontaneous generation for high forms of life, they accepted it for low forms and particularly those as minute as Protozoa.

The idea of spontaneous generation was the center of a bitter scientific battle in the time of Pasteur (see page 189). The experiments of Pasteur and John Tyndall (1820–1893) for a time seemed to disprove completely spontaneous generation. However, as in so many disputes that seem definitely settled, recent investigators, among them Dr. Gary Nathan Calkins, have been bold enough to ask: What conditions existed in early periods of the world's history that do not exist today? Has it been positively proved that spontaneous generation in low forms cannot occur? The geologist, the colloid chemist, and the biologist may be able to answer these questions at some future date.

Gary Nathan Calkins, the protozoologist, was born in Valparaiso, Indiana, in 1869. He was graduated from Massachusetts Institute of Technology in 1890. Seven years later he received a Ph.D. from Columbia. After his graduation from the Institute of Technology, he lectured there and at the same time served as an assistant biologist

of the Massachusetts State Board of Health. In 1903 he went to Columbia as a professor of invertebrate zoology



GARY N. CALKINS

As a protozoologist, Calkins has contributed important knowledge to the field of biology (*Science Service*)

and of protozoology. Besides his work at Columbia he has had an important part in other activities. For four years he was a biologist for the New York State Cancer Laboratory. During 1913-1914 he was president of the American Society of Cancer Research. Two of Dr. Calkins's books are *The Protozoa* and *The Smallest Living Things*.

In studying Protozoa, Calkins's point of view is very broad. He has studied them in order to observe how they carry on the vital functions as well as how they affect the human body when they are parasites in it. He believes that a "complete knowledge of any one of these living things would solve the riddle of all life."

For some time it has been conceded that the nuclear material in a cell is the most active part of the cell. Calkins experimented on the exact activity of this nuclear material. He chose a protozoan that, like the paramecium, has two nuclei, a larger macronucleus and a smaller micronucleus. He divides an animal so that each part contained half of the material of each nucleus. Each part healed, grew, and reproduced. On the other hand, when he divided an animal so that one part had a small

amount of material from the macronucleus and none from the micronucleus, a different condition resulted. This part healed, fed, and grew, but it showed no signs of reproducing and died in a short time. From repeated experiments, he concluded that the material in the micronucleus controlled reproduction.

Under observation in laboratories, a paramecium can be seen to divide after it has reached a certain size. The two new animals then grow and divide again. There comes a time, however, when this method of reproduction is modified. In this case, two paramecia become joined along one side. The nuclear material in the two cells undergoes changes and moves about so that when the two separate each paramecium has some of the nuclear material of the other. It was thought that this union, or conjugation, must occur at intervals if paramecia were to continue to live. About 1904, Calkins proved that if the paramecia were kept in a suitable medium they would continue to divide indefinitely without conjugation. He carried on this experiment until thousands of animals were produced that showed no deterioration. This and similar experiments by other workers have raised the question of the immortality of Protozoa. There is no growing old and dying of the individual cells under these circumstances, but at each division new cells are formed, and so on, generation after generation.

In studying Protozoa in relation to disease, Calkins has contributed knowledge which has application in the treatment of diseases caused by Protozoa. He found that these organisms may build up a resistance to some poisonous substances, such as arsenic, mercury, and quinine, if administered in small doses. This is important

because these chemicals are used in treating some protozoan diseases in human beings and may explain why some diseases recur after treatments.

Calkins has also made an extensive study of Protozoa that become parasitic in the digestive tracts of man and other animals. Some of these organisms are actually beneficial to the host. For example, the wood-eating ants could not digest the wood fibers if they were not acted upon by Protozoa in the digestive tract. On the other hand, in amebic dysentery, frequently fatal in human beings, ulcers and abscesses are formed in the intestines by Protozoa. It is remarkable that some one-celled organisms can withstand the action of the digestive juices and continue to live and multiply. By studying the irritability of the protoplasm in these simple animals, in relation to different chemical environments, Calkins has made a definite contribution to the understanding of parasitism.

While Calkins was trying to solve questions about the requirements and activities of protoplasm by studying one-celled organisms, Alexis Carrel developed a technique for studying a group of cells in a tissue.

Alexis Carrel was born in Sainte-Foy-lès-Lyon, France, in 1873. His father was a silk merchant there. Carrel attended the University of Lyons where he received a degree in science when he was eighteen years old. His great interest was in medicine, and after studying and serving as an interne in a hospital in Lyons, he received his degree in medicine in 1900. Five years later he left France for Canada, where he stayed a few months and then came to the United States. From 1906 to 1939 he was connected with the Rockefeller Institute for Medical

Research. In 1939 Dr Carrel was one of the five scientists to be affected by the enforcement of the retirement ruling of the Institute (see page 281).

Many amazing results have come from Carrel's experiments. In surgery, the remarkable deftness of his hands has been demonstrated over and over. He developed a new technique for sewing up blood vessels. For this he was awarded the Nobel Prize (see page 153) in 1912. He has replaced sections of arteries with pieces of veins. In one experiment, he removed a



ALEXIS CARREL.
Carrel has developed important techniques for the study of living tissues (*Culver Service*)

kidney from one cat and transplanted it into the body of another, where it continued to function

In 1913 he married Anna de La Motte, one of the assistants in his laboratory. Together they went to France in 1914 and established a laboratory hospital. Here they worked unceasingly, and here also the famous Carrel-Dakin method of treating wounds saved many lives. Henry Drysdale Dakin had discovered a solution which had strong antiseptic properties but which did not destroy the tissue around the wound. Carrel devised a method of using the solution so that the wound was kept moist all the time. Not only were many lives saved by this new method, but the period of healing was greatly shortened.

The Carrel-Dakin method made the name of Alexis Carrel well known to surgeons and nurses. However, an experiment begun in 1912 caught the popular fancy and put his name in newspapers and magazines. In January of that year, he removed a piece of muscle from the heart of a live chicken. The muscle has lived and continued to grow ever since. The needs of the cells are known and supplied. Food in the form of embryo juice or some other liquid nutrient is added to the medium on which the tissue grows. At intervals, the tissue is washed with a chemical solution that removes the products of oxidation. The flasks containing the tissue have specially made necks so that the danger of infection from bacteria in the air is reduced to a minimum.

A chicken that was more than ten years old would be a very old bird. Yet this muscle tissue taken from the heart in 1912 is still alive. Further than that, it grows so rapidly that in about sixty days a cubic millimeter could grow into a cubic meter, if it were undisturbed and if such a large mass could be kept alive.

Startling experiments such as this do not always have practical applications. However, this new technique is the beginning of a new era. Carrel has shown that all tissues with the exception of brain tissue can be grown outside the body. This opens up the possibility of growing glandular tissue outside the body for transplanting into human beings whose glands are injured or diseased.

The growth of the tissue of the chicken's heart was a great accomplishment. Carrel was not satisfied. He wanted to keep entire organs alive. This can now be done because the mechanical ingenuity of Charles A. Lind-

bergh (see page 438) has made the mechanical heart a reality.

It is seldom that a really great scientist writes a book that becomes a best seller. Nevertheless, in 1935, when *Man the Unknown* was published, it immediately became popular and its popularity has continued. In the preface of this book Dr. Carrel says that he spends a large part of his time studying living cells in the laboratory and another large part studying people outside the laboratory. His book indicates that he has a wide knowledge of both the cells of man and the man of cells.

All scientific knowledge gained about cells, single or in groups, may eventually find practical application in the control of disease and the lengthening of the useful period in the life of human beings.

Hints for Further Reading

“Alexis Carrel,” *Les Prix Nobel en 1912*, 60.

CALKINS, GARY N., *The Biology of the Protozoa*.

———, *The Protozoa*.

———, *The Smallest Living Things*.

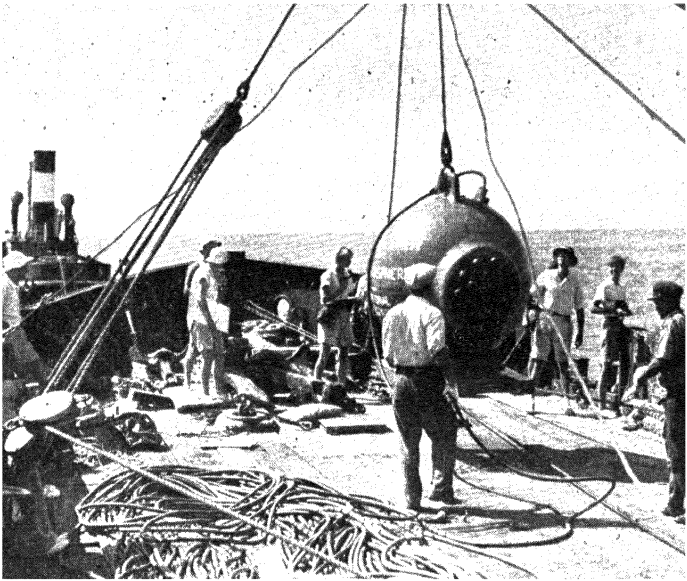
LAW, FREDERICK H., *Modern Great Americans*.

as thoroughly as he could. Sharks, which hold terror for most people, have no terror for him. He frequently mentions seeing them swim by rather close to his unprotected body. The depth that can be reached by a person using a helmet is not great. Walking along the floor of the ocean, Beebe sometimes came to abrupt drops. The impenetrable blackness of the water below him stirred his imagination. As a boy, he was a devoted reader of Jules Verne's books, and it may be that his maturer curiosity about life in the deep was a development of the longings inspired when he read *Twenty Leagues under the Sea*. Anyway, when he came to these drops, he wanted more than anything else to go down into the blackness.

Undersea exploration could not be carried on at great depths until a structure could be made that would withstand the tremendous pressure of water. At the same time, the physical needs of the explorer must be met. A sufficient amount of oxygen must be constantly supplied to him, and carbon dioxide and water vapor removed from the atmosphere within the structure.

William Beebe discussed with Otis Barton his desire to go down under the seas. The result was the construction of the bathysphere.

In April, 1930, Beebe set out for his laboratory at Nonsuch, an island near Bermuda. Mr. Barton met him there with the bathysphere. This huge metal sphere weighs two tons and has withstood a pressure of 1,360 pounds to the square inch. Oxygen is supplied from tanks. Trays of calcium chloride and soda lime remove the water vapor and carbon dioxide from exhaled air.



BEEBE'S BATHYSPHERE

The construction of the bathysphere is a striking example of man's successful attempts to overcome factors in his environment that limit his activities (*Time*)

The first descent of the bathysphere took place on June 6, 1930. On that day Beebe and Barton were lowered 800 feet. In 1934 they descended 3,028 feet, more than half a mile.

What were the results of these unique and perilous trips? Beebe has seen many strange fish and other animals that live in the darkness beyond the reach of sunlight. He has found that many organisms live in definite strata in the water while others have the ability of adapting themselves to changes of pressure and may be found near the surface or at great depths. The lumi-

nous organs of fish have been a source of amazement to him. Much research work is necessary before either the whole purpose of these luminous organs and the chemical and physical changes which go on in them can be understood.

A very practical person might not consider that the many descents of the bathysphere were important enough to compensate for the expense and danger. But since there seems to be a natural balance between living things and between them and their environments, the time may come when a knowledge of deep-sea life will be very important. Further than that, the principles which were used in the construction of the bathysphere have already stirred ideas in the minds of men interested in reclaiming from the bottom of the ocean treasures that have sunk too deep for divers in ordinary diving suits to recover.

As a collector on land and in the ocean, Beebe has found many species of animals previously unknown to zoologists. Besides the necessary technical qualifications of a scientist, Beebe possesses a rare appreciation of the beauty to be found in nature and the even more rare ability to put into vivid words what he has seen. Someone has described his style in writing as glamorous. Whatever the quality may be, he has exerted an influence on hundreds of readers. Conceptions of the jungle and of the sea are changed by reading his magazine articles and books. Museum specimens have a new interest when connected with the descriptions of the surroundings in which the animals lived.

The Arcturus Adventure, Beneath Tropic Seas, Exploring with Beebe, and Half Mile Down are some of his popular

books. *The Arcturus Adventure* is an account of a trip of 13,600 miles made in 1925. One of the main purposes of this trip was to study life in the Sargasso Sea. This name is used to designate an area in the Atlantic Ocean where there are no pronounced currents and where masses of floating seaweed collect. All kinds of stories have grown up about the Sargasso. One of the most prevalent was that sunken vessels collected there. The Sargasso proved disappointing to Beebe, for a series of storms had broken up the mass of weeds and extended work was not feasible. Beebe then sailed for the Galápagos Islands off the coast of South America.

After passing through the Panama Canal, the "Arcturus" came to what is known as a "current rip," a meeting place of two ocean currents traveling at different velocities. Beebe says that the number of organisms in the rip was unbelievable.

Fish of many kinds were found feeding on the abundance of smaller organisms. Dolphins and birds were present in great numbers to feed on the fish. A poisonous water snake nearly three feet long was caught here.

In an old magazine, Beebe had once read that insects, called water striders, laid their eggs on floating feathers. He was somewhat skeptical, but one day he picked up a booby feather in the rip and saw an egg mass on it. He put the feather in an aquarium on the boat and by morning found that the eggs had hatched into tiny water striders. He found more feathers with eggs on them. On one feather he estimated there were twenty thousand eggs. They were in different stages of development, showing that more than one insect had visited the feather to lay her eggs. Here was another strange relationship, a

bird's feather as the hatching place of a water insect's eggs.

At the Galápagos Islands Beebe collected a great many specimens, and while there he had the thrilling experience of seeing a volcano in eruption.

Beebe's method of collecting marine forms is interesting. Nets of different sizes and shapes are let out so that they will be pulled through the water at different levels. Thus the nets on the shortest lines will contain those forms of plant and animal life whose habitat is within a few feet of the surface, whereas the lowest net and a special net known as a dredge, that is dragged on the bottom, will have the forms adapted for life under great pressure, lower temperature, and less light. Beebe observed that many of the forms caught at considerable depths reached the surface in poor condition. Experiment proved in many cases that temperature and not pressure changes seemed to be the cause and that when the organisms were put in water in the refrigerator they revived.

Since 1930, Beebe has been director of a marine laboratory at Nonsuch, near the coast of Bermuda, where oceanographic work in all its phases is carried on: the study of marine forms, the measuring of the depth of the ocean, the examination of the bottom to determine how the islands were formed. The largest single-celled organisms so far known are found in this region. They are called "sea bottles" and have been found as large as an inch and a half in diameter. They contain chlorophyll and are classified as algae. The size of these cells makes them especially useful in determining the effects of electricity and chemical substances on the functions of living cells.



WILLIAM BEEBE

This picture shows Beebe reading from one of his own books so that phonograph records can be made for the blind (*Courtesy American Foundation for the Blind*)

While Beebe has been collecting animals that have not been known before from the jungles and the depths of the sea, Roy Chapman Andrews has been digging fossils in the Gobi Desert. Many of the fossil remains are of animals that ceased to exist before primitive man made his appearance on the earth.

Andrews, who led the expeditions into the heart of Mongolia, was born at Beloit, Wisconsin, in 1884. As a boy he was particularly fond of the out-of-doors. On week days he hunted as often as he could. On Sundays, when he was not allowed to take his gun, he stalked animals just the same and took notes on them. He has said that it seemed to him that the animals he most

wanted to shoot were easier to find on Sundays than on other days.

After being graduated from Beloit College in 1906, he went to New York where he applied for a position at the Natural History Museum. He was told there were no vacancies. Andrews insisted that there must be a job of some kind. He was finally hired to scrub floors, mix clay for models, and help with the preparation of skins.

Not long after he began to work at the museum, he was assigned the task of helping to build a model of a whale. This model was twenty-six feet long, and although made of papier-mâché, it weighed several tons. It still hangs in the museum.

His interest in whales was further stimulated when one of these animals was killed off the shore of Long Island, and he had the opportunity to examine it. At this time very little was known about the life of whales, the largest living mammals. Andrews began to study whales in earnest and in 1908 went to Alaska for this purpose. *Whale Hunting with Gun and Camera*, the book that grew out of this study, was published in 1916 and republished in 1935. During 1909-1910 he was the naturalist on the U. S. S. "Albatross," on a trip to the Dutch East Indies, Borneo, and the Celebes. The following year he explored in Korea. From that time his activities turned toward Asia, although he made one more trip to Alaska in 1913.

Paleontologists (see page 80) and other scientists interested in tracing the development of man and other animals had for some time believed that Central Asia was the logical place for finding fossils. For centuries "dragon bones," really fossils, have been used in China in compounding medicines. A few fossils had been picked up by

explorers and scientists, but no exhaustive work had been done. Dr. Henry Fairfield Osborn, head of the American Museum of Natural History, had even made some definite predictions about what would be found there. Exploration in Mongolia presented many difficulties because of the topography of the country and because of the unwillingness of the governments to allow foreigners to explore. Added to these difficulties was the fact that the country was overrun with brigands.

Roy Chapman Andrews became head of the first Asiatic expedition of the American Museum of Natural History in 1916. This first expedition was conducted mainly in the interests of zoology. From that time, with the exception of the year 1918 when he was in service in the World War, Andrews was either doing field work in Asia or making preparation for the supplies and equipment of the now famous expedition of 1922 into Mongolia.

From his previous experience, Andrews concluded that the use of automobiles in the desert was practical. Heretofore, camels had been used by explorers for transporting all their supplies and equipment. With these animals an average of only ten miles a day could be covered. Andrews estimated that with automobiles he could cover a hundred miles a day. The success his expeditions proved the estimate to be nearly correct. The result was that, with the new method of transportation, his party accomplished in one season as much as they could have in ten with camels alone. Camels were not entirely replaced, however, for a caravan bringing supplies and taking back fossils and other specimens was continuously trekking across the desert. The camels served another purpose very different from transportation. In June they shed their

wool, so they became convenient sources of packing material.

If Andrews should write a book about the experiences of the expeditions and leave out all the excitement of the fossil discoveries, it would even then have all the elements necessary for a thrilling story. There were encounters with brigands and officials on the borders. At one place the caravan was held up for days. One excuse for the delay was that copies of *Asia*, *The Saturday Evening Post*, *World's Work*, and other magazines were found in the baggage by the officials and considered to be dangerous literature. At the same place there was trouble over a box of flashlight batteries that were thought to be bombs. Storms of almost unbelievable ferocity scattered the explorers' belongings many times. At one camp poisonous snakes, seeking shelter in the tents, made dangerous companions. Although the men in the expeditions were temporarily excited by these events, the real thrills came to them when they made some important discovery.

During the expeditions in Môngolia, the fossil bones of the *Baluchitherium*, an enormous prehistoric mammal were found. It is estimated that the shoulders of this huge beast were about thirteen feet from the ground. The added length of its neck and head made it possible for it to feed on leaves sixteen or seventeen feet above ground. The skull of the *Baluchitherium* was removed with all possible skill and treated to keep it from disintegrating before it was wrapped in cloth covered with flour paste to form a hard covering. In spite of all the care that was taken, the skull was broken into 360 pieces. The restoration of the skull shows how much knowledge had been

gained since Cuvier (see page 87) began his work on fossil bones.

The discovery of the *Baluchitherium* is important to scientists because of its relation to other animals and because of the belief that it was contemporary with very early man. This means that in whatever stratum of rock the bones of this huge animal are found, a thorough search will be made for evidence of prehistoric man.

The finding of the dinosaur eggs made the Asiatic expedition well known. Why the dinosaur eggs should have attracted as much attention from the public as they have, no one is able to explain. Seen in a museum they are not very impressive. But when one stops to consider that about ninety-five million years ago the shells were filled with living protoplasm, the idea does stir one's imagination. How do paleontologists know that these pieces of stone were once dinosaur eggs? Some were nearly ready to hatch when an unknown calamity stopped their development. The fossilized embryos can be made out.

The expeditions led by Andrews had other results beyond the tons of fossils that were dug. With the natives the expeditions were never very popular, for they imagined all sorts of disasters would follow. When they lost their herds the year following the digging of the first fossils, the natives believed they were being punished for disturbing the "dragon bones." However, there were exceedingly practical results to the country at large. The use of automobiles by the scientists led to the establishment of commercial automobile routes. Also, topographers mapped much new country, and geologists made studies of the rocks. At one place a considerable

deposit of iron was found which will be valuable if a railroad is ever built across Mongolia.

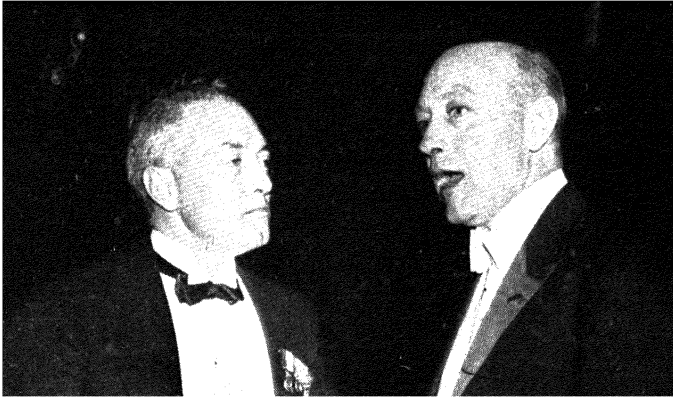
The study of animals was not confined to fossils. Many living animals were shot or trapped and the skins sent to America, where they may be seen in museums.

Andrews has contributed many interesting articles to magazines. He published three books about whales before he became absorbed in exploration in Central Asia. In *Across Mongolian Plains* and *On the Trail of Ancient Man*, he tells the story of his work in Mongolia.

The successful expeditions of Andrews mark a high point in the application of scientific knowledge in exploration, but the Antarctic expeditions of Richard E. Byrd are an even greater proof of the ways in which this knowledge has been put to practical use under adverse conditions.

Andrews had plenty of difficulties to overcome, but the region where his expeditions worked was not isolated as Little America is, nor did he have the problems of lack of light, extreme cold, and scarcity of food. Game was plentiful in much of the territory covered by Andrews. On the other hand, Byrd's men were completely isolated and had no possible way of getting to civilization during many months of the year. Before the Bay of Whales froze over, seals were killed for the dogs and for the men, because seal meat is an excellent preventive of scurvy. But with the coming of winter, the animals left for open water, and there was nothing left to kill.

Rear Admiral Richard Evelyn Byrd was born in Winchester, Virginia, in 1888. He attended the Virginia Military Institute for two years and then went to the University of Virginia. In 1908 he entered Annapolis.



RICHARD E. BYRD AND ROY CHAPMAN ANDREWS

The two explorers were photographed while talking together at a dinner in honor of Admiral Byrd. Byrd has conquered space in his polar flights. Chapin has turned back the pages of biological history by his discoveries of the remains of prehistoric life in the Gobi Desert (*Wide World*.)

After graduating from there, he spent four years with the fleet.

When he was fourteen, Byrd wrote in his diary that he was going to the North Pole. He went further than that in his plans and drew designs of different pieces of apparatus he would use. For a time after the end of the World War, the idea of polar exploration was pushed into the background by his desire to make a solo flight across the Atlantic. Circumstances forced him to give this up.

In 1925 Byrd joined Donald B. MacMillan's expedition to Greenland, expecting to fly over the pole. For the first time an American expedition had airplanes for polar exploration. As far as reaching the pole was concerned, the expedition was a failure. But in less than four days of good flying weather, during the trip, the planes flew

six thousand miles. In comparison with the time taken to explore Arctic regions with dog teams, airplane exploration was seventy-five times as fast.

The following year, Byrd and Floyd Bennett actually flew over the North Pole. They left from Kings Bay in Spitsbergen and covered the distance to the top of the world and back, 1,360 miles, in fifteen and a half hours. After this flight Byrd was advanced to the rank of commander in the Navy.

The first Antarctic expedition was organized and left America in the autumn of 1928. In November, 1929, the first airplane to circle the South Pole carried Byrd, Bernt Balchen, Harold I. June, and Ashley C. McKinley. In 1933 the second expedition sailed back to Little America.

There are two questions to be considered in regard to these expeditions: What advances in science made them a success? What did the expeditions contribute to scientific knowledge?

The most obvious answer to the first question is that airplanes and tractors were used, and that electric lights and heat were possible. A less obvious answer is that the study of nutrition had made it possible to calculate not only how much food would be needed, but what proportions of different nutrients were most adequate. One of the great hardships of polar expeditions in the past has been scurvy. Foods rich in vitamins were taken, and, to "make assurance doubly sure," Byrd took an extra supply of beans that could be sprouted if symptoms of scurvy should appear.

Besides physical health, mental health had been a serious problem in earlier polar expeditions. The radio and movies played their part in keeping normal the mental state of the men in Byrd's party.

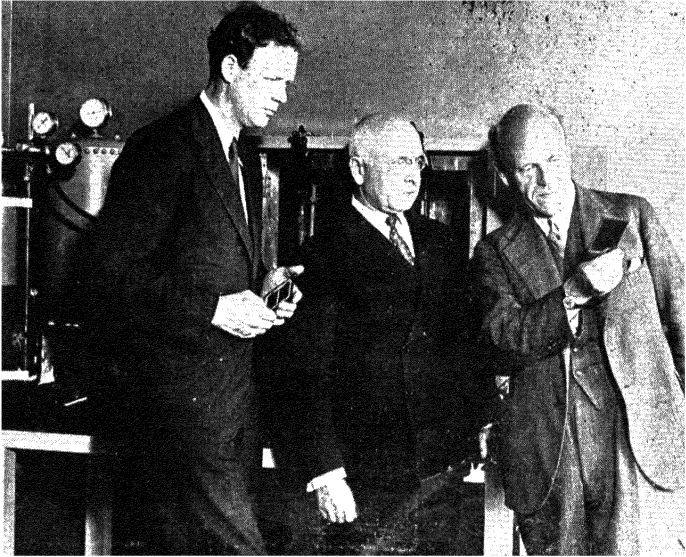
The contributions to scientific knowledge were many. The second expedition was equipped to make investigations in more than twenty divisions and subdivisions of science. Large areas of unknown country were mapped. Coal was found in abundance, proving that the climate in some remote time in the past was different from what it is now. Cosmic rays were studied. What effect these rays have on life is not yet known, but increased study of them is leading scientists to believe that their effects are great.

Climate and weather are controlling conditions that make life possible or impossible. For years it has been the dream of meteorologists to be able to predict in advance what weather conditions will be for long periods of time. For example, if a drought could be predicted long enough before it happened, much suffering could be prevented. Conditions at the polar regions are believed to be factors influencing world-wide weather. Meteorological observations of many kinds were taken during the expeditions. The magnetic forces in the southern hemisphere have not been definitely known. These and electrical disturbances were also studied.

The more problems of living things are studied, the more definitely they appear to be closely related to other phenomena of the world. The unraveling of the mysteries of physical phenomena on any expedition may furnish clues in solving the mystery of life itself.

Richard E. Byrd was given the rank of rear admiral in 1929. Since his return from the Antarctic, he has lectured and shown his films before thousands of people who now have an idea what the bottom of the world looks like. He has published *Skyward*, *Little America*, and *Discovery*.

The names of Byrd and Lindbergh became associated in people's mind because of their famous flights. The



CHARLES LINDBERGH, ALEXIS CARREL, AND ALBERT FISCHER

The work of Lindbergh and Carrel which resulted in the construction of the mechanical heart was of great scientific importance. Professor Fischer of Denmark, shown at the left of Carrel, was at one time assistant on the scientific staff of the Rockefeller Institute (*Pictures, Inc.*)

mention of Byrd's name now brings to mind great and successful expeditions in Antarctica. Lindbergh has stepped into a new rôle as a scientist. As a matter of fact, this is not a new rôle, but it was not made public until the mechanical heart was exhibited at the Danish Biological Institute in Copenhagen in the summer of 1936.

Charles Augustus Lindbergh was born in Detroit, Michigan, in 1902. When a few weeks old he was taken to his parents' home on a farm near Little Falls, Minnesota. His paternal grandfather, who was at one time secretary to the King of Sweden, had come to America

about 1860. His maternal grandfather was a dentist in Detroit, who, after a long series of experiments with materials suitable for the fillings of teeth, succeeded in making a porcelain filling.

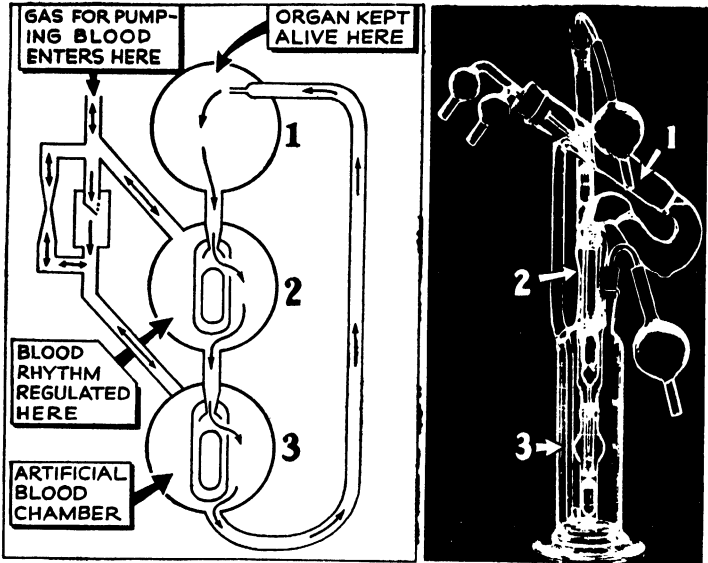
The first few years of his life, Lindbergh spent on the farm. After his father became a member of Congress, the family moved about so much that the boy never attended school for a full year. Traveling was always a source of pleasure to him.

Planning to become a mechanical engineer, Lindbergh entered the University of Wisconsin where he remained a year and a half. The story of his study of aviation, of his barn-storming tours is known to everyone. His service as a mail pilot gave him the experience he needed for his transatlantic flight.

On May 20, 1927, he took off in the "Spirit of St. Louis" on a solo flight that was to make him world famous not many hours later. His flying time was thirty-three and a half hours.

The idea of Lindbergh as a scientist came as a surprise to many people who had not been aware of his activities in this field. Before he made his historic flight, he had suggested the use of airplanes to archeologists as an efficient way to locate ruins. His suggestion did not bear fruit at the time. Later he proved the importance of his idea when he took an archeologist of the staff of the Carnegie Institution on a flight above the region where excavations were being made. In Yucatan he carried two archeologists over some ruins that have not yet been visited by an overland route.

In 1933, in the interests of the Pan-American Airways, Lindbergh and his wife made a survey of possible routes



A DIAGRAM OF THE MECHANICAL HEART

This apparatus, in which entire organs may be kept alive, was developed by Charles A. Lindbergh and Alexis Carrel (*Keystone View*)

to Europe. On this trip they took with them a piece of apparatus called the "sky hook." By the use of this apparatus, slides were exposed at high altitudes over the Atlantic. Later these slides were sent to the Department of Agriculture for examination. To the surprise of many scientists, bacteria and the spores of molds were on the slides. Thus, it was demonstrated that the causative organisms of diseases in plants and animals can be spread over wide areas by currents of air.

From the point of view of a biologist, the construction of the artificial heart is Lindbergh's most important contribution to the science of biology. The story of how he began to work on this piece of apparatus has recently

been made public. In the summer of 1930 Lindbergh met Dr. Paulel J. Flagg, an authority on anesthetics and the founder of an American society to prevent death by asphyxiation. A few months later Flagg asked Lindbergh if he were interested in medicine. His response was emphatically in the affirmative. As a result of their discussion of the fields of medicine, Flagg arranged the meeting between Charles A. Lindbergh and Alexis Carrel that resulted in Lindbergh's going to work at once, and in privacy, at the laboratories of Rockefeller Institute. For five years he experimented until the mechanical or artificial heart, operated by oxygen and carbon dioxide, became a practical piece of apparatus. When it was displayed in Copenhagen, the Danish people christened it the "Lindbergh" heart.

At the present time several of these mechanical hearts are in use at Rockefeller Institute. By means of this apparatus living hearts, livers, and glands of small animals are kept alive. These organs can now be studied. Glandular tissue can be grown for the production of hormones to be used in the treatment of diseases. The importance of the mechanical heart cannot even be predicted.

The records of distance, time, and the achievements of the men mentioned in this chapter will become part of the permanent history of science. However, they will not represent final records. Men will go farther beneath the sea than Beebe has gone. Fossils that will clear up many points that are only guessed at today will be found.

There are several schemes, which at the moment seem impractical, for obtaining power from either the coal or the terrific winds at the South Pole. But over long periods

of history, more than one impractical scheme has proved to be very practical indeed. Long-time weather forecasts may also be possible by studying conditions at the two poles.

A more careful examination of microscopic organisms in air currents high above the earth may make it possible to control diseases of plants more efficiently.

Any or all of these possibilities that may result from the conquest of time and space will broaden the scope of biology and give man more and more control over his environment.

Hints for Further Reading

- ANDREWS, ROY CHAPMAN, "Adam's Grandparent," *Saturday Evening Post*, CCII (March 22, 1930), 18+.
- , "Ends of the Earth," *Saturday Evening Post*, CCII (Sept. 14–Oct. 12, 1929).
- , "Explorers and Their Work," *Saturday Evening Post*, CCIV (Aug. 22, 1931), 6–7.
- , "Gobi Death Traps," *Saturday Evening Post*, CCIII (Oct. 25, 1930), 18–19+.
- , "My Museum Complex," *World's Work*, LVIII (Oct., 1929), 55–59.
- BEEBE, WILLIAM, "Half Mile Down," *National Geographic Magazine*, LXVI (Dec., 1934), 661–704.
- BYRD, RICHARD E., *Discovery*.
- , *Little America*.
- , *Skyward*.
- LINDBERGH, ANNE MORROW, *Listen! the Wind*.
- "Lindbergh Adds to Fame As Scientist," *Literary Digest*, CXXII (Aug. 22, 1936), 16–17.

Biology in the Making

THERE are three main reasons why men have studied biology through the centuries. First of all, they are curious about themselves and about all other living things. They want to know how many kinds of plants and animals there are and what relationships exist between them. They want to know of what they and other living things consist; how they function as organisms; and how different parts of the organisms function.

In the second place, men want to improve living things upon which they depend for food and clothing and shelter. It is not good business to raise crops that give small yields.

In the third place, one of the great desires of human beings is to be physically and mentally fit and to live as long as possible. Men want health and long life for themselves and for their families and friends. Therefore, they strive to prevent and to cure diseases.

As far back as we can trace the beginnings of biological thought, we find these three purposes underlying investigation. However, the increase in biological knowledge has not progressed at a steady pace, nor do we find in different periods an even distribution of the names of men who have made important discoveries. Looking back through

the centuries, we are conscious that before the beginning of the seventeenth century there are comparatively few men whose names have lived down to the present. Moreover, there are long periods of time when biological thought seems to have been at a standstill.

If we consider these facts in relation to the general history of civilization and the spread of culture, we soon see that these were normal circumstances. It must be remembered that for centuries education, even of the most rudimentary kind, was limited to comparatively few people. Only the exceptionally fortunate young men were able to avail themselves of the best education to be had at the time in church schools and universities. Furthermore, the tools that existed for research work were crude. Not even the microscope had been invented until the seventeenth century. For hundreds of years at a time attitudes of mind handicapped investigation along many lines. During several periods there was such violent opposition to the dissection of human bodies that it was not safe for anyone to undertake it. There were also several centuries when the influence of the ancients, for example Aristotle and Galen, was so great that no headway could be made in any field where actual observations differed from the accounts of those ancient authorities. While superstitions and false ideas were uppermost in the minds of the most intelligent people, it is not surprising that we find a general lack of what is today known as the scientific attitude of mind.

During the seventeenth and eighteenth centuries the study of biology was accelerated in several directions by different factors. The boundaries of the known world were being rapidly increased. During these two centuries

countries were explored, not alone with hope of finding gold or other precious metals, but as territory to be controlled and colonized. Naturalists who were prepared to study the climate, soil, and plant and animal life were included in the personnel of the expeditions sent out by European countries. They collected, as far as possible, every plant and animal that was strange to them. It was a golden age for men interested in classification. Somewhat later it was classification that gave an impetus to the study of comparative anatomy, thus making it a new branch in biological study.

Necessarily, the earliest observations dealing with the structure of organisms were confined to the parts visible to the naked eye. The invention of the microscope served two purposes. By its use curiosity about some things, for example the capillaries, was satisfied. On the other hand, when a whole world of micro-organisms came into view, curiosity about them was stimulated to a great degree.

Biology cannot advance alone. It depends on other sciences for techniques and apparatus. By the last half of the eighteenth century the science of chemistry was shaking off the superstitions of alchemy, and the biologist then had a scientific way to explain such processes as respiration. Later, organic chemistry was to give the solution to more than one biological problem.

In the meantime the attitude toward investigation had changed. Men were thinking in terms of cause and effect, and the modern scientific attitude had made a beginning. One of the early proofs of this was the founding of the Royal Society in England in the seventeenth century and of societies of a like nature in France, Italy, Germany, and the Scandinavian countries. Also, progress was being



UNCONTROLLED MEDICINE

In this mural in Queens County General Hospital, Long Island, the artist, William C. Palmer, shows some of the medical practices of other days. The patient is lying in the street while the masqued plague doctor stands over him with a stick for taking his temperature and another doctor holds to his eyes a device which was supposed to cure any ailment. Vaccination, anesthesia, antiseptics—the things we take for granted today—were unknown. Superstitions and false ideas prevailed in the minds of most people, and there was a general lack of what today is called the “scientific attitude of mind” (*Bourges Color Photography*)

made both in the subject matter of education and in the number of people who were receiving an education.

The stage was set for the amazing developments in scientific thought that came in the nineteenth century. In addition to the broader unfoldings of the previous centuries, there were developments in more specialized fields. The study of geology opened the way for a systematic research on prehistoric animals, and for the theory of evolution. The improved microscope, new techniques



CONTROLLED MEDICINE

The second of the Palmer murals depicts preventive medicine, largely unknown at the time portrayed in the first mural. Vaccination is performed with the aid of modern, sterile equipment. In addition to the sterilizer on the table and the ultra-violet-ray light, the ether and oxygen tanks can be seen at the left, and the X-ray machine at the right. Everything in the operating room including the clothing of doctors and nurses must be made sterile. Medicine has come far from the days when the red and white pole was set out to advertise the barber-surgeon. (*Bourges Color Photography*)

in staining slides, and the use of animals under controlled situations revolutionized the study of medicine.

The work of scientists in the nineteenth century brought many results of tremendous importance in themselves, moreover, from that time the scope of biology has spread like a rapidly growing plant with new branches sprouting from the older ones. And carrying the comparison a little farther, we may say that just as the buds at the ends of the branches hold the undeveloped

leaves, so there are undeveloped possibilities in all of the new branches of biology.

Every daily paper has news about scientific investigations. Many fields of research are continually brought to the notice of the public. Here are a few topics that might have been seen in the papers recently: New techniques are being developed to control cancer. Visual purple, a chemical substance in the eye, has been isolated. Aviators who suffer from night blindness are being given vitamin A to overcome this defect. Controlled experiments in mental telepathy are being carried on. Vitamin C has been isolated from paprika by Albert von Szent-Györgyi, winner of a 1937 Nobel Prize (see page 153).

At first glance some of the bits of scientific news, such as the isolation of visual purple, have an air of finality about them. However, this will not end research on visual purple. Its isolation has not brought the complete solution to all the chemical and physiological problems of sight. It has spurred investigators on to further work. Other bits of news, as for example the experiments in mental telepathy, bring to mind age-old disputes on the subject that cannot be settled until proof one way or the other seems convincing from the scientific point of view.

Biology has been in the making for centuries and is still in the making. How are these men, these biologists, who change the unknown into the known, different from the rest of us? They are not so different on the whole, but each research worker has some qualification that makes him successful in solving problems. It may be that he possesses especially keen eyesight or has unusual skill with his fingers. Perhaps insatiable curiosity drives him on from one experiment to another in spite of obstacles and

failures. One man may have the ability to see a relationship between phenomena that escapes others because his imagination is more keen than theirs. Yet another may feel that only by classification, by reducing the seeming chaos of nature to some orderliness on paper, can he be satisfied. Some men are spurred on by the pain and suffering of others to find means to alleviate pain. The economic aspects of biology may supply the motive for another worker, who wants to improve or increase the food supply of the world.

Few research workers are deluded by the idea that wealth or fame is just around the corner for them. A man may make a fortune from a discovery, or he may become famous before his death; but the chance of either of these events is not great enough to have much effect on him when he begins his researches. Perhaps the one most common characteristic of all research workers is scientific curiosity—the impelling desire to know the hows and whys of things.

There is no conceivable end to the study of biology. A solution of one problem brings to light others, usually of a more difficult nature. There never was a time in the history of civilization when men had such delicate apparatus with which to work. There never was a time when scientific training was within the reach of so many people. There never was a time when so many men and women were taking up scientific research as a life work. And as long as men are curious about themselves and other living organisms, as long as they want to improve their crops and herds, as long as they desire to prevent and cure disease, they will find numberless problems to solve. Biology is in the making.

Hints for Further Reading

- American Council of Learned Societies, *Dictionary of American Biography*.
- BOLTON, SARAH K., *Famous Men of Science*.
- CANNON, WALTER B., *The Wisdom of the Body*.
- CARREL, ALEXIS, *Man, the Unknown*.
- CATTELL, J. M., and J. CATTELL (editors), *American Men of Science*.
- CURTIS, FRANCIS D., OTIS W. CALDWELL, and NINA H. SHERMAN, *Biology for Today*.
- DAMPIER-WHETHAM, WILLIAM C. D., SIR, *A History of Science and Its Relations with Philosophy and Religion*.
- DE KRUIF, PAUL H., *Men Against Death*.
Dictionary of National Biography.
- EAST, EDWARD M. and OTHERS, *Biology in Human Affairs*.
Encyclopedia Britannica.
- FULTON, JOHN F. (editor), *Selected Readings in the History of Physiology*.
- GINZBERG, BENJAMIN, *The Adventure of Science*.
- GRAY, GEORGE W., *The Advancing Front of Science*.
- HART, IVOR B., *Makers of Science*.
- HEGNER, ROBERT W., *College Zoology*.
- HOOKE, JOSEPH D., SIR (editor), *Journal of the Right Honorable Sir Joseph Banks*.
- JAFFE, BERNARD, *Outposts of Science*.
- KIMBALL, DEXTER S., (editor), *The Book of Popular Science*.
- LOCY, WILLIAM A., *Biology and Its Makers*.
- , *The Growth of Biology*.
- , *The Story of Biology*.
- MURRAY, ROBERT H., *Science and Scientists in the Nineteenth Century*.

- NEEDHAM, JAMES G., *General Biology*.
- NORDENSKIÖLD, ERIC, *The History of Biology*.
- RADL, EMANUEL, *The History of Biological Theories*.
- ROBERTSON, T. BRAILSFORD, *The Spirit of Research*.
- SINGER, CHARLES J., *From Magic to Science*.
- , *The Story of Living Things*.
- THORNDIKE, LYNN, *A History of Magic and Experimental Science*.
- WELD, CHARLES R., *A History of the Royal Society, with Memoirs of the Presidents*.
- WELLS, H. G., J. S. HUXLEY, and G. P. WELLS, *Science of Life*.
- WHEAT, FRANK M., and ELIZABETH T. FITZPATRICK, *General Biology*.
- WILLIAMS, HENRY S., *The Story of Nineteenth-century Science*.
- WOLF, ABRAHAM, *Essentials of Scientific Method*.

Chronological List

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
	B.C.		
Hippocrates	460-359 or 377?	Island of Cos, Aegean Sea (now Italian ter- ritory)	The greatest physician of ancient times. Au- thor of Hippocratic Oath.
Aristotle	384-322	Stagira in ancient Macedonia, a Greek colony	Made a definite at- tempt to classify ani- mals. Often spoken of as the "Father of Biology." Philosopher and naturalist.
Theo- phrastus	?-287?	Island of Lesbos, Greece	Made an attempt to classify plants. Often called the "Father of Botany."
	A.D.		
Pliny the Elder	23-79	Novum Comum (Como), Lom- bardy, Italy	Author of books on natural science which exerted a great influ- ence on scientific thought for many centuries.
Ptolemy	Made ob- servations between 127 and 151	Probably near Thebes in an- cient Egypt	His theory of plan- etary motion and a geocentric universe retarded the advance of astronomy. Was important as a geog- rapher.
Galen	130-200?	Pergamum in an- cient Mysia, Asia Minor	Greatest authority on physiology until the Renaissance.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Copernicus	1473–1543	Thorn in Polish Pomerania	His theory of heliocentric universe revolutionized the study of astronomy and stimulated other branches of science.
Paracelsus	1493–1541	Near Einsiedeln, Switzerland	Began the use of mineral substances as medicines. Believed that life-phenomena were chemical processes. Taught that Galen should not be considered an authority.
Vesalius	1514–1564	Brussels (now in Belgium)	Great anatomist. Originator of much surgical technique and many surgical instruments. Corrected many erroneous ideas about anatomy.
Gesner	1516–1565	Zürich, Switzerland	Wrote <i>Historia Animalium</i> , which is sometimes spoken of as marking a border line between the ancient and modern methods of studying animal life.
Fallopio	1523–1562	At or near Modena, Italy	Anatomist. Discovered the Fallopian tubes.
Eustachio	?–1574	Italy	Anatomist. Discovered the Eustachian tubes

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Fabricius ab Aqua- pendante	1537-1619	Italy	connecting the middle ear with the pharynx. Discovered the valves in the veins. He was Harvey's teacher. Greatly improved the technique of surgery.
Helmont	1577-1644	Brussels (now in Belgium)	Coined the word "gas." Made an experiment with a willow tree to determine how a plant got its nourishment.
Harvey	1578-1657	Folkestone, England	Traced the course of the blood through the heart, arteries, and veins.
Redi	1626 ² -1697	Italy	Carried on experiments to disprove spontaneous generation.
Malpighi	1628-1694	Crevalcuore (now in Italy)	Discovered the capillaries in the tissues of the lungs. Saw the stomates in leaves. Made important studies of the structure and life history of the silkworm.
Grew	1628-1712	Warwickshire, England	Independently discovered the stomates. Proposed a theory of sexuality in plants.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Leeuwen- hoek	1632-1723	Delft, Holland	Described the different types of bacteria. Saw the capillaries in living specimens of tadpoles and fish. Saw and described several protozoa.
Hooke	1635-1703	Isle of Wight, England	Named the cell. Wrote an important book on the use of the microscope.
Camerarius	1665-1721	Tübingen (now in Germany)	Given credit ^e for first proving by experimentation the sexuality of plants.
Hales	1677-1761	Beckesbourne, Kent, England	Invented a ventilator for prisons. Studied plant nutrition. Believed some part of the air was converted into food and that light was necessary for the purpose.
Linnaeus	1707-1778	Råshult, Sweden	Developed the binomial nomenclature used in classifying plants and animals.
Ingenhousz	1730-1799	Breda (now in Holland)	Proved that a gas was given off by plants during photosynthesis and that sunlight was necessary for this process.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Kolreuter	1733-1806	Sulz (now in Germany)	Studied pollination and the production of hybrid plants. Recognized the relationship between insects and cross-pollination.
Priestley	1733-1804	Fieldhead, Yorkshire, England	Was the first person to make oxygen from an oxide of mercury. Proved that green plants "purified" the air in which animals had been kept until the animals had died.
Senebier	1742-1809	Geneva, Switzerland	Studied effect of different colored light on the process of photosynthesis.
Lavoisier	1743-1794	Paris, France	Chemist. Put the subject of chemistry on a quantitative and qualitative basis. Showed relation of oxygen to process of burning. Was studying relation of oxidation of food to production of energy in the human body at time of his death.
Lamarck	1744-1829	Bazantin, Picardy, France	Proposed a theory of evolution based on "use and disuse" of

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Laplace	1749–1827	Beaumont-en-Auge, France	<p>organs and the ability of acquired characteristics to be inherited. Sometimes called the “Founder of Invertebrate Paleontology.”</p> <p>Proposed the nebular theory to explain the creation of the earth. Assisted Lavoisier with his experiments on energy production in the human body.</p>
Jenner	1749–1823	Berkeley, Gloucestershire, England	Began the use of vaccination against smallpox.
Malthus	1766–1854	Near Guildford, Surrey, England	His book, <i>The Principle of Population</i> , had a great influence on Darwin when he was formulating his theory of the origin of species.
Saussure	1767–1845	Geneva, Switzerland	Used quantitative methods to study photosynthesis and respiration in plants. Proved the mineral matter in plants came from the soil.
Cuvier	1769–1832	Montbéliard, France	Called the “Founder of Vertebrate Paleontology.” Opposed

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Brown	1773-1858	Montrose, Scotland	Lamarck's theory of evolution. Began the modern study of comparative anatomy. Called attention to the nuclei of cells. Made observations on the streaming of protoplasm and the growth of the pollen tube in the pistil of a flower.
Dutrochet	1776-1847	Old province of Poitou, France	Made a thorough study of osmosis. Also concluded that only cells with chlorophyll could manufacture food.
Purkinje	1787-1869	Libochowitz, Bohemia	Physiologist. He established the first physiology laboratory, was the first scientist to use the word "protoplasm," and among the first to propose the cell theory. Made important investigations of the cells of the brain and the heart.
Lyell	1797-1875	Kirriemuir, Scotland	His study of geology paved the way for Darwin's theory of evolution.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Wöhler	1800–1882	Frankfort on the Main, Germany	Was the first person to synthesize an organic compound, urca. Sometimes called the “Founder of Organic Chemistry.”
Dujardin	1801–1860	Tours, France	Used the term “sarcode” to designate living matter now called “protoplasm” and studied the properties of it.
Boussingault	1802–1887	Paris, France	Studied importance of nitrates to plants.
Liebig	1803–1873	Darmstadt (now in Germany)	Studied importance of nitrates and how soil could be renewed by the use of commercial fertilizers.
Schleiden	1804–1881	Hamburg (now in Germany)	Came to the conclusion that the fundamental unit in plants was the cell.
von Mohl	1805–1872	Stuttgart (now in Germany)	Used term “protoplasm” and popularized it. Was an excellent microscopist, and his descriptions of cell structure clarified a number of points.
Agassiz	1807–1873	Môtiers, Switzerland	Classified fossil fish. Made very important contributions to the

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Darwin	1809–1882	Shrewsbury, England	theory of glaciation. Was largely responsible for the establishment of the Harvard Museum of Comparative Zoology. Proposed a theory of evolution based on variation and the survival of the fittest. The <i>Origin of Species</i> produced a lasting effect on biological thought.
Henle	1809–1885	Fürth (now in Germany)	As a teacher had a great influence on Robert Koch's work. He himself laid the foundation for modern histology.
Schwann	1810–1882	Rhenish Prussia (now in Germany)	Came to the conclusion that the fundamental unit in animal tissue was the cell.
Simpson	1811–1870	Bathgate, Scotland	Introduced the use of chloroform as an anesthetic.
Bernard	1811–1870	Saint-Julien, France	Showed the glycogenic function of the liver and importance of the vasomotor circulation.

CHRONOLOGICAL LIST.--(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Long	1815-1878	Danielsville, Georgia	First used ether for a surgical operation in 1842.
Zeiss	1816-1888	Weimer, Germany	Gave up study of botany to improve microscopes. Founded important optical company.
Morton	1819-1868	Charlton, Massachusetts	Used ether for an operation in the Massachusetts General Hospital in 1846.
Tyndall	1820-1893	County Carlow, Ireland	Primarily a physicist. Carried on careful experiments to disprove spontaneous generation.
Galton	1822-1911	Birmingham, England	Coined the word "eugenics." Made extensive study of variations in human beings.
Pasteur	1822-1895	Dôle, France	Recognized the relation between microorganisms and disease and fermentation. Developed a treatment for hydrophobia.
Mendel	1822-1884	Austrian Silesia	Stated the laws of inheritance.
Wallace	1823-1913	Usk, Monmouthshire, England	Independently came to many of the con-

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Schultze	1825-1874	Freiburg (now in Germany)	clusions that Darwin did about the origin of species. Clarified the cell theory by recognizing the protoplasm with the nucleus as the vital part of a cell.
Lister	1827-1912	Upton, England	His work on antiseptics revolutionized modern surgery.
Sachs	1832-1897	Breslau (now in Germany)	Experimented on the tropisms of plants. Studied the starch granules in green cells. Exerted a wide influence on experimental biology through his own work and that of his pupils.
Weismann	1834-1914	Frankfort on the Main, Germany	Carried on extensive experiments with rats to show that acquired characteristics cannot be inherited. Was a champion of Darwinism in Germany.
Chamberlin	1843-1928	Mattoon, Illinois	Geologist. With Moulton advanced the planetesimal hypothesis.
*Koch	1843-1910	Klausthal (now in Germany)	Discovered the bacterium that causes

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.--(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Atwater	1844-1907	Johnsburg, New York	tuberculosis. Greatly improved techniques for studying diseases produced by micro-organisms. Studied nutrition in man by use of calorimeter.
Mechnikov	1845-1916	Kharkov, Russia (now U.S.S.R.)	Discovered that phagocytes of the blood destroyed bacteria and caused a certain amount of natural immunity.
Laveran	1845-1922	Paris, France	Discovered the parasite that causes malaria.
de Vries	1848-1935	Haarlem, Holland	Studied mutations as a possible explanation of a cause of evolution.
Burbank	1849-1926	Lancaster, Massachusetts	Improved plants and created new varieties
*Pavlov	1849-1916	Ryazan, Russia (now U.S.S.R.)	Studied digestion and reflexes.
Reed	1851-1902	Gloucester County, Virginia	Member of the Yellow Fever Commission in Cuba.
Löffler	1852-1915	Frankfort on the Oder (now in Germany)	Discovered bacterium causing diphtheria
*Fischer, Emil	1852-1919	Euskirchen (now in Germany)	Chemist. Synthesized sugars and developed a test for them.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Roux	1853-1933	Confolens, France	Immunologist. Made a special study of diphtheria toxin.
Gorgas	1854-1920	Mobile, Alabama	Introduced modern methods of sanitation in Cuba and the Panama Canal Zone.
*von Behring	1854-1917	Hansdorf (now in Germany)	Immunologist. Studied diphtheria; produced antitoxin in animals.
Rubner	1854-1932	Munich, Germany	Studied nutrition in relation to production of energy.
Grassi	1854-1925	Rovellasca, Italy	Independently proved that malaria is transmitted by the <i>Anopheles</i> mosquito.
*Ehrlich	1854-1915	Breslau, Germany	Immunologist. Studied diphtheria and found antitoxin for human use could be produced from horses.
Wilson	1856-1939	Geneva, Illinois	Cytologist. Made important contributions to knowledge of the cell.
*Ross	1857-1932	Almora, India	Proved that malaria was spread by mosquitoes.
Howard	1857—	Rockford, Illinois	Entomologist. Was instrumental in controlling insect pests by use of parasites.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
*Eijkman	1858–1930	Holland	Studied beriberi, a deficiency disease caused by lack of vitamin B.
Loeb	1859–1924	Mayen, Germany	Tried to explain life in terms of physics and chemistry. Produced artificial parthenogenesis in eggs of sea urchins. Carried on much of his research work in the United States.
Smith, Theobald	1859–1934	Albany, New York	Parasitologist. Proved that Texas fever in cattle was spread by ticks.
Bayliss	1860–1924	Wednesbury, England	Physiologist. With Starling discovered the action of secretin.
Bateson	1861–1926	Whitby, England	Made important studies on heredity.
*Hopkins	1861—	Eastbourne, England	Biochemist. Recognized that "food accessories," now called "vitamins," are necessary for proper nutrition.
*Sherrington	1861—	London, England	His work on the nervous system is compared in importance with Harvey's work on the circulatory system.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Flexner	1863—	Louisville, Kentucky	Has made important contributions in prevention and treatment of infantile paralysis.
Park	1863–1939	New York City	Introduced into the United States the wide use of antitoxin for diphtheria.
Lazear	1866–1900	Baltimore, Maryland	Member of the Yellow Fever Commission. Contracted the disease and died.
Davenport	1866—	Stamford, Connecticut	Has made important studies on eugenics.
Starling	1866–1927	Bombay, India	Worked with Bayliss on hormones which he called "chemical messengers."
*Morgan	1866—	Lexington, Kentucky	His work on vinegar flies has increased knowledge of inheritance. One of the founders of the "theory of genes."
Stiles	1867—	Spring Valley, New York	Discovered that thousands of the people in the South were infected with hookworms. Carried on an active campaign to eradicate this parasite.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Jennings	1868—	Tonica, Illinois	Carried on extensive experiments on lower animals to show why and how they responded to stimuli.
*Landsteiner	1868—	Vicnna, Austria	Proved human blood may be divided into four main types. Came to United States in 1922.
*Spemann	1869—	Stuttgart, Germany	Showed that very young embryonic tissue had the potential ability of developing into more than one kind of tissue, but that tissue transplanted from one species to another developed characteristics of the species from which it was taken.
Calkins	1869—	Valparaiso, Indiana	Protozoologist. Has studied the vital functions in the Protozoa and their relations to disease.
Benedict	1870—	Milwaukee, Wisconsin	Improved methods of studying metabolism in both man and animals.
Cannon	1871—	Prairie du Chien, Wisconsin	Physiologist. Discovered relations between

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
*Willstätter	1872—	Karlsruhe, Germany	emotions and secretions of the ductless glands. Isolated chlorophyll. Studied animal and plant pigments. With Duisberg produced the anesthetic "aver-tin."
*Carrel	1873—	Sainte-Foy-les-Lyon, France	Developed new techniques in surgery, in the treatment of wounds, and for the growing of tissue cultures. With Lindbergh developed the "mechanical heart."
Goldberger	1874-1929	Austria-Hungary	Conducted experiments on pellagra and its relation to vitamin G. Spent most of his life in United States.
Blakeslee	1874—	Geneseo, New York	Geneticist. Has carried on important investigations on the genes in the cells of Jimson weed.
Noguchi	1876-1928	Inawashiro, Japan	Investigated yellow fever.
Beebe	1877—	Brooklyn, New York	Has studied life in the sea at a greater depth than any other scientist.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
McCollum	1879—	Fort Scott, Kansas	Discovered the presence of vitamins A, B, and D in foods.
*Fischer, Hans	1881—	Hoechst on the Main, Germany	Chemist. Has studied the molecular composition of chlorophyll.
Evans	1882—	Modesto, California	Discovered vitamin E and obtained it in the pure form.
*Warburg	1883—	Freiburg, Germany	Carried on extensive investigations on respiration and photosynthesis.
Andrews	1884—	Beloit, Wisconsin	Studied whales and led the expeditions in Asia during which the dinosaur eggs were found.
*Meyerhof	1884—	Hannover, Germany	Carried on extensive investigations on the chemical changes that occur in living organisms.
*Hill	1886—	England	Studied the chemical and physical changes in muscles and nerve cells.
Kendall	1886—	South Norwalk, Connecticut	Isolated thyroxine and has made extensive study of chemical composition of hormones.

* Designates the Nobel Prize winners.

CHRONOLOGICAL LIST.—(Continued)

<i>Scientists</i>	<i>Dates</i>	<i>Place of birth</i>	<i>Major contributions</i>
Byrd	1888—	Winchester, Virginia	Led the expeditions to the South Pole during which many facts of scientific importance, such as the discovery of coal, were made.
*Adrian	1889—	England	Studied the electrochemical changes in nerve cells.
Painter	1889—	Salem, Virginia	Has studied the genes and developed a technique for photographing chromosomes.
Muller	1890—	New York City	Has produced mutants in vinegar flies by the use of X rays.
*Banting	1891—	Alliston, Ontario, Canada	His study of diabetes led to the production of insulin by himself and Best.
Conant	1893—	Dorchester, Massachusetts	Chemist. Has studied the molecular composition of chlorophyll.
Harington	1897—	England	Synthesized crystals of thyroxine.
Lindbergh	1902—	Detroit, Michigan	With Alexis Carrel developed the "mechanical heart."
Stanley	1904—	Ridgeville, Indiana	Has isolated a protein believed to be the virus causing the tobacco-mosaic disease.

* Designates the Noble Prize Winners.

Glossary

- acidic medium:** a liquid or more or less solid substance which gives an acid reaction.
- adrenal gland:** a small ductless gland near the anterior end of each kidney.
- adrenalin:** the commercial name for an extract of the adrenal glands. It is used as a heart stimulant.
- Aedes:** a genus of mosquitoes. The most important species is a transmitting agent of yellow fever.
- afferent nerve:** a nerve which carries impulses to the brain, often called a sensory nerve.
- alchemy:** the medieval chemical science which was practiced with many mysterious rites. The avowed purposes of alchemy were to change common metals into gold, cure diseases, and prolong life.
- alga** (pl. **algae**): a simple plant of the phylum *Thalophyta* which has no roots, stems, or leaves. Pond scum and seaweeds are examples.
- alkali** (pl. **alkalies**): a base. A substance which will turn pink litmus paper blue.
- ammonium cyanate:** a white crystalline substance which breaks down into the organic substance "urea."
- amoeba** or **ameba** (pl. **amoebae** or **amebas**): a simple one-celled animal that has no definite shape but is constantly changing as the protoplasm protrudes at different points.
- amoebic** or **amebic dysentery:** an inflammation of the large intestine caused by the presence of certain kinds of amoebae in the intestinal canal.
- amphibian:** an animal with a backbone that spends the early stage of its life in water and breathes by

means of gills. Most adult forms develop lungs. Examples are frogs, toads, and newts.

anemia: a condition of the blood in which the red corpuscles are reduced in number or are lacking the normal amount of hemoglobin.

angiosperm: a plant of the phylum *Spermatophyta* in which the seeds develop in a closed ovary.

aniline dye: originally the word referred to dyes made from a chemical called "aniline." The word is now applied to any synthetic inorganic dye.

animalcule: a term which was formerly used to designate a minute organism. After these organisms were examined under a microscope many of them were found to be plants and not animals.

Annelida: a phylum of the invertebrates which includes such animals as the earthworm.

Anopheles: a genus of mosquitoes carrying the malaria parasite from one person to another.

anthrax: an infectious and usually fatal disease of cattle, sheep, and other animals.

anthropology: the study of man with respect to his origin, his distribution, his environmental and social relations, and also the origin and relationship of the different races.

antibody: one of the substances or bodies in the blood which neutralize toxins or destroy foreign bodies in the blood.

antiseptic: a chemical substance which is unfavorable to the growth of bacteria and which does not have a very poisonous or irritating effect on living tissue.

antitoxin: a substance that neutralizes the poison, toxin, produced by micro-organisms in the body.

- apothecary:** a person who prepares and sells drugs or compounds for medicinal use. The word has been replaced in this country to a great extent by the word "druggist."
- Arachnida:** a class of *Arthropoda* in which the spiders are grouped.
- areola:** a small space. Brown used the term to describe the nucleus of a cell.
- arsenic:** one of the chemical elements. Arsenic and its soluble compounds are very poisonous.
- atom:** the smallest particle of an element that takes part in a chemical reaction.
- auricle:** a chamber in the heart which receives the blood from the veins.
- autopsy:** the dissection of a dead body for the purpose of determining the cause of death.
- Avertin:** a basal anesthetic.
- bacillus:** a rod-shaped bacterium.
- bacterium** (pl. **bacteria**): a one-celled plant belonging to the phylum *Thallophyta*. Many diseases are caused by bacteria. However, some bacteria produce useful changes in organic matter.
- Baluchitherium:** a genus of prehistoric animals related to the rhinoceros.
- basic medium:** a liquid or more or less solid substance which gives an alkaline reaction.
- bathysphere:** the specially constructed metal chamber first used by Beebe for deep-sea observations.
- beriberi:** a deficiency disease caused by lack of vitamin B. The nerves become inflamed with the result that muscular control is affected.

- binomial nomenclature:** a system of classification in which every organism is given two names, that of the genus and that of the species.
- biochemistry:** the study of the chemical reactions that occur in living organisms.
- bismuth:** a metallic chemical element. Salts of bismuth are used as medicines.
- Bryophyllum*:** a genus of tropical plants used for experimental purposes in the study of regeneration.
- bubonic plague:** a serious disease that often prevails in the Orient. The death rate is very high.
- calcium chloride:** a chemical compound of the elements calcium and chlorine.
- calorie:** a unit for measuring the amount of heat given off by a substance. See also page 325.
- calorimeter:** an apparatus used for measuring quantities of heat.
- cambium layer:** the region of growth in the stem of a dicotyledon.
- carbohydrate:** a chemical compound composed of carbon, hydrogen, and oxygen in definite ratios. The sugars, starches, and celluloses are examples of carbohydrates.
- carbon dioxide:** a gaseous product formed by the oxidation of carbon.
- carmine:** a dye of a red or purplish red color. It is used as a stain in microscopic work.
- carotin:** a ruby-red crystalline substance found in the chloroplasts of some plants. Carrots contain a considerable amount of it.
- catastrophism:** a belief, held in the eighteenth and nineteenth centuries, that the geological formations

then exist ng could only be explained as the results of great catastrophies which had happened in the past.

cellulose: the substance which makes up the chief part of the solid structure of plants; that is the cell walls.

centrosome: a minute body in many animal and some plant cells which influences mitosis, one of the methods of cell division.

cerebro-spinal meningitis: a disease caused by an infection resulting in an inflammation of the brain and spinal chord.

chemotaxis: a sensitiveness to chemical substances, as is seen in minute free-swimming organisms. They may be attracted or repelled by chemical substances in solution.

chemotropism: the sensitiveness shown by organs of plants, such as the roots, to chemical substances.

chlorophyll: the green coloring matter in plants.

chloroplast: a minute granule in plant cells containing chlorophyll.

cholera: a serious disease of the intestinal tract.

chromosome: a body in a nucleus by means of which inheritable characters are transmitted. The genes are in the chromosomes.

chronic: lasting a long time, constant.

cilia: minute projections of protoplasm as from the surface of a paramecium or from the cells in the respiratory tract.

coagulate: to congeal, thicken, or solidify. White of egg coagulates when heated.

cocaine: a narcotic obtained from coca leaves.

cochlea: the shell-shaped part of the inner ear of man.

- colloid chemist:** a person engaged in colloid chemistry, which see.
- colloid chemistry:** the study of substances of a gelatinous nature, such as gelatin and albumin.
- combustion:** rapid oxidation or burning.
- comparative anatomy:** the study of the structure of different kinds of organisms with a view to tracing their biological relationships.
- conjugation:** the act of joining or uniting.
- cornea:** the transparent part of the coat of the eyeball over the iris and pupil.
- cortin:** a hormone produced by the adrenal gland.
- cosmic rays:** penetrating waves of high frequency which are believed to originate outside the earth's atmosphere.
- cretin:** a type of mental deficient who is also deformed or physically degenerate.
- cross-pollination:** the transfer of pollen from the anther of one flower to the stigma of another
- Crustacea:** a class of *Arthropoda*. Lobsters, crabs, crayfish, and shrimps belong to this class.
- crustacean:** an animal belonging to the class *Crustacea*.
- crystalline:** having a regular molecular structure so that the substance forms crystals.
- culture:** cultivation of micro-organisms in or on a prepared medium.
- curare:** a substance prepared from the bark of a South American plant which paralyzes the motor nerves when it is in the blood stream.
- cytologist:** a person who studies the structures and functions of cells.

- cytoplasm:** the protoplasm of a cell exclusive of the nucleus.
- deficiency disease:** a diseased condition that is caused by the lack of some substance in the body of an organism.
- diabetes (sugar diabetes):** a disease during which sugar in the blood does not undergo normal chemical changes and, therefore, passes into the urine.
- dietary:** fixed allowance of food.
- dinosaur:** a prehistoric reptile.
- dioecius:** having staminate and pistillate flowers on different plants.
- diurnal:** recurring every day; as a diurnal fever.
- dominant (dominant character):** a character prevailing over other inheritable characters.
- duodenum:** a section of the small intestine into which the food enters upon leaving the stomach.
- Echinodermata:** a phylum of marine invertebrates including the starfishes and sea urchins.
- efferent nerve:** a nerve which carries impulses from the nerve centers to the muscles and glands, often called a motor nerve.
- elephantiasis:** a tropical disease which causes the skin to become greatly thickened. The arms and legs become inflamed and swollen.
- embryo:** the first or undeveloped stage of a young animal. The term is also used in connection with the vital parts of a seed, such as a bean.
- endocrine (endocrine gland):** a gland which secretes a hormone that passes directly into the blood or lymph.
- entomologist:** a person who specializes in the study of insects.

- enzyme:** a chemical substance in living organisms that promotes chemical changes, such as the enzymes in digestive juices.
- epidermal:** pertaining to the epidermis or outer layer of cells of a plant or animal.
- epinephrin:** a chemical substance secreted by the adrenal glands.
- ether:** an anesthetic.
- eugenics:** the science which deals with the influences that improve the native or inborn qualities of a race or breed, especially the human race.
- evolution:** the history of the steps through which organisms have passed in becoming the existing or fossil species of today.
- excitant:** anything which arouses or increases activity in an organism.
- excretory:** pertaining to the elimination of wastes from an organism.
- ferment** (noun): an organism or chemical substance capable of producing chemical changes in organic matter.
- fermentation:** the changes produced in organic matter, such as those produced by the action of living organisms, such as yeast.
- fibrinogen:** a substance in the blood which causes clotting or coagulation.
- flora:** the plants, taken collectively, that are native to a region or that belong to some geological period.
- fungus disease:** a disease of a plant or animal caused by a parasitic fungus, such as smut in cereal grains.
- fuschin:** a dye giving a brilliant dark red color when dissolved.

galvanometer: an instrument for detecting an electric current or for measuring its intensity.

galvanotropism: a response to an electric current as shown by an organism or any of its parts.

gastric: pertaining to the stomach.

gene: a region or specific body in a chromosome believed to be responsible in some way for a heritable character.

generic: pertaining to a genus, which see.

geneticist: a person who studies genetics.

genetics: the branch of biology which deals with heredity and variation, particularly in relation to their evolutionary aspects.

genus (pl. **genera**): in classification allied species make up a genus; allied genera make up a family.

geotropic: stimulated positively or negatively by gravitational attraction.

germ plasm theory: a theory advanced by Weismann in which he differentiated between the reproductive and somatic cells.

glycogen: a carbohydrate which is stored in the liver of most animals.

granule: a small particle.

gum arabic: a sticky substance obtained from several species of *Acacia* used in pharmacy and in the manufacture of adhesives and confectionery.

gymnosperm: a plant having naked seeds, such as a pine.

hemoglobin or **haemoglobin:** the iron compound in the red corpuscles that gives them their characteristic color.

- hemophilia:** a condition in which blood does not clot so that the person bleeds profusely and uncontrollably even from slight wounds.
- herbarium:** a collection of dried and pressed plants.
- heredity:** the transmission of characteristics or qualities from parent to offspring.
- histology:** the branch of biology that treats of the minute structure of plant and animal tissues.
- homogenous:** having a resemblance in structure.
- hookworm:** a parasitic roundworm.
- hormone:** a chemical substance produced by a ductless gland that acts as a "chemical messenger" or co-ordinator.
- horticulture:** the science of growing fruits, vegetables, and flowers.
- host:** an organism on or in which a parasite lives.
- hybrid:** a plant or animal produced by crossbreeding plants or animals that are not of the same variety or species or race.
- hydra:** a simple multi-cellular animal found in fresh water on submerged sticks and leaves. (When written with a capital, *Hydra* means the genus made up of these animals.)
- hydrochloric acid:** a colorless acid composed of hydrogen and chloride. It is found in a very dilute form in gastric juice.
- hydrogen:** an odorless, colorless, tasteless gas. It is lighter than any other known chemical element.
- hydroid:** an animal in the genus *Hydra*.
- hydrophobia:** rabies. A form of madness which attacks dogs and is transferred to man and other animals by the saliva of the mad dog when he bites them.

- hygrometer:** an instrument for measuring the degree of moisture in the atmosphere.
- hypnotism:** the practice of inducing a state resembling normal sleep, but differing from it because the subject is responsive to the suggestions of the hypnotizer.
- hypothesis:** a tentative theory, frequently assumed as a working basis.
- incipient:** a commencing or beginning, as the incipient stage of disease.
- incubator:** an apparatus in which the desired degree of heat can be maintained. Eggs are hatched and micro-organisms are grown in specially built incubators.
- immunology:** the study of conditions which make an organism able to resist disease.
- immunize:** the process of introducing vaccines or serums into an organism to protect it from specific diseases.
- indigenous:** native to a country.
- indigo:** a dark blue dye; formerly made from plants, now prepared synthetically.
- infantile paralysis:** a disease occurring chiefly in children which causes an inflammation of tissues that may result in permanent deformities.
- Infusoria:*** minute organisms found in decomposing organic matter. (More recently the term has been limited to protozoa that have cilia.)
- inoculation:** the introduction of micro-organisms or small quantities of organic substances into an organism.
- inorganic:** pertaining to matter that is not or has not been alive, such as minerals.

insecticide: a substance used to kill insects.

insulin: a substance extracted from the islets of Langerhans in the pancreas. It is used in the treatment of sugar diabetes.

insulin shock: a condition of sudden weakness and fatigue accompanied by nervousness. If the shock is very severe, the person may become unconscious. The condition is caused by the lowering of the blood-sugar content below the normal amount.

interne: a physician or surgeon serving in a hospital in preparation for independent practice.

invertebrate: an animal without a backbone.

iodoform: a compound of carbon, hydrogen, and iodine used as a healing and antiseptic dressing for wounds.

irradiation: exposure to some type of rays, as to ultra-violet light or X rays.

islet of Langerhans: a special area of tissue in the pancreas, the cells of which secrete insulin.

jaundice: a disease characterized by the yellow color of the skin and eyeballs.

lactic acid: an acid formed by the fermenting of milk, sugars, and starches.

larva (pl. **larvae**): an insect in the stage between the egg and the pupa. Caterpillars and maggots are larvae.

lymph: blood plasma containing colorless corpuscles that bathes cells and is taken up by the lymphatic vessels.

macronucleus: the larger of two nuclei in such organisms as a paramecium.

maggot: the larval stage of some insects such as that of the housefly. The term is most often used in con-

nection with forms that live on decaying organic matter.

malaria: a disease during which the red corpuscles are destroyed by parasitic protozoa.

mammal: an animal which feeds its young with milk secreted by the mammary glands.

mechanistic conception of life: the theory that eventually all the manifestations of life can be explained by the laws of physics and chemistry.

medulla oblongata: the lowest or posterior part of the brain.

medullated: having a sheath resembling marrow.

membrane: (1) the limiting surface of an animal cell.

(2) In multicellular animals, a thin sheet of cells; as the mucous membrane in the nose.

mental deficiency: a condition which shows that the brain of an individual does not function normally.

mercury gauge: device in which the variations in the height of a column of mercury show differences in pressure.

mesmerism: a term used for hypnotism coined from the name of F. A. Mesmer. See also page 284.

metabolism: the sum of the processes which occur in the building up and breaking down of protoplasm in a living organism.

metaphysics: that branch of knowledge which deals with the nature, character, and causes of being.

meteorological: of or pertaining to conditions of the atmosphere.

meteorologist: a specialist in meteorology.

metronome: an instrument for marking exact time.

The number of strokes of the pendulum per minute can be regulated.

micron: a thousandth part of a millimeter.

micronucleus: the smaller of two nuclei in such organisms as a paramecium.

micro-organism: a very minute organism, of microscopic or ultramicroscopic size.

molecule: a particle of matter composed of two or more atoms in chemical combination.

mollusk: an animal belonging to the phylum *Mollusca*, such as the oyster.

mucus: a slippery secretion of the lining membranes of the passages and cavities of the body.

multicellular: consisting of many cells.

mutant: an organism showing a sudden variation from its parents in some well-marked character or characters.

Neanderthal man: a prehistoric man. Parts of the skeleton of this man were found in the Neanderthal, a valley in the Rhine province.

nebula: a large body in the heavens composed of gaseous or finely divided matter.

nebular hypothesis: the hypothesis advanced by Laplace by which he explained the solar system as formed from a nebula.

neuron: a nerve cell with its processes.

newt: a small salamander of semiaquatic habits.

nitrate: a salt of nitric acid.

nitrogen: a gaseous chemical element which makes up about four-fifths of the atmosphere.

nitrogenous: containing nitrogen.

- nitrous oxide:** commonly called "laughing gas"; a compound of nitrogen and oxygen used as an anesthetic, especially in dentistry.
- novocaine:** a local anesthetic.
- nucleus of cell:** the most active part of a cell, usually found near the center of the cell. Since it usually reacts to stains in a different way from the rest of the cell, it can be made visible in stained microscopic slides.
- nutrient:** a nourishing ingredient of a food.
- nutrition:** the sum of the processes by which a plant or animal takes in and utilizes food substances.
- oceanography:** geography that deals with the ocean.
- organic compound:** a carbon compound of definite structure. The term is often used of carbon compounds produced in plants and animals.
- organism:** a plant or animal capable of carrying on the vital functions.
- oscillograph:** an apparatus for recording or indicating alternating-current wave forms.
- osmosis:** the diffusion of two fluids of unequal densities through a membrane.
- osmotic pressure:** the pressure produced by the phenomenon of osmosis. This pressure is one of the causes of the circulation of sap in trees.
- ovary:** a female reproductive organ.
- ovule:** an immature seed in the ovary of a flower. It contains the embryo sac and the egg cell.
- oxidation:** the chemical union of oxygen with another substance.
- oxide:** a compound formed by the union of oxygen with an element or a radical.

- paleolithic:** pertaining to the period at which the earliest known human culture existed.
- paleontology:** the science that deals with the life of past geological periods.
- pancreas:** a very important organ which is both a ductless gland and a gland with a duct. It secretes a digestive juice and a hormone.
- paramecium** (pl. **paramecia**): a slipper-shaped protozoan.
- parasite:** a plant or animal that lives on another living organism to the detriment of the host.
- parasitism:** a condition in which one organism lives on another and produces discomfort or ill effects in the host.
- parasitology:** the study of parasitic forms of life.
- parthenogenesis:** a form of reproduction in which an unfertilized egg develops into a new individual.
- pathological:** pertaining to the causes and nature of diseases and to the changes in organisms which result from diseases.
- pathologist:** a person who studies the causes, manifestations, and results of diseases in plants or animals.
- pedometer:** an instrument for indicating the number of steps taken in walking so that distances may be estimated.
- pellagra:** a deficiency disease believed to be caused by lack of vitamin G. It is common in the southern part of the United States.
- pepsin:** an enzyme found in the gastric juice of higher animals.
- peristaltic:** pertaining to the wavelike muscular contractions of the alimentary canal.

- phagocyte:** a colorless corpuscle in the blood that is active in destroying harmful organisms and substances in the body.
- pharmacology:** the science of drugs.
- pharmacopoeia:** a book containing detailed information about drugs, chemicals, and medicinal preparations used in pharmacy.
- phenylhydrazine:** a colorless oil which reacts with aldehydes and ketones.
- phlegm:** thick mucus, especially that secreted in the respiratory tracts.
- phloem:** the part of a dicotyledonous stem through which liquids pass downward.
- photosynthesis:** the process by which carbohydrates are manufactured in green plant cells.
- phototropism:** a response to the stimulus of light.
- phylum** (pl. **phyla**): one of the primary divisions of the plant or animal kingdom.
- physiologist:** a specialist in the physical processes and activities of organisms.
- pigment:** coloring matter.
- pistil:** the female reproductive organ in a flower. It is made up of the stigma, style, and ovary.
- pituitary gland:** a small gland attached to the underside of the brain.
- poliomyelitis:** infantile paralysis, which see.
- pollen:** the powdery substance formed in the anthers of flowers containing sperm cells.
- pollination:** the transfer of pollen from an anther to a stigma.
- polyneuritis:** inflammation of several nerves at one time.

porphyrin: a chemical substance obtained from chlorophyll or hemoglobin.

predatory: preying upon other animals.

propagation: multiplication of organisms.

protein: a complicated compound found in living cells.

All proteins contain carbon, oxygen, hydrogen, and nitrogen. Most proteins also contain sulphur.

protoplasm: the living substance in cells.

Protozoa: a phylum of one-celled animals.

protozoan (pl. **protozoa**): one of the *Protozoa*.

protozoology: the branch of biology dealing with the *Protozoa*.

pseudopodium (pl. **pseudopodia**): temporary projection of protoplasm from a one-celled animal, such as the amoeba, or from a free cell of a higher organism.

psychologist: a person who studies the functionings of the mind.

pulmonary: pertaining to the lungs.

pupal: pertaining to a pupa, the third stage in the complete metamorphosis of insects.

putrefaction: the decay or decomposition of organic matter.

putrefy: to cause to decay.

reagent: a chemical substance which takes part in reactions.

recessive: pertaining to a character, such as shortness in pea plants, which is subordinate to another character, such as tallness.

reflex: an involuntary act or movement.

reflex arc: the path of a nervous impulse from a point of stimulation to a point of reaction.

- regeneration:** regrowth of a part that has been lost or destroyed, such as an arm of a starfish.
- rennet:** a substance in the gastric secretion of an unweaned calf which curdles milk.
- retina:** the sensitive membrane of the eye which receives the image of an object. The rods and cones in it react to light.
- rickets:** a deficiency disease in children which results in abnormal development of the bones.
- Rocky Mountain spotted fever:** a disease occurring in the Rocky Mountain region. The causative organism is spread by a wood tick.
- saccharine:** a chemical compound made from coal tar. It is used as a substitute for sugar by diabetics.
- salivary gland:** a gland which secretes saliva.
- salversan:** a compound of arsenic used in the treatment of some protozoan diseases.
- saphrophytes:** plants without chlorophyll that live on dead organic matter.
- sarcode:** the term used by Dujardin to indicate the living substance of one-celled animals.
- sargassum weed:** a kind of seaweed common in the warmer parts of the Atlantic ocean.
- scion:** a small twig removed from one plant to be grafted on another.
- scurvy:** a deficiency disease. Some of the symptoms are anemia and bleeding of the gums and mucous membranes.
- sea anemone:** an invertebrate animal often of a bright color belonging to the phylum *Coelenterata*.
- secretin:** a hormone secreted in the walls of the small intestine which stimulates the pancreas to secrete pancreatic juice.

self-pollination: the transfer of pollen from the anther to the stigma of the same flower.

sensory impulse: an impulse which results from the stimulation of a sense organ.

serum: the watery substance that is left after coagulation takes place in blood. The word is also used in referring to this liquid when it contains antibodies that can be used in the prevention and cure of diseases.

sleeping sickness: a disease common in parts of Africa. The causative organism is transmitted to animals by the bite of flies, one of which is the tsetse fly.

soda lime: a mixture of caustic soda and slaked lime that absorbs moisture, carbon dioxide, and other gases.

soluble nitrates: salts of nitric acid that will dissolve in water.

somatic: pertaining to the body.

species: a term applied to a group of individuals which closely resemble each other. See also page 28.

spirochete: a slender, spirally undulating micro-organism.

spleen: a glandlike ductless organ near the stomach. It plays a part in the production and destruction of red corpuscles.

spontaneous generation: pertaining to the theory that organic matter changed into living organisms, as rotting meat into maggots. See also page 412.

spore: a nucleated mass of protoplasm with or without a cell wall, capable of developing into a new individual. There are asexual and sexual spores.

stamen: a part of a flower made up of a filament and an anther.

- sterility:** not fertile, incapable of reproduction.
- stethoscope:** an instrument used to listen to sounds in the body, such as the heart beat.
- stigma:** the apex of the pistil of a flower usually specially adapted for receiving pollen.
- stimulus:** anything which causes a reaction in an organism.
- stomate:** a breathing hole in the epidermis of a leaf.
- strata:** layers of sedimentary rock.
- syphilis:** a specific disease caused by a spirochete.
- tentacle:** a flexible elongated structure, such as a tentacle of a hydra.
- tetanus:** a painful disease which affects the muscles. When the muscles of the lower jaw are affected, the disease is called lockjaw.
- thermotropism:** a turning in response to the stimulus of heat.
- thigmotropism:** a response to contact with a solid, such as the growth of tendrils around a supporting branch.
- thymol:** a chemical substance having antiseptic properties.
- thyroid gland:** a ductless gland near the larynx in man.
- thyroxine:** the active substance secreted by the thyroid gland.
- tobacco mosaic:** a virus disease of tobacco.
- topography:** a description of the surface features, hills, streams, lakes, and so on of a region.
- toxin:** a poison formed during the metabolism of organisms, such as bacteria.
- toxin-antitoxin:** a mixture of toxin and antitoxin used to produce immunity to a disease.

- toxoid:** a toxin treated in such a way that it is not dangerous but will still cause the formation of antibodies in the blood.
- trachea** (pl. **tracheae**): a tube through which air passes, such as the wind-pipe in man.
- transfusion:** the transferring of blood from one person to another.
- tribromethanol:** an anesthetic sold under the commercial name of Avertin.
- tropism:** a turning toward or away from a stimulus.
- tuberculin:** a sterile liquid containing specific substances extracted from the tubercle bacillus; used as a test for tuberculosis in children and cattle.
- tubule:** a small tube.
- ultraviolet light:** light with a frequency beyond the visible violet end of the spectrum.
- unicellular:** pertaining to an organism consisting of one cell, such as an amoeba.
- urea:** a crystalline nitrogenous compound. It is found in the urine of mammals and other animals.
- vaccination:** the inoculation with a vaccine.
- vaccine:** a preparation of killed pathogenic microorganisms used for an injection into the body.
- vasomotor nerve:** a nerve that controls the size of a blood vessel.
- venation:** the arrangement of veins, as in a leaf.
- ventricle:** a chamber in the heart from which the blood is forced into arteries.
- Vermes:** in old classification the group "Vermes" included many of the invertebrates. The term is not used in recent classification.
- vertebrate:** an animal with a backbone.

vesicle: a cavity or sac.

virus: for explanation see page 236.

vitamin: a chemical substance essential for normal nutrition.

vivisection: an operation on a living animal for physiological or pathological investigation.

volatile: pertaining to a substance that evaporates readily.

Vorticella: a genus of one-celled animals with a ciliated bell-shaped body supported on a contractile stem.

xanthophyll: a dark brown compound usually associated with chlorophyll and carotin in plants.

xerophthalmia: a disease of the eyes resulting from lack of vitamin A.

xylem: the region in a dicotyledonous stem through which liquids pass upward.

General Bibliography

- ADAMS, FRANK D. "Sir Charles Lyell," *Science*, LXXVIII (Sept. 1, 1933), 177-183.
- ADRIAN, EDGAR D. "The Activity of Nerve Cells," *Nature*, CXXXII (Sept. 23, 1933), 465-468.
- . *Mechanism of Nervous Action*. Philadelphia: University of Pennsylvania Press, 1932. Pp. x + 103.
- AGASSIZ, ELIZABETH C. (editor). *Louis Agassiz; His Life and Correspondence*. Boston: Houghton Mifflin Co., 1895. Pp. xviii + 794.
- "Alexis Carrel," *Les Prix Nobel en 1912*, 60. Stockholm: P. A. Norstedt and Söner, 1913.
- American Council of Learned Societies. *Dictionary of American Biography* (edited by Allen Johnson and Dumas Malone). New York: Charles Scribner's Sons, 1928-37. 20 vols.
- ANDREWS, ROY CHAPMAN. "Adam's Grandparent," *Saturday Evening Post*, CCII (Mar. 22, 1930), 18+.
- . "Ends of the Earth," *Saturday Evening Post*, CCII (Sept. 14-Oct. 12, 1929).
- . "Explorers and Their Work," *Saturday Evening Post*, CCIV (Aug. 22, 1931), 6-7.
- . "Gobi Death Traps," *Saturday Evening Post*, CCIII (Oct. 25, 1930), 18-19+.
- , "My Museum Complex," *World's Work*, LVIII (Oct., 1929), 55-59.
- . *On the Trail of Ancient Man*. New York: G. P. Putnam's Sons, 1926. Pp. xxiv + 375.
- . "Secrets of the Gobi," *Saturday Evening Post*, CCIII (Jan. 17, 1931), 14-15.

- "Appointment of A. V. Hill to the Baker Lectureship at Cornell University," *Science*, LXIV (Dec. 24, 1926), 615-616.
- ASHBURN, PERCY M. "Progress in Preventive Medicine," *Hygeia*, XI (May, 1933), 446-449.
- ATWATER, W. O., and F. G. BENEDICT. *A Respiration Calorimeter with Appliances for the Exact Determination of Oxygen*. Washington: Carnegie Institution of Washington, 1905. Pp. x + 193.
- "Award of the Conway Evans Prize to Sir Charles Sherrington," *Science*, LXVI (Dec. 30, 1927), 645.
- "Award of the Nobel Prize for Medicine" (re: T. H. Morgan), *Nation*, CXXXVII (Nov. 1, 1933), 497.
- "The Award of the Willard Gibbs Medal to Dr. Richard Willstätter," *Science*, LXXVII (April 21, 1933), 385-386.
- BARLOW, NORA (editor). *Charles Darwin's Diary of the Voyage of H. M. S. "Beagle."* New York: The Macmillan Co., 1933. Pp. xxx + 451.
- BAST, THEODORE H. "Max Johann Sigismund Schultze," *Annals of Medical History*, III (March, 1931), 166-178.
- BATESON, BEATRICE. *William Bateson, F.R.S., Naturalist*. New York: The Macmillan Co., 1928. Pp. ix + 473.
- BATESON, WILLIAM. *Mendel's Principles of Heredity*. New York: The Macmillan Co., 1930. Pp. xiv + 413.
- BEEBE, WILLIAM. *The Arcturus Adventure*. New York: G. P. Putnam's Sons, 1926. Pp. xix + 439.
- . *Beneath Tropic Seas*. New York: G. P. Putnam's Sons, 1928. Pp. xiii + 234.
- . "Depths of the Sea," *National Geographic Magazine*, LXI (Jan., 1932), 64-88.

- . "Half Mile Down," *National Geographic Magazine*, LXVI (Dec., 1934), 661-704.
- . *Nonsuch: Land of Water*. New York: Harcourt, Brace and Co., Inc., 1932. Pp. xv + 259.
- . "A Round Trip to Davy Jones' Locker," *National Geographic Magazine*, LIX (June, 1931), 653-678.
- BELIN, ADOLPH. "Ivan Petrovich Pavlov, the Darwin of Physiology," *Hygeia*, XIV (July, 1936), 642-643.
- BENEDICT, F. G. "The Rationale of Weight Reduction," *Scientific Monthly*, XXXIII (Sept., 1931), 264-266.
- . "Reptiles Used in the Study of Human Physiology," *Scientific Monthly*, XXXIV (May, 1932), 421-428.
- "Biochemistry and Medicine" (re: F. G. Hopkins), *Science*, LXX (Dec. 20, 1929), 610.
- BLAKESLEE, ALBERT F. "The Work of Hugo de Vries," *Scientific Monthly*, XXXVI (April, 1933), 379-380.
- BOLTON, SARAH K. *Famous Men of Science*. New York: The Thomas Y. Crowell Co., 1926. Pp. vii + 333.
- BONNER, JAMES. "Vitamin B, a Growth Factor for Higher Plants," *Science*, LXXXV (Feb. 12, 1937), 183-184.
- BONNEY, THOMAS G. *Charles Lyell and Modern Geology*. London: Cassell and Co., Ltd., 1901. Pp. vi + 224.
- BOYLE, JAMES E. "Insects and Men," *Atlantic Monthly*, CXLIV (Oct., 1929) 529-535.
- BREUER, F. W., and FRANK C. WHITMORE. "Richard Willstätter, Willard Gibbs Medalist for 1933," *Scientific Monthly*, XXXVII (Oct., 1933), 377.
- BRODIE, MAURICE, and WILLIAM H. PARK. "Active Immunization Against Poliomyelitis," *American Journal of Public Health*, XXVI (Feb., 1936), 119-125.

- BRODRICK, JAMES. "Galileo in Rome," *Catholic World*, CXXXII (Oct., 1930), 90-92.
- BRONK, DETLEV W. "The Nobel Prize in Physiology and Medicine: Professor Edgar Douglas Adrian," *Scientific Monthly*, XXXV (Dec., 1932), 571-572.
- BROWN, LAWRASON. "Robert Koch," *Annals of Medical History*, VII (March, 1935), 99-112.
- BROWN, ROBERT. *The Miscellaneous Botanical Works of Robert Brown*. London: Published for the Ray Society by R. Hardwicke, 1866-1868. 2 vols.
- BUCHBINDER, LEON. "Yellow Fever, a Filterable Virus Disease," *Archives of Pathology*, X (Oct., 1930), 598-605.
- BURBANK, LUTHER, and WILBUR HALL. *The Harvest of the Years*. Boston: Houghton Mifflin Co., 1931. Pp. xxvi + 296.
- "The Bureau of Entomology and Dr. L. O. Howard," *Science*, LXVI (Oct. 28, 1927), 391.
- BYRD, RICHARD E. *Discovery*. New York: G. P. Putnam's Sons, 1935. Pp. xxi + 405.
- , *Little America*. New York: G. P. Putnam's Sons, 1930. Pp. xvi + 422.
- , *Skyward*. New York: G. P. Putnam's Sons, 1928. Pp. xv + 359.
- CADDY, FLORENCE. *Through the Fields with Linnaeus*. New York: Longmans, Green and Co., 1887. 2 vols.
- CALKINS, GARY N. *The Biology of the Protozoa*. Philadelphia: Lea and Febiger, 1933. Pp. xi + 607.
- . "Organization and Variation in Protozoa," *Scientific Monthly*, XXII (April, 1926), 341-351.
- . *The Protozoa*. New York: The Macmillan Co., 1901. Pp. xvi + 347.

- . *The Smallest Living Things*. New York: The University Society, Inc., 1935. Pp. iv + 135.
- CANNON, WALTER B. *The Wisdom of the Body*. New York: W. W. Norton and Co., Inc., 1932. Pp. xv + 312.
- CARREL, ALEXIS. "The Immortality of Animal Tissue and Its Significance," *Golden Book Magazine*, VII (June, 1928), 787-789.
- . *Man, the Unknown*. New York: Harper and Brothers, 1935. Pp. xv + 346.
- CATTELL, J. M., and J. CATTELL (editors). *American Men of Science*. New York: The Science Press, 1933. Pp. viii + 1278.
- CHAMBERLIN, R. T. *Biographical Memoir of Thomas Chrowder Chamberlin* (pamphlet). Washington: National Academy of Sciences, XV (1934), 307-407.
- "Chemists Find Some Secrets of Long Life," *Literary Digest*, CXVI (Sept. 30, 1933), 17.
- "Christian Eijkman" (in German), *Les Prix Nobel en 1929*, 78. Stockholm: P. A. Norstedt and Söner, 1913.
- CLENDENING, LOGAN. *Behind the Doctor*. New York: Alfred A. Knopf, 1933. Pp. xxi + 458.
- COHEN, JOSEPH G., and WILL SCARLET. *Modern Pioneers*. Boston: Allyn and Bacon, 1930. Pp. x + 309.
- CONKLIN, EDWIN G. "Professor Hans Spemann, Nobel Laureate in Physiology and Medicine," *Scientific Monthly*, XLII (Feb., 1936), 191-194.
- CONNORS, C. H., and V. A. TIEDJENS. *Chemical Gardening for the Amateur*. New York: Wm. H. Wise & Co., 1939. Pp. x + 255.
- "Cortical Excitatory State and Variability in Human Brain Rhythms," *Science*, LXXXIII (March 13, 1936), 259-260.

- CUMLEY, RUSSELL W. "The Story of the Gene," *School Science and Mathematics*, XXXV (Dec., 1935), 943-954.
- CURTIS, FRANCIS D., OTIS W. CALDWELL, and NINA H. SHERMAN. *Biology for Today*. Boston: Ginn and Co., 1934. Pp. xvi + 692.
- CUVIER, GEORGES. *The Animal Kingdom*. London: G. Henderson, 1834-1837. 4 vols.
- DAMPIER-WHETHAM, WILLIAM C. D., SIR. *A History of Science and Its Relations with Philosophy and Religion*. New York: The Macmillan Co., 1932. Pp. xxi + 514.
- DARBY, H. H., and H. T. CLARKE. "The Plant Origin of Vitamin D," *Science*, LXXXV (March 26, 1937), 318-319.
- DARROW, FLOYD L. "Keeping Up with Science," *St. Nicholas*, LVII (June, 1930), 619-623.
- DARWIN, CHARLES. *Autobiography of Charles Darwin*. London: Watts and Co., 1929. Pp. iv + 154.
- . *The Origin of Species by Means of Natural Selection*. New York: E. P. Dutton and Co., Inc., 1928. Pp. xxiv + 488.
- DAVENPORT, CHARLES B. "Biological Experiment Station for Studying Evolution," *Carnegie Institution of Washington Yearbook*, No. 1 (1902), 280-282.
- . "Heredity and Disease," *Scientific Monthly*, XXXIV (Feb., 1932), 167-169.
- DAVIS, WATSON. "The Evolution Theory Entering a New Phase," *Current History*, XXVII (Feb., 1928), 707-708.
- DE KRUIF, PAUL H. *The Fight for Life*. New York: Harcourt, Brace and Co., 1938. Pp. vi + 342.

- . "Jacques Loeb," *American Mercury*, V (July, 1925), 273-279.
- . *Men Against Death*. New York: Harcourt, Brace and Co., 1932. Pp. viii + 363.
- DEMEREK, MILISLAV. "What Is a Gene?" *Studies in Heredity*. Carnegie Institution of Washington, Supplementary Publications, No. 8 (July, 1934). Pp. 42. *Dictionary of National Biography*. New York: Oxford University Press, 1927.
- DIETZ, DAVID. "Adrian and Sherrington," *Current History*, XLV (March, 1937), 107-108.
- . "Exploring the Brain," *Current History*, XLV (March, 1937), 108.
- . "Insulin and Insanity," *Current History*, XLV (March, 1937), 109.
- . "Vitamin A Is Isolated," *Current History*, XLV (March, 1937), 109.
- DOBELL, CLIFFORD (editor). *Anthony van Leeuwenhoek and His Little Animals*. New York: Harcourt, Brace and Co., 1932. Pp. vii + 435.
- "Dr. Flexner and the Rockefeller Institute," *Scientific Monthly*, XLI (Oct., 1935), 373-376.
- "Dr. Flexner to Retire from Rockefeller Institute," *Journal of the American Medical Association*, CIV (June 22, 1935), 2274.
- "Dr. Karl Landsteiner's Discovery of Blood Groups," *Science*, LXXII (Nov. 7, 1930), Supplement, p. x.
- DRACHMAN, JULIAN M. *Studies in the Literature of Natural Science*. New York: The Macmillan Co., 1930. Pp. x + 487.
- DREWITT, FREDERIC G. D. *The Life of Edward Jenner*. New York: Longmans, Green and Co., 1933. Pp. xi + 151.

- DUFFUS, ROBERT L. "Jacques Loeb: Mechanist," *Century Magazine*, CVIII (July, 1924), 374-383.
- DUKES, CUTHBERT. *Lord Lister*. Boston: Small, Maynard and Co., 1924. Pp. 185.
- EAST, EDWARD M., and Others. *Biology in Human Affairs*. New York: McGraw-Hill Book Co., Inc., 1931. Pp. xi + 399.
- ECKSTEIN, GUSTAV. *Noguchi*. New York: Harper and Brothers, 1936. Pp. ix + 419.
- Encyclopedia Britannica* (14th ed.). New York: Encyclopedia Britannica, Inc., 1929. 24 vols.
- "A European Parasite Laboratory," *Science*, LXXIV (Dec. 4, 1931), Supplement, 12-14.
- FAIRCHILD, DAVID G. *The World Was My Garden*. New York: Charles Scribner's Sons, 1938. Pp. xiv + 494.
- FOSTER, MICHAEL, SIR. *Claude Bernard*. New York: Longmans, Green and Co., 1899. Pp. xi + 245.
- FRANCHINI, JOSEPH. "Ch. Alphonse Laveran, 1845-1922," *Annals of Medical History*, III (May, 1931), 280-288.
- "Frederick Gowland Hopkins," *Les Prix Nobel en 1929*, 79. Stockholm: P. A. Norstedt and Söner, 1930.
- FÜLÖP-MILLER, RENÉ. *Triumph over Pain*. Indianapolis: Bobbs, Merrill and Co., 1938. Pp. xii + 438.
- FULTON, JOHN F. "The Nobel Prize in Physiology and Medicine: Sir Charles Scott Sherrington," *Scientific Monthly*, XXXV (Dec., 1932), 569.
- (editor). *Selected Readings in the History of Physiology*. Springfield, Ill.: Charles C. Thomas, Publisher, 1930. Pp. xx + 317.
- FUNK, CASIMER. *The Vitamines*. Baltimore: Williams and Wilkins Co., 1922. Pp. 502.

- GAGE, SIMON H. "Theobald Smith; Investigator and Man," *Science*, LXXXIV (Aug. 7, 1936), 117-122.
- GALTON, FRANCIS. *Memories of My Life*. London: Methuen and Co., 1908. Pp. viii + 339.
- GARRISON, FIELDING H. *An Introduction to the History of Medicine*. Philadelphia: W. B. Saunders Co., 1929. Pp. 996.
- GAUPP, ERNST. *August Weismann* (in German). Jena: Verlag von Gustav Fischer, 1917. Pp. viii + 297.
- GEISER, SAMUEL W. "Herbert Spencer Jennings," *Bios*, V (March, 1934), 3-18.
- GINZBERG, BENJAMIN. *The Adventure of Science*. New York: Simon and Schuster, Inc., 1930. Pp. xvi + 487.
- GOODMAN, HERMAN. "Ehrlich," *The Medical Times*, LII (Aug., 1924), 175-177.
- GORGAS, MARIE D., and BURTON J. HENDRICK. *William Crawford Gorgas; His Life and Work*. New York: Doubleday, Doran and Co., Inc., 1935. Pp. 5 + 359.
- GOULD, ALICE B. *Louis Agassiz*. Boston: Small, Maynard and Co., 1901. Pp. xviii + 154.
- GRAY, GEORGE W. *The Advancing Front of Science*. New York: McGraw-Hill Book Co., Inc., 1937. Pp. xiii + 364.
- . "Chemical Foundations of Mind," *Harper's Magazine*, CLXXIV (April, 1937), 509-519.
- GROSS, SAMUEL D. *John Hunter and His Pupils*. Philadelphia: P. Blakiston, 1881. Pp. 106.
- GWATHMEY, JAMES T. *Anesthesia*. New York: The Macmillan Co., 1924. Pp. xxviii + 799.
- HAGGARD, HOWARD W. *Devils, Drugs, and Doctors*. New York: Harper and Brothers, 1929. Pp. xxii + 405.

- . *Mystery, Magic, and Medicine*. New York: Doubleday, Doran and Co., Inc., 1933. Pp. 192.
- “Hans Spemann” (in German). *Les Prix Nobel en 1935*, 56. Stockholm: P. A. Norstedt and Söner, 1937.
- HARRIS, LESLIE J. “Vitamins,” *Annual Review of Biochemistry*, IV (1935), 331–382.
- HARROW, BENJAMIN. *Eminent Chemists of Our Time*. New York: D. Van Nostrand Co., Inc., 1927. Pp. xx + 471.
- HART, IVOR B. *Makers of Science*. New York: Oxford University Press, 1923. Pp. 2 + 320.
- HATHAWAY, ESSE V. *Partners in Progress*. New York: McGraw-Hill Book Co., Inc., 1935. Pp. vii + 303.
- HAWKS, ELLISON. *Pioneers of Plant Study*. New York: The Macmillan Co., 1928. Pp. x + 288.
- “The Healing Effects of Urea,” *Science*, LXXXIV (Aug. 14, 1936), Supplement, 8.
- “Healthy Diets: Education on Calorics and Vitamins Spreading in Underfed World,” *Literary Digest*, CXXII (Oct. 24, 1936), 36–37.
- HEGNER, ROBERT W. *College Zoology*. New York. The Macmillan Co., 1926. Pp. xxiii + 645.
- HEINICKE, A. J., and M. B. HOFFMAN. “An Apparatus for Determining the Absorption of Carbon Dioxide by Leaves under Natural Conditions,” *Science*, LXXVII (Jan. 13, 1933), 55–58.
- HELLMEN, DORIS C. (editor). “An Unpublished Diary of Robert Jenner,” *Annals of Medical History*, III (July, 1931), 412–438.
- HENDRICK, BURTON J. *The Life and Letters of Walter Page*. New York: Doubleday, Doran and Co., 1925–1926. 3 vols.

- HERRICK, GLENN W. "Dr. L. O. Howard and the Capper Award," *Scientific Monthly*, XXXIII (Aug., 1931), 189-192.
- HERRINGHAM, WILMOT. "The Life and Times of Dr. William Harvey," *Annals of Medical History*, IV (July, 1932), 347-363.
- HILL, A. V. *Adventures in Biophysics*. Philadelphia: University of Pennsylvania Press, 1931. Pp. ix + 162.
- . "Are Athletes Machines?" *Scientific American*, CXXXVII (Aug., 1927), 124-126.
- . "Heat Production of Muscle and Nerve," *Nature*, CXXXV (May 4, 1935), 721-724.
- . "The International Status and Obligations of Science," *Scientific Monthly*, XXXVIII (Feb., 1934), 146-156.
- . *Living Machinery*. New York: Harcourt, Brace and Co., 1927. Pp. xxi + 306.
- . *Muscular Movement in Man*. New York: McGraw-Hill Book Co., Inc., 1927. Pp. 104.
- . "Scientific Studies of Athletes," *Scientific American*, CXXXIV (April, 1926), 224-225.
- . "A Tribute to Pavlov," *Science*, LXXXIII (April 10, 1936), 351-353.
- . "Wave Transmission As the Basis of Nerve Activity," *Scientific Monthly*, XXXVII (Oct., 1933) 316-324.
- HITCHCOCK, A. S. *Descriptive Systematic Botany*. New York: John Wiley and Sons, Inc., 1925. Pp. vii + 216.
- HOOVER, JOSEPH D., SIR (editor). *Journal of the Right Honorable Sir Joseph Banks*. London: The Macmillan Co., 1896. Pp. li + 466.

- HOPKINS, FREDERICK G. "Discovery and Significance of Vitamins," *Smithsonian Institution Annual Report* (1935), 265-273.
- . "Some Chemical Aspects of Life," *Smithsonian Institution Annual Report* (1934), 129-152.
- HOWARD, LELAND O. *Fighting the Insects*. New York: The Macmillan Co., 1933. Pp. xviii + 333.
- . *History of Applied Entomology*. Washington: Smithsonian Institution, 1930. Pp. viii + 564.
- . "Striking Entomological Events of the Last Decade of the Nineteenth Century," *Scientific Monthly*, XXXI (July, 1930), 5-18.
- HOWARD, LELAND O., HARRISON G. DYAR, and FREDERICK KNAB. *Mosquitoes of North and Central America and the West Indies*. Washington: Carnegie Institution of Washington, 1912-1917. 4 vols.
- "The Human Speed Limit" (re: A. V. Hill), *Literary Digest*, XCIII (May 28, 1927), 24.
- HUXLEY, JULIAN, assisted by JAMES FISHER. *Living Thoughts of Darwin*. New York: Longmans, Green and Co., 1939. Pp. 151.
- HYKES, O. V. *J. E. Purkyně et la Médecine Moderne* (translated from Czech into French by Marcel Aymonin). Prague, 1937. Pp. 30.
- , and F. K. STUDNIČKA. "Jan Evangelista Purkyně (Purkinje)," *Osiris* (published in Bruges, Belgium, by the Saint Catherine Press, Ltd.), II, Part 10 (Oct., 1936), 464-483.
- ILTIS, HUGO. *Life of Mendel*. New York: W. W. Norton and Co., Inc., 1932. Pp. 336.
- "In Honor of W. H. Park," *Science*, LXXXIV (Sept. 18, 1936), 261-262.

- “Ivan Petrovitch Pavlov,” *The Journal of Organotherapy*, XX, No. 3 (May–June, 1936), 138–140.
- JAFFE, BERNARD. *Crucibles; the Lives and Achievements of the Great Chemists*. New York: Tudor Publishing Co., 1934. Pp. viii + 377.
- . *Outposts of Science*. New York: Simon and Schuster, Inc., 1935. Pp. xxvi + 547.
- JENNINGS, HERBERT S. *Behavior of the Lower Organisms*. New York: Columbia University Press, 1931. Pp. xiv + 366.
- . *The Biological Basis of Human Nature*. New York: W. W. Norton and Co., Inc., 1930. Pp. xviii + 384.
- . “Thomas Hunt Morgan, Nobel Laureate,” *Scientific Monthly*, XXXVII (Dec., 1933), 567.
- . *The Universe and Life*. New Haven: Yale University Press, 1933. Pp. 94.
- “Karl Landsteiner” (in German), *Les Prix Nobel en 1930*, 102. Stockholm: P. A. Norstedt and Söner, 1931.
- KELLOGG, VERNON L. *Evolution*. New York: D. Appleton-Century Co., Inc., 1924. Pp. x + 291.
- KELLY, HOWARD A. *Walter Reed and Yellow Fever*. New York: McClure, Phillips and Co., 1906. Pp. xv + 293.
- KENDALL, EDWARD C. *Thyroxine*. New York: The Chemical Catalogue Co., Inc., 1929. Pp. 265.
- KERNER, ANTON J. *Natural History of Plants, Their Forms, Growth, Reproduction, and Distribution* (translated and edited by F. W. Oliver). New York: Henry Holt and Co., Inc., 1895–1896. 2 vols.
- KIMBALL, DEXTER S. (editor). *The Book of Popular Science*. New York: Grolier Society, 1928–1932. 16 vols.

- LANDSTEINER, KARL. "Serological and Allergic Reactions with Simple Chemical Compounds" (abstract), *Scientific Monthly*, XLIII (Oct., 1936), 379-380.
- LAW, FREDERICK H. *Modern Great Americans*. New York: D. Appleton-Century Co., Inc., 1926. Pp. viii + 286.
- LA WALL, CHARLES H. *The Curious Lore of Drugs and Medicine*. Garden City, N. Y.: Garden City Publishing Co., Inc., 1936. Pp. xv + 665.
- LEBENSOHN, JAMES E. "The Story of Local Anesthesia," *Hygeia*, XII (Nov., 1934), 973-974.
- LEE, S. W., MRS. *Memoirs of Baron Cuvier*. New York: J. and J. Harper, 1833. Pp. 197.
- LEVENE, P. A. "The Award of the Nobel Prize in Medicine to Doctor Hans Fischer," *Scientific Monthly*, XXXII (Feb., 1931), 191-192.
- LINDBERGH, ANNE MORROW. *Listen! the Wind*. New York: Harcourt, Brace and Co., 1938. Pp. xii + 275.
- "Lindbergh Adds to Fame as Scientist," *Literary Digest*, CXXII (Aug. 22, 1936), 16-17.
- LOCY, WILLIAM A. *Biology and Its Makers*. New York: Henry Holt and Co., Inc., 1908. Pp. xxvi + 477.
- . *The Growth of Biology*. New York: Henry Holt and Co., Inc., 1925. Pp. xiv + 481.
- . *The Story of Biology*. Garden City, N. Y.: Garden City Publishing Co., Inc., 1934. Pp. xiv + 495.
- LOEB, JACQUES. *Forced Movements, Tropisms and Animal Conduct*. Philadelphia: J. B. Lippincott Co., 1918. Pp. 209.
- . *Proteins and the Theory of Colloidal Behavior*. New York: McGraw-Hill Book Co., Inc., 1924. Pp. xiv + 380.

- LUSK, GRAHAM. "A Tribute to the Life and Work of Max Rubner," *Science*, LXXVI (Aug. 12, 1932), 129-135.
- LYELL, CHARLES. *Travels in North America in the Years 1841-42; with Geological Observations on the United States, Canada, and Nova Scotia*. New York: Wiley and Halsted, 1856. 2 vols.
- MCCOLLUM, ELMER V., and NINA SIMMONDS. *Food, Nutrition, and Health* (2nd ed. rev.). Baltimore: The Authors, 1931. Pp. vii + 148.
- MACDOUGAL, D. T. *The Green Leaf; the Major Activities of Plants in Sunlight*. New York: D. Appleton-Century Co., Inc., 1930. Pp. 141.
- MACFIE, RONALD C. *Romance of Medicine*. London: Cassell and Co., Ltd., 1907. Pp. viii + 312.
- MCKINLEY, EARL B. "Theobald Smith," *Science*, LXXXII (Dec. 20, 1935), 575-586.
- MACLEOD, J. J. R. "Harvey's Experiments on Circulation," *Annals of Medical History*, X (Dec., 1928), 338-348.
- MARTIN, C. J. "Ernest Henry Starling, C.M.G., M.D., F.R.S.," *British Medical Journal*, I (May 14, 1927); 900-906.
- "Memorial to Professors Bayliss and Starling," *Science*, LXIX (Feb. 1, 1929), 131.
- METCHNIKOFF, OLGA. *Life of Elie Metchnikoff, 1845-1916*. Boston: Houghton Mifflin Co., 1921. Pp. xxiii + 297.
- MEYERHOF, OTTO. *Chemical Dynamics of Life Phaenomena*. Philadelphia: J. B. Lippincott Co., 1924. Pp. 3 + 110.

- MIDDLETON, WILLIAM S. "The Medical Aspect of Robert Hooke," *Annals of Medical History*, IX (Fall, 1927), 227-243.
- MIRSKY, A. E. "Professor Otto Warburg, Recipient of Nobel Prize in Medicine," *Scientific Monthly*, XXXIV (March, 1932), 283-287.
- MORGAN, THOMAS HUNT. *Regeneration*. New York: The Macmillan Co., 1901. Pp. xii + 316.
- . *The Scientific Basis of Evolution*. New York: W. W. Norton and Co., Inc., 1935. Pp. xiii + 306.
- . "What Is Darwinism?" *Yale Review*, XVII (April, 1928), 431-446.
- . "William Bateson," *Smithsonian Institution Annual Report* (1926), 521-532.
- . "William Bateson," *Science*, LXIII (May 28, 1926), 531-535.
- MULLER, HERMANN J. "Heritable Variations, Their Production by X Rays and Their Relation to Evolution," *Smithsonian Institution Annual Report* (1929), 345-362.
- . "Physics in the Attack on the Fundamental Problems of Genetics," *Scientific Monthly*, XLIV (March, 1937), 210-214.
- MULLER-FREIENFELS, RICHARD. *The Evolution of Modern Psychology* (translated by W. Béran Wolfe). New Haven: Yale University Press, 1935. Pp. xvi + 513.
- MURPHY, CHARLES J. *Struggle; the Life and Exploits of Commander Richard E. Byrd*. New York: Frederick A. Stokes Co., 1928. Pp. xii + 368.
- MURRAY, ROBERT H. *Science and Scientists in the Nineteenth Century*. New York: The Macmillan Co., 1925. Pp. xvii + 450.

- NEEDHAM, JAMES G. *General Biology*. Ithaca, N. Y.: Comstock Publishing Co., Inc. Pp. xiv + 542.
- Neurological Institute of Magill University. *Neurological Biographies and Addresses*. New York: Oxford University Press, 1936. Pp. viii + 178.
- New York Academy of Medicine. *Medicine and Mankind*. New York: D. Appleton-Century Co., 1936. Pp. vi + 216.
- "Ninety Years of General Anesthesia," *Literary Digest*, CXXII (Oct. 24, 1935), 34-35.
- "Nobel Prize Goes to German Doctor" (re: Hans Spemann), *New York Times* (Oct. 25, 1935), 15.
- "Nobel Prize in Medicine for America" (re: Karl Landsteiner), *Literary Digest*, CVII (Nov. 22, 1930), 33.
- "The Nobel Prize in Physiology and Medicine for 1932" (re: Edgar Adrian and Sir Charles Sherrington), *Science*, LXXVI (Nov. 11, 1932), 427-429.
- "Nobel Prizes for Pioneers in the Field of Vitamin Research," *Scientific Monthly*, XXX (Feb., 1930), 186-189.
- NORDENSKIÖLD, ERIC. *The History of Biology*. New York: Alfred A. Knopf, Inc., 1928. Pp. x + 629.
- OLMSTED, J. M. D. "Claude Bernard's Posthumously Published Attack on Pasteur and Pasteur's Defense," *Annals of Medical History*, IX (March, 1937), 114-124.
- OPITZ, RUSSELL B. "Purkinje," *Journal of the American Medical Association*, XXXII (April, 1899), 812-814.
- OSBORN, HENRY FAIRFIELD. *From the Greeks to Darwin; Development of the Evolution Idea Through 24 Centuries*

- (2nd ed. rev.). New York: Charles Scribner's Sons, 1929. Pp. xvi + 398.
- . *Impressions of Great Naturalists* (2nd ed. rev.). New York: Charles Scribner's Sons, 1928. Pp. xxviii + 243.
- OSLER, WILLIAM. *The Evolution of Modern Medicine*. New Haven: Yale University Press, 1921. Pp. xiv + 243.
- OSTERHOUT, W. J. V. *Biographical Memoir of Jacques Loeb* (pamphlet). Washington: National Academy of Sciences, XIII (1930), 318-401.
- "Otto Heinrich Warburg," (in German), *Les Prix Nobel en 1931*, 79. Stockholm: P. A. Norstedt and Söner, 1933.
- "Otto Meyerhof" (in German), *Les Prix Nobel en 1923*, 88-89. Stockholm: P. A. Norstedt and Söner, 1924.
- PACKARD, ALPHEUS S. *Lamarck, the Founder of Evolution, His Life and Work*. New York: Longmans, Green and Co., 1901. Pp. xii + 451.
- PAINTER, T. S. "A New Method for the Study of Chromosome Rearrangements and the Plotting of Chromosome Maps," *Science*, LXXVIII (Dec. 22, 1933), 585-586.
- PARK, ROSWELL. *An Epitome of the History of Medicine*. Philadelphia: The F. A. Davis Co., 1899. Pp. xiv + 370.
- PARK, WILLIAM H. "Half-mast on the Pasteur Institute" (re: Emile Roux), *Scientific Monthly*, XXXVII (Dec., 1933), 570-574.
- PARKER, G. H. "Anthony van Leeuwenhoek and His Microscopes," *Scientific Monthly*, XXXVII (Nov., 1933), 434-441.

- PEACHEY, GEORGE C. *A Memoir of William and John Hunter*. Plymouth: Printed for the author by William Brendon and Son, Ltd., 1924. Pp. ix + 313.
- PEATIE, DONALD C. "Louis Agassiz: Inspired Scientist," *Nature Magazine*, XXII (Dec., 1933), 265-266.
- "Presentation of the Daniel Girard Elliott Medal to Professor Edmund B. Wilson," *Scientific Monthly*, XXVIII (Jan., 1929), 91-93.
- "Professor Laveran," *British Medical Journal*, I (June 17, 1922), 979.
- "Prof. Max Rubner," *Nature*, CXXIX (June 18, 1932), 893.
- PUNNETT, REGINALD C. *Mendelism*. New York: The Macmillan Co., 1927. Pp. xv + 236.
- RADL, EMANUEL. *The History of Biological Theories* (translated and adapted from the German by E. J. Hatfield). New York: Oxford University Press, 1930. Pp. xii + 408.
- ROBERTS, HERBERT F. *Plant Hybridization before Mendel*. Princeton: Princeton University Press, 1929. Pp. xiv + 374.
- ROBERTSON, T. BRAILSFORD. *The Spirit of Research*. Adelaide, S. Australia: F. W. Preece and Sons, 1931. Pp. xi + 210.
- ROBINSON, MABLE L., *Runner of the Mountain Tops: The Life of Louis Agassiz*. New York: Random House, 1939. Pp. 290.
- ROBINSON, VICTOR. *Pathfinders in Medicine*. New York: Medical Life Press, 1929. Pp. xvii + 810.
- . *The Story of Medicine*. New York: A. C. Boni, 1931. Pp. 5 + 527.

- Rockefeller Foundation, The. *Annual Report for 1935* (re: T. H. Morgan) 151-152; (re: H. M. Evans) 163-164. New York, 1936.
- ROMANS, GEORGE J. *An Examination of Weismannism*. Chicago: The Open Court Publishing Co., 1893. Pp. ix + 221.
- ROSS, RONALD. *Memoirs; with a Full Account of the Great Malaria Problem and Its Solution*. New York: E. P. Dutton and Co., Inc., 1923. Pp. xi + 547.
- RUSSELL, HENRY, N. "Worlds from a Catastrophe," *Scientific America*, CXLV (Aug., 1931), 92-93.
- SACHS, VON, JULIUS. *The History of Botany 1530-1860* (authorized translation by H. E. F. Garnsey, revised by Isaac Bayley Balfour). Oxford: Clarendon Press, 1890. Pp. xv + 568.
- ST. MICHALSKI. "Kopernik," *Science*, LXXIII (June 5, 1931), 616.
- "Scientific Events of the Year," *Science*, LXXXV (Jan. 1, 1937), Supplement, 8.
- "Scientific Events of the Year," *Science*, LXXXV (Jan. 8, 1937), Supplement, 8.
- SCOTT, FLORA M. "The Botany of Marcello Malpighi, Doctor of Medicine," *Scientific Monthly*, XXV (Dec., 1927), 546-553.
- SEIFRIZ, WILLIAM E. *Protoplasm*. New York: McGraw-Hill Book Co., Inc., 1936. Pp. x + 584.
- SHANER, RALPH F. "Lamarck and the Evolution Theory," *Scientific Monthly*, XXIV (March, 1927), 251-255.
- SIGERIST, HENRY E. *The Great Doctors*. New York: W. W. Norton and Co., Inc., 1933. Pp. 436.

- SINGER, CHARLES J. *From Magic to Science*. New York: Livright Publishing Corporation, 1928. Pp. xix + 253.
- . *The Story of Living Things*. New York: Harper and Brothers, 1931. Pp. xxxv + 572.
- “Sir William Bayliss, F.R.S.” *British Medical Journal*, II (Sept. 13, 1924), 489–490.
- SMITH, THEOBALD. *Parasitism and Disease*. Princeton: Princeton University Press, 1934. Pp. xiii + 196.
- SPEMANN, HANS. “The Mode of Operation of the Organizer” (abstract), *Scientific Monthly*, XLIII (Oct., 1936), 378–379.
- SPOEHR, HERMAN A. *Photosynthesis*. New York: The Chemical Catalogue Co., Inc., 1926. Pp. 393.
- STANLEY, W. M. “Isolation of Crystalline Protein, Possessing the Properties of Tobacco-Mosaic Virus,” *Science*, LXXXI (June 28, 1935), 644–645.
- , and H. S. LORING. “Isolation of Crystalline Tobacco-Mosaic Virus Protein from Diseased Tomato Plants,” *Science*, LXXXIII (Jan. 24, 1936), 85.
- STILES, CHARLES WARDELL. “The Country Slaughterhouse As a Factor in the Spread of Disease,” *Year Book of the United States Department of Agriculture*, 1896, 155–166.
- STUDNIČKA, F. K. *Jan Ev. Purkyně et la Théorie Cellulaire* (in French). Prague, 1937. Pp. 66–75.
- SULLIVAN, MARK. *Our Times; the United States, 1900–1925*. New York: Charles Scribner’s Sons, 1926–1935. 6 vols.
- TAYLOR, FRANCES L. *Crawford W. Long and the Discovery of Ether Anesthesia*. New York: P. B. Hoeber, Inc., 1928. Pp. xiii + 237.

- THONE, F. "New Discovery Speeds Up Evolution," *Scientific American*, CXXXVIII (March, 1928), 235.
- THORNDIKE, LYNN. *A History of Magic and Experimental Science*. New York: The Macmillan Co., 1923-1934. 4 vols.
- THWING, CHARLES F. "Harvard and Its New President" (re: James Conant), *Review of Reviews*, LXXXVIII (Dec., 1933), 40+.
- TOBEY, JAMES A. "By the Light of a Vitamin," *Current History*, XLVI (April, 1937), 93-94.
- TRACY, HENRY C. *American Naturalists*. New York: E. P. Dutton and Co., Inc., 1930. Pp. viii + 282.
- TRELEASE, SAM F. "Award of the American Association Prize to Dr. Stanley," *Scientific Monthly*, XLIV (Feb., 1937), 193-195.
- VALLERY-RADOT, RENÉ. *The Life of Pasteur*. New York: Doubleday, Doran and Co., Inc., 1923. Pp. xxi + 484.
- VRIES, DE, HUGO. *Plant-breeding*. Chicago: The Open Court Publishing Co., 1907. Pp. xiii + 360.
- WALSH, JAMES J. *Catholic Churchmen in Science*. Philadelphia: American Ecclesiastical Review, 1917. Pp. ix + 221.
- . "A Protestant View of a Catholic Scientist," *Catholic World*, CXXIII (April, 1926), 1-12.
- WEISMANN, AUGUST. *The Evolution Theory*. London: E. Arnold, 1904. 2 vols.
- WELD, CHARLES R. *A History of the Royal Society, with Memoirs of the Presidents*. London: J. W. Parker, 1848. 2 vols.

- WELLS, H. G., J. S. HUXLEY, and G. P. WELLS. *Science of Life*. New York: Doubleday, Doran and Co., Inc., 1931. 4 vols.
- WHEAT, FRANK M., and ELIZABETH T. FITZPATRICK. *General Biology*. New York: American Book Co., 1932. Pp. viii + 566.
- WHEWELL, WILLIAM. *History of the Inductive Sciences*. London: J. W. Parker, 1837. 3 vols.
- "Wilbur Olin Atwater," *Science*, XXVI (Oct. 18, 1907), 523-524.
- WILDER, BURT G. "What We Owe to Agassiz," *Popular Science Monthly*, LXXI (July, 1907), 5-20.
- "William Maddock Bayliss—Physiologist," *Science*, LX (Nov. 14, 1924), 448-449.
- WILLIAMS, HENRY S. *Luther Burbank*. New York: Hearst's International Library Co., 1915. Pp. xii + 333.
- . *The Story of Nineteenth-century Science*. New York: Harper and Brothers, 1900. Pp. viii + 474.
- WILLIAMS, R. R. "Who's Who in the Beri-Beri Vitamin Field," *Science*, LXXIX (May 4, 1934), 410.
- WILLIAMS-ELLIS, AMABEL (editor). *Voyage of the Beagle*. Philadelphia: J. B. Lippincott Co., 1931. Pp. 5 + 279.
- WILLIS, BAILEY. "Thomas Chrowder Chamberlin," *Scientific Monthly*, XXVIII (Jan., 1929), 89-91.
- WILLIS, ROBERT. *The Works of William Harvey*. London: Printed for the Sydenham Society, 1847. Pp. xcvi + 624.
- WILLSTÄTTER, RICHARD. "A Chemist's Retrospects and Perspectives," *Science*, LXXVIII (Sept. 29, 1933), 271-274.

- WILSON, EDMUND B. *The Cell in Development and Heredity*. New York: The Macmillan Co., 1928. Pp. xxxvii + 1232.
- WOLF, ABRAHAM. *Essentials of Scientific Method*. New York: The Macmillan Co., 1928. Pp. 160.
- "The Work of Dr. Karl Landsteiner," *Science*, LXXII (Dec. 12, 1930), 605-606.
- "Work of Professor Spemann," *Science*, LXXXII (Nov. 1, 1935), Supplement, 8.
- WRIGHT, WILLARD H. "Unhooking the Hookworm," *Hygeia*, XII (April, 1934), 328-330.
- ZINSSER, HANS. "The Award of the Nobel Prize in Medicine to Dr. Karl Landsteiner," *Scientific Monthly*, XXXII (Jan., 1931), 93-96.
- . *Biographical Memoir of Theobald Smith* (pamphlet). Washington: National Academy of Sciences, XVII (1936), 261-303.
- ZIRKLE, CONWAY. *The Beginnings of Plant Hybridization*. Philadelphia: University of Pennsylvania Press, 1935. Pp. xiii + 231.

Index

[Figures in **boldface** type indicate the pages where the complete treatment of a scientist's life or of a subject is given.]

- A
- Acquired characteristics, 111, 144, 145-146
- Across Mongolian Plains*, by Andrews, 432
- Adrenal glands, 372, 373
- Adrenalin, 372, 374, 375
- Adrian, Edgar, **406-408**
picture of, 408
writings of, 406
- Aedes* mosquito, 225, 227
- Aesculapius, 8, 297
- Afferent nerves (*See* Sensory nerves)
- Agassiz, Alexander, 103
- Agassiz, Auguste, 93, 94
- Agassiz, Louis, **93-104**, 253
at Harvard University, 100-103
pictures of, 99, 102
writings of, 97
- Agassiz Museum, 100-102
- Agramonte, Aristides, 217
- Agriculture, Department of, 239, 330, 438
- Alchemy, 179, 301, 443
- Alexander the Great, 8, 9, 10
- American Chemical Society, 306
- American Museum of Natural History, 429
- American Red Cross, 340
- American Society of Biochemists, 346
- Amoeba, 349, 350-351
- Anatomy, early knowledge of, 32-34
foundation for present understanding of, 36, 38-45
(*See also* Comparative anatomy)
- Andrews, Roy Chapman, **427-432**
picture of, 433
writings of, 428, 432
- Anesthetics, **283-297**, 318, 383
importance of, 283
use of local, 297
- Angiosperms, 60
- Aniline dye, 199, 267
- Animal Industry, Bureau of, 245
- Animals, modern classification of, 27-29
- Animals and Plants under Domestication*, by Darwin, 122
- Anodynes, early, 283-284
- Anopheles* mosquito, 217, 227, 230

Antarctic expeditions, 432, 434-435, 436

Anthrax, Koch's study of, 195-196, 198
 Pasteur's study of, 190-192

Antibodies, 272

Antiquity of Man, The, by Lyell, 93, 103

Antiseptics, **201-204**, 262
 (See also Surgery, antiseptic methods in)

Antitoxin, for diphtheria, 242, 261-266
 for tetanus, 242, 264

Antivaccination groups, 184

Antivivisectionists, 382-383

Aphelinus, 256-257

Apollo Lykeios, 10

Archology, and aviation, 437

Arctic expeditions, 433

Arcturus Adventure, by Beebe, 424, 425-426

Aristotle, **5-12**, 442
 influence of, 11
 picture of, 7
 writings of, 12

Aristotle's lantern, 9

Army worms, 254

Artaxerxes, 177

Artemi, Peter, 20

Artificial heart (See Mechanical heart)

Artificial pollination (See Pollination)

Asclepiads, 6, 8, 175

Ashford, Bailey K., 245, 246

Astronomers, 82-83

Athletes, experiments on, 400-403

Atwater, Wilbur Olin, **329-330**, 347
 picture of, 329

Avertin, 318

B

Bacillus, anthrax, 190, 195
 diphtheria, 260, 261
 plague, 199
 tubercule, 197, 267

Bacteria, 190, 199, 205, 238, 278
 described by Leeuwenhoek, 56
 infections caused by, 202, 262
 Koch's study of, 195-196
 solid medium for, 196

Bacteriology, 234
 beginning of science of, 196-198
Bacteriology in Medicine and Surgery, by Park, 266

Baeyer, von, Adolf, 314

Balchen, Bernt, 434

Baluchtherium, 430-431

Banks, Sir Joseph, 58, 59, 183

Banting, Sir Frederick, 347, **386-391**
 picture of, 389

Barber-surgeons, 34, 182

Barger, George, 371

Baron, Moses, 387, 390

Barton, Otis, 422-423

Basin of Sensation, The, by Adrian, 406

Bateson, William, **140-143**, 156
 picture of, 143
 writings of, 141

Bathysphere, 422-424

Bayliss, Sir William Maddock, 375-376, **379-381**
 picture of, 380

Bayliss and Starling Studentship, 381

"Beagle," H. M. S., 115, 116, 117

Beebe, William, 5, **421-427**
 pictures of, 423, 427
 writings of, 421, 424, 425-426

- Beetles, destroyed by fungi, 276
 Japanese, 251-252, 257
- Behavior of animals, 360
 inharmonious, 150-151
 in response to stimuli, 349-353,
 356, 361, 362-364, 393-410
- Behavior of the Lower Organisms, The*,
 by Jennings, 361, 362
- Behring, von, Emil, 261, **262-264**
 picture of, 268
- Behringwerk, 264
- Bell, Alexander Graham, 150
- Beneath Tropic Seas*, by Beebe, 424
- Benedict, Francis G., 330, **331-332**,
 347
 picture of, 333
- Bennett, Floyd, 434
- Beriberi, 336-337, 338
- Bernard, Claude, **381-386**, 388
 picture of, 383
 writings of, 385
- Best, Charles H., 387, 391
- Bigelow, Henry J., 294
- Biggs, Herman M., 265
- Binomial nomenclature, 23, 27-31
- Biochemistry, 62, 78, 339
- Biological Basis of Human Nature, The*,
 by Jennings, 362
- Biological laboratories, at Cold
 Spring Harbor, 149-150, 157,
 158
 at Nonsuch, 422, 426
 at Wood's Hole, 154, 359
- Biology, Aristotle's contribution to,
 5-7, 9, 11
 origin of term, 10
 purpose of, 441
 scope of, 439-440, 441-447
- Bishop, Katherine S., 343
- Blakeslee, Albert F., 153, **157-158**,
 159
 picture of, 158
 writings of, 157
- Blood, corpuscles of, 55, 272, 277
 functions of, 272-273, 277
 types of, 279-281
 (*See also* Circulation of blood)
- Bloxam, Rosa (Mrs. Ronald Ross),
 212
- Blushing, explanation of, 384
- Boerhaave, Hermann, 19
- Bonaparte, Louis Napoleon, 385
- Bonaparte, Napoleon, 83, 88, 186
- Book of Chemistry for Medical
 Students*, by McCollum, 343
- Botany, classification in, 3, 26-27,
 59-60
 founding of scientific, 12
 importance of cell theory to, 64,
 66-67
- Boussingault, Jean Baptiste, **310-
 311**
 picture of, 310
 writings of, 311
- Boyle, Robert, 48
- Braun, Alexander, 95-96
- Braun, Cecile (Mrs. Louis Agas-
 siz), 95
- Brazil, Agassiz's expedition in, 101
- Bridges, Calvin B., 153, 159
- Brooks, William Keith, 141
- Brown, Robert, **58-62**, 65, 75, 96
 picture of, 61
- Brownian movement, 62
- Bryophyllum*, 359
 picture of, 360
- Buckland, William, 88
- Buffon, de, Georges Louis, 108
 writings of, 108
- Bunyan, Paul, myth of, 352

- Burbank, Luther, 140, **169-174**
 picture of, 171
 writings of, 170, 174
- Byrd, Richard Evelyn, **432-436**
 picture of, 433
 writings of, 435
- C
- Calkins, Gary N., **413-416**
 picture of, 414
 writings of, 414
- Caloric values of nutrients, 329
- Calories, definition of, 325-326
 required for health, 332
- Calorimeter, 326-327, 330-331
- Camerarius, Rudolf, **165**
 writing of, 165
- Camp Lazear, 222, 223
 diagram of, 222
- Cannon, Walter Bradford, **373-374**, 380
 picture of, 373
- Capillaries, 44
 early microscopic studies of, 43, 57
 size of, 40
- Capper Award, to L. O. Howard, 258
- Carbolic acid spray, used by Lister, 203-204
- Carbon dioxide, 303
 in food making of plants, 309, 311, 318-319, 322
 produced in oxidation, 305, 306, 307-308, 372
- Carnegie Institution, 149, 157
- Carotin, 316
- Carrel, Alexis, **416-419**, 439
 pictures of, 417, 436
 writing of, 419
- Carrel-Dakin treatment, 417-418
- Carroll, James, 217, 221-222
- Cartier, Jacques, 335
- Cary, Elizabeth (Mrs. Louis Agassiz), 100
- Catastrophism, theory of, 87
- Cattle, diseases of, 195-196, 198, 240-242
- Cavendish, Henry, 304
- Cell, division of, 75
 naming of, 51
- Cell in Development and Inheritance, The*, by Wilson, 153
- Cell theory, 46-78, 147, 198
 importance of microscope to, 76, 78
 Purkinje's statement of, 68, 73
 Schleiden's contribution to, 68
 Schultze's contribution to, 69-70, 76, 77
 Schwann's statement of, 67
- Celsius, Olof, 20
- Centrosomes, 78
- Cerebro-spinal meningitis, 270
- Chamberland filter, 234
- Chamberlin, Thomas C., 82
- Chandler Medal, to Kendall, 371
- Characteristics, acquired, 111, 144, 145-146
 dominant, 136
 recessive, 136
 sex-linked, 155
- Charpentier, de, Jean, 98
- Chemical Dynamics of Life Phenomena*, by Meyerhof, 403
- "Chemical messengers," 369, 376, 377
 (See also Hormones)
- Chemical Warfare Service, 320
- Chemicals, necessary to body, 342-343

- (Chemicals, use of, for growing plants, 322-323
 Chemistry, 303-305, 309, 443
 biochemistry, 62, 78, 339
 organic, 300, 313, 315, 319, 320, 443
 Chemotropism, 350
 Chloroform, early use of, 294-296
 Chlorophyll, 309, 310, 315-316, 319-320, 321-322
 Chlorophyll-a, 316, 322
 Chlorophyll-b, 316, 322
 Cholera, 405
 Chromosomes, 157, 158
 in nuclei, 78
 number of, in body cells of man, 147, 344
 number of, in body cells of vinegar fly, 147
 Circulation of blood, 44, 350
 Fabricius's study of, 37-39
 Galen's ideas on, 37-38, 393
 Harvey's study of, 38-40
 Leeuwenhoek's study of, 43, 55, 57
 Malpighi's study of, 43, 57
 Class, classification term, 28, 29
 Classification, 3-31, 443, 447
 ancient, 3-5
 by Aristotle, 5, 10-12, 30
 by Brown, 59-60
 effect of, on English language, 29-30
 by Gesner, 16-17
 influence of exploration on, 17-18
 by Lamarck, 109
 by Linnaeus, 23, **26-29**, 30-31
 modern scheme of, 27-29
 by Pliny, 13, 14
 by Theophrastus, 12
 Cod-liver oil, vitamins in, 340-342
 Cold Spring Harbor Laboratory, 149-150, 157, 158
Collected Studies on Immunity, by Ehrlich, 267
 Collip, James Bertram, 391
 Colloids, 62, 78, 358, 379-380
 Color blindness, 155
 Comparative anatomy, 86-87, 103, 443
 as evidence of evolution, 124
 Conant, James Bryant, **320-321**
 picture of, 321
 Conservation of energy, laws of, 328, 329
 Cook, Captain James, 26, 58, 183, 303, **335**
 Copernican theory, 81-82
 Copernicus, Nikolaus, **81-82**
 Copley Medal, to Theobald Smith, 243
 Coral reefs, formation of, 101, 118
 Corn borer, 251
 control of, by parasites, 257
 Corpuscles, colorless, 269, 272, **277-279**
 red, 272, 342
 Corpuscles, white (*See* Corpuscles, colorless)
 Correlation theory of Cuvier, 85, 86-87
 Correns, Karl Erich, 137
 Cortin, 372, 375
 "Courage hormone" (*See* Epinephrin)
 Cowpox, 181, 184
 Cretins, 370
Critica Botanica, by Linnaeus, 26
 Cross-breeding, in animals, 142-143, 150-151, 167

Cross-pollination, 142, **162-163**,
166-168, 170, 173
by Mendel, 135-136
(*See also* Pollination)
Cultures, pure, 196
Curare, 384-385
Current rip, 425-426
organisms in, 425
Cuvier, Georges, **83-89**, 103-104,
106, 124, 183
pictures of, 85, 89
Cytology, 147, 148-149, 198
Cytoplasm, 70

D

Dakin, Henry Drysdale, 417
Darwin, Charles Robert, 106,
111, 112, **113-123**, 126, 127,
141, 159, 275
picture of, 123
writings of, 112, 121-122, 275
Darwin, Erasmus, 127
Date trees, artificial pollination of,
163
Davenport, Charles Benedict, **149-152**, 159, 361
picture of, 151
writings of, 150
Davy, Sir Humphrey, 285-286
Davy Medal, to Willstätter, 318
Deficiency diseases, 251, 334-336,
337, 342, 343
and vitamins, 334-347
Descent of Man, The, by Darwin,
122
De Vries (*See* Vries)
Diabetes, 381, 384, **386-391**
camps for diabetic children, 391
treatment of, 387, 388, 390

Diet, deficiency diseases caused by,
251, 335-336
importance of special, 332, 334
Rubner's study of, 328-329
(*See also* Nutrition and Vitamins)
Digestion, 375-376, 388
effect of fright on, 373-374
Pavlov's study of, 396-397
Dinosaur eggs, 431
Dioecious plants, 163
Diphtheria, 260-266, 269
Dirt-eating, symptom of hook-
worm, 245
Discovery, by Byrd, 435
Disease, 238, 251, 438
early beliefs regarding, 175
and germ theory of, 181-205,
270
and phagocyte theory, 278-279
treatment of, in 17th century,
180, 182
(*See also* Medicine and specific
diseases)

Disinfectants, Lister's use of, 201
Döllinger, von, Johann J., 96
Dominance, Law of, 136
Dominant characteristics, 136
Drewitt, F. Dawtrey, 186
Drosophila melanogaster, 154-157
Duisberg, Carl, 318
Dujardin, Felix, 62, **63-64**, 77, 412
Dukes, Cuthbert, 200
Dutrochet, Henri, 310
Dyes, 199, 267, 268

E

Earthworms, 351, 352
Eating-cells (*See* Phagocytes)
Echinodermata, 358
Efferent nerves (*See* Motor nerves)

- Ehrlich, Paul, 199, 263, **266-269**
 picture of, 268
 writings of, 267
- Eijkman, Christian, **336-338**, 347
- Electricity, in human brain, 353
- Electro-chemical theory of nerve impulses, 394, 406-410
- Elements, early meaning of, 47
Elements of Geology, by Lyell, 93
Elements of Human Physiology, by Starling, 379
- Elephantiasis, 209
- Embryos, 40, 69, 124
 grafting tissues in, 364-365
- Endocrine glands, 368, 369
- Energy, source of, in human body, 328, 329, 390
- Entomologists, work of, 250, 258
- Entomology, Bureau of, 252, 254, 255
- Enzymes, 316, 318, 322
- Epinephrin, 372-373
Essay on the Food of Plants and the Renovation of Soils, by Ingenhouz, 308
- Evays in Eugenics*, by Galton, 132
- Essays on the Principle of Population*, by Malthus, 119
- Ether, use of, 285-294
- Eugenics, 132, 149, 150, 159
- Eugenics Record Office, 150
- Eustachian tubes, 36-37
- Eustachio, Bartolommeo, 36-37
- Evans, Herbert McLean, **343-345**, 347
 picture of, 344
- Evolution, Bateson's study of, 141
 Burbank's lectures on, 173
 Darwin's theory of, 119-121, 122
 evidence for modern theory of, 124-125, 281, 444
- Evolution, Lamarck's theory of, 106, 110-112
 Wallace's theory of, 120-121
 Weismann's study of, 145-146
- Experimental Research in Field of Evolutionary Physiology*, by Spemann, 366
- Exploring with Beebe*, by Beebe, 424
- F
- F₁ generation, 136
- F₂ generation, 136
- Fabricius ab Aquapendente, 36, 37-38, 39
- Fallopian tubes, 36
- Fallopio, Gabriello, 36
- Family, classification term, 28, 29
- Fermentation, 187, 189, 300, 302
- Fertilization, in flowers, 60, 62, 140, 166
 in lower organisms, artificial, 358-359, 364
 (See also Pollination)
- Fibrinogen, 272
- Fighting the Insects*, by Howard, 258
- Finger Prints*, by Galton, 131
- Finlay, Carlos, 220
- Fischer, Emil, **315**, 403
- Fischer, Hans, **319-320**
- Fisher, Ronald Aylmer, 132
- "Fixed air," 305
 (See also Carbon dioxide)
- Fixity of species, 28, 103
 controversy regarding, 105-106
 Cuvier's belief in, 88, 106
 (See also Origin of species)
- Flagg, Paulel J., 439
- "Flea-glasses," 47
- Fletcher, W. M., 339

- Flexner, Simon, 233-234, 236, **270**
 picture of, 269
- Flore Française*, by Lamarck, 107-108
- Fly, Hessian, 251
 housefly, 257-258
 tachina, 254-255
 vinegar, 154-157
- "Fly-glasses," 47
- Food (*See* Diet and Nutrients)
- Foods, Nutrition, and Health*, by McCollum and Simmonds, 343
- Fossils, Agassiz's work on, 97-98, 101, 102, 103
 Cuvier's work on, 83, 85, 87-88, 89, 103
 discoveries of, in Central Asia, 428-429, 430-431
 Lamarck's work on, 109
 picture of fossil fish, 97
 and theory of evolution, 104, 124
- Foster, Sir Michael, 338
- Fruit, first use of term, 12
 improvements in, 162, 169, 170, 174
 (*See also* Plant breeding)
- Fuchsin, 267
- Fundamenta Botanica*, by Linnæus, 26
- G
- Galápagos Islands, 117, 118-119, 421
 picture of, 117
- Galen, Cladius, 36, 37-38, **177**, **179**, 393
 influence of, 33
- Galileo, 82
- Galton, Sir Francis, **127-132**, 133, 141, 149, 159
 introduces term "eugenics," 132
 picture of, 128
 writings of, 129, 131, 132
- Galton Laboratory, 132
- Galvani, Luigi, 352
- Galvanotropism, 352
- Gärtner, Karl Freidrich, 169
- Gas, invention of term, 300
 mustard, 321
 "Gas sylvestre," 300
- Gelatin medium, for bacteria cultures, 196
- Gene, 146, 154, 157, 159
 definition of, 152-153
 (*See also* Heredity and Mutations)
- Genera Plantarum*, by Linnaeus, 26
- General Anatomy*, by Henle, 198
- Generation, F₁, 136
- Generation, F₂, 136
- Generation, spontaneous, 11, 69, 189, 412-413
- Generation of Animals, The*, by Aristotle, 12
- Generic name, 26
- Genetics, 142
- Genus, classification term, 28, 29
- Geology, 81, 116, 444
 Agassiz's work in, 98, 103
 Cuvier's work in, 103
 Lyell's work in, 88, 90-93
- Geotropism, 352
- "Germ of laziness" (*See* Hookworm)
- Germ plasm theory, 145
- Germ theory of disease, 181-205, 270
- Gesner, von, Konrad, **15-17**
 picture of, 16
 writings of, 15-16

- Glacial theory, developed by Agassiz, 98, 101, 103
- Glands, 368-377, 386-388, 391
 adrenal, 372, 373
 endocrine, 368, 369
 pancreas, 375-376, 381, 386-388, 396
 thyroid, 342, 369-372
- Glycogen, 384, 388
- Gobi desert (*See* Mongolia)
- Goethe, von, Johann Wolfgang, 70, 74
- Goiter, 369-372
- Goldberger, Joseph, **345-346**, 347
 picture of, 346
- Goltz, Friedrich, 354
- Gorgas, William Crawford, 216, 218, **225-230**
 picture of, 228
- Gorgas Memorial Institute, 230
- Grafting, in plants, 162, 169, 172
 of tissues, in embryos, 364-365
- Grant, George R., 288
- Grassi, Giovanni, 217
- Gray, Francis, 101
- Grew, Nehemiah, 51, **164**, 302, 322
 picture of, 164
- Grey, Asa, 62, 120
- Guitry, Sacha, 192
- Gymnosperms, 59-60
- H
- Hæmophilia, 155
- Hales, Stephen, 303-304
 writings of, 303
- Half Mile Down*, by Beebe, 424
- Haller, von, Albrecht, 26
- Handbook of Experimental Physiology of Plants, The*, by Sachs, 312
- Hanging drop slide, 196
- Harington, Charles R., 371
- Harriman, Mrs. E. H., 150
- Harvard Museum of Comparative Zoology, 100-102
- Harvest of Years, The*, by Burbank, 170
- Harvey, William, 33, **37-41**, 347
 importance of, to biological sciences, 41, 45
 picture of, 39
 writings of, 38
- Heart, Harvey's study of, 38-40
 (*See also* Circulation of blood and Mechanical heart)
- Heidenhein, Rudolf, 395
- Heiser, Victor G., 249
- Helmholtz, von, Herman L., 73
- Helmont, van, Jan Baptista, 300, 302
 picture of, 301
- Hemoglobin, 273, 316, 320, 342
- Henle, Jakob, 198
 writings of, 198
- Henslow, John Stevens, 114, 115
- Herbals, 15
- Herbs, used as medicine, 177, 179, 181
- Heredity, **126-159**, 174, 361
 Mendel's Laws of, 136-138, 142-143, 148, 152, 155
 (*See also* Inheritance)
- Heredity in Relation to Eugenics*, by Davenport, 150
- Herschel, Sir John, 114
- Hessian fly, 251
- Hill, Archibald V., 385, **400-403**, 408-409
 picture of, 408
 writings of, 400
- Hippocrates, 46, **176-177**, 179, 334
 pictures of, 176, 178

- Hippocratic Oath, 176
- Histology, 72
- Historia Animalium*, by Gesner, 15
- History of Botany, The*, by Sachs, 311, **312**
- History of Plants, The*, by Aristotle, 12
- Hohenheim, von, Theophrastus (See Paracelsus)
- Holst, Alex, 343, 347
- Hoof and mouth disease, 235
- Hooke, Robert, **48-53**, 58, 70
picture of microscope of, 50
writings of, 52
- Hooker, Sir Joseph D., 121
- Hookworm, 243, 244-250
called "germ of laziness," 247-248
eradication of, 249-250
- Hopkins, Frederick G., **337-339**, 347
picture of, 337
- Hormones, 344, **368-377**, 386-391, 439
cortin, 372, 375
epinephrin, 372-373
insulin, 386-388, 390-391
secretin, 376, 377, 396
thyroxine, 370-372, 375
- Horticulture, 174
(See also Plant breeding)
- Housefly, 257-258
- How Plants are Trained to Work for Man*, by Burbank, 174
- Howard, Leland O., 52, 112, **253-259**
picture of, 252
writings of, 257, 258
- Humboldt, von, Alexander, 62, 96, 113, 114, 116
writings of, 113
- Hunter, John, 183
- Hunterian Museum, 183
- Hutchinson, Woods, 258
- Huxley, Julian, 122
- Huxley, Thomas, 78, 122
- Hybridization, 137-138
- Hybrids, 136, 142, 150-151
Kolreuter's study of, 167-169
(See also Heredity)
- Hydra, reactions of, 362
- Hydrophobia, 192
- Hykeš, O. V., 73
- Hypnotism, 284-285
- I
- Iltis, Hugo, 135
- Immigration, Davenport's study of, 152
- Immunity, problems of, 242, 267, 269, 278-279
- Immunization, against anthrax, 190, 192
against diphtheria, 260, 263-266
against smallpox, 184-186, 308
- Infantile paralysis, 270
- Infusoria*, 274
- Ingenhouz, Jan, **307-308**, 309
picture of, 307
writings of, 308
- Inheritance, 140-142, 146
of characteristics in plants, 135-136, 174
and gene theory of, 154-155
and germ plasm theory, 145
of human characteristics, 131-132, 150, 152
laws of, 136-138, 142-143, 148, 152, 155
- Inoculation, against diphtheria, 263-266

Inoculation, against hydrophobia, 192
 of sheep, against anthrax, 190, 192, 198
 against smallpox, 181, 184-186, 308
 (*See also* Immunity and Immunization)

Inquiries into Human Faculty and Its Development, by Galton, 132

Insects, 238, 250-259
 as agents of pollination, 166
 economic significance of, 251
 parasite control of, 255-258
 warfare against, 258-259
 (*See also specific insects*)

Instincts, 396

Insulin, 386-388, 390-391

Insulin shock, 390

Integrative Action of the Nervous System, The, by Sherrington, 406

International Board of Health Exhibit, 130

Invertebrate paleontology, 104, 109

Invertebrates, artificial parthenogenesis in, 358-359, 364
 reactions of, 350-351, 353, 361, 362-364
 regeneration in, 364

Iodine, and thyroid gland, 342, 370, 371

Iodoform, 262

Islets of Langerhans, 386, 387, 388

Iwanowski, Dmitri, 234

J

Jackson, Charles Thomas, 292
 James, William, 354

Janssen, Johann and Zacharias, 47

Japanese beetle, 251-252
 parasitic control of, 257

Jardin des Plantes, 144

Jardin du Roi, 108, 109

Jenner, Edward, **181-187**
 conquest of smallpox by, 184-186
 picture of, 185

Jennings, Herbert Spencer, 353, **360-363**
 picture of, 361
 writings of, 361, 362

Jimson weed, as experimental plant, 157, 158, 168

June, Harold, 434

Jussieu, de, Bernard, 59, 107

K

Kendall, Edward Calvin, **370-371**, 375
 picture of, 373
 writings of, 371

Key—Catalogue of the Protozoa, Worms, Crustacea, Arachnoids and Insects of Man, Primates, Chiroptera, Insectivora, Carnivora, by Stiles, 250

Kingdom, classification term, 28, 29

Kissenger, John, 222-223

Kitazato, Shibasaburo, 199, 263

Klebs, Edwin, 260

Koch, Robert, **194-199**, 240, 263, 267, 405
 picture of, 197

Koch's Postulates, 198

Kolreuter, Joseph G., 157, **165-169**
 picture of, 167

L

- Lactic acid, 187, 339, 401-402
- Lamarck, Jean, **106-113**, 120, 124, 126, 141
 picture of, 107
 writings of, 108, 110, 112
- La Motte, de, Anna (Mrs. Alexis Carrel), 417
- Landsteiner, Karl, 279, **281-282**
 picture of, 280
- Langerhans, Paul, 386
 (See also Islets of Langerhans)
- Laplace, de, Pierre, 82, 83, 326
- Laughing gas (See Nitrous oxide)
- Laveran, Charles Louis, **207-209**, 214
 picture of, 209
- Laveran, Mmc., 209
- Lavoisier, Antoine, 304, **306**, 309, 326, 347
- Law of Use and Disuse, 111
- Laws of heredity, 136
- Lazear, Jesse William, 217, 221, **224-225**
 camp named for, 222-223, 224
- Learning, process of, 397-398
- Leeuwenhoek, van, Antony, **53-58**, 411-412
 pictures of, 54, 56
- Leeuwenhoek, Maria, 57-58
- Leguminosae*, on Galápagos Islands, 119
- Lenin, 399
- Lessons in Experimental Physiology Applied to Medicine*, by Bernard, 385
- Letter on the Sex of Plants*, by Camerarius, 165
- Leuckart, Karl, 144
- Liebig, von, Justus, 310, **311**, 314, 326
 picture of laboratory of, 314
- Life of Edward Jenner*, by Drewitt, 186
- Lind, James, 335
- Lindbergh, Charles A., 418-419, **436-439**
 picture of, 435
- Lindbergh heart (See Mechanical heart)
- Linnaean Society, 26, 59, 121
- Linnaeus, Carolus, **18-27**, 106
 classification system of, 23, 26-29, 30-31
 pictures of, 21, 25
 writings of, 23, 26
- Linnaeus, Nils, 18-19
- Linné, von, Carl (See Linnaeus, Carolus)
- Lister, Baron Joseph, 69, 187
199-205, 211, 214
- Little America, 434-435
- Little America*, by Byrd, 435
- Liver, function of, 384
- Liverpool School of Tropical Medicine, 214
- Living Machinery*, by Hill, 400
- Locusts, 251
- Locy, William A., 57
- Loeb, Jacques, 351, **353-360**, 363
 picture of, 355
- Löffler, Friedrich, 235, 260
- Long, Crawford W., 287, **288-291**
 picture of, 290
- Lucretius, 169
- Ludwig, Carl, 395
- Lusk, Graham, 328
- Lyell, Charles, **88-93**, 103-104, 111
 picture of, 91

Lyell, Charles, writings of, 90, 92,
93, 103, 114, 115

M

McCollum, Elmer, V., 339-343,
347

picture of, 341

writings of, 343

McKinley, Ashley C., 434

Maclcod, John J., 387, 390

MacMillan, Donald B., 433

Macronucleus, 414-415

Magendie, François, 382

Magnesium, effect of, on rats, 342

Malaria, 207-217

parasite of, 208

spread of, 212-214

Malpighi, Marcello, 33, **41-45**,
302, 322

picture of, 42

Malpighian tubes, 42

Malthus, Thomas, 119

Man the Unknown, by Carrel, 419

Manson, Sir Patrick, 209, 212, 214

Marchal, Paul, 256

Marine Biological Laboratory at
Woods Hole, 154, 359

Martin, C. J., 375

Martius, von, Karl, 96

Massachusetts General Hospital,
287, 293-294

Materials for the Study of Variation,
by Bateson, 141

Mechanical heart, 419, 438-439
diagram of, 438

Mechanism of Nervous Action, by
Adrian, 406

Mechnikov, Ilya, 204, 214, 269,
273-278

picture of, 276

Mechnikov, Olga, 269

Medical Pneumatic Institute, 285

Medical Research Council of Great
Britain, 132

Medicine, early history of, 175,
180, 182, 444

experimental, 381-384

and germ theory, 181-205, 270

(*See also Disease and Surgery*)

Medicines, early, 177, 179, 180-
181, 269

Medium, for bacteria cultures, 196

Meister, Joseph, 192-193

picture of, 193

Memoirs, by Ross, 213, 216

Mendel, Gregor Johann, **133-**
138, 140, 142, 143, 159

picture of, 133

Mendelian Laws, 136-138, 152,
155

application of, 142-143, 148

Mendel's Principles of Heredity, by
Bateson, 141

Meningitis, cerebro-spinal, 270

Mesmer, Franz, 284-285, 291

Mesmerism, 284-285, 291

Metabolism, 331, 370, 372

Metchnikoff, Eli (*See Mechnikov*)

Methods and Discoveries, by Burbank,
174

Meyerhof, Otto, 403-404

writings of, 403

Micrographia, by Hooke, 52

Micronucleus, 414-415

Microscopes, 55, 72, 164, 442

early, 47, 51

importance of, 76, 78, 443, 444

improvements in, by Hooke, 50,
51

by Leeuwenhoek, 54, 56-57

by Zeiss, 66

- Microscopical Researches into the Accordance in the Structure and Growth of Plants and Animals* by Schwann, 67
- Miller, Charles Philip, 281
- Mitchell, Silas Weir, 233-234
- Mohl, von, Hugo, 63, 69, **74-75**, 77
picture of, 76
- Mongolia, expeditions into, 429-432
- Moraëus, Sara (Mrs. Carolus Linnaeus), 23
- Moran, James, 222-223
- Morgan, Thomas Hunt, **153-156**
picture of, 155
- Morton, William T., 287, 291, **292-294**
picture of, 293
- "Mosquito Day," 213
- Mosquitoes, 52
Aedes, 225, 227
Anopheles, 217, 227, 230
cradication of, 214, 216, 227, 257
and malaria, 199, 208, 212-214, 227, 230, 257
and yellow fever, 220-223, 227, 257
- Mosquitoes of North and Central America and the West Indies*, by Howard, 52, 257
- Moths, 251
parasites of, 255
- Motor nerves, 393, 406-407
- Motu cordis et sanguinis, de*, by Harvey, 38
- Moulton, Forest R., 82
- Muller, Hermann J., 153, **156-157**
picture of, 155
- Müller, Johannes Peter, **64-65**, 68, 76
- Murray, G. R., 370
- Muscles, 339, 393, 400-410
cause of fatigue in, 401-402
energy produced in, 401
fibers of, 407
impulses affecting, 404, 406, 408, 409-410
- Mutations, 140, 156-158
and Mendelian Laws, 157
produced by chemicals, 158
produced by X rays, 156-157, 159
(See also Variation in species)
- N
- Nägeli, Carl W., 137
- Naples Zoological Station, 356, 361
- Narrative of an Explorer in Tropical South Africa*, by Galton, 129
- Natural History*, by Buffon, 83, 108
- Natural History*, by Pliny, 13-14, 17, 19
- Natural History of Invertebrate Animals*, by Lamarck, 110, 112
- Natural selection, 145
laws of, 119
- Neanderthal man, 93
- Nebular hypothesis, 82
- Nelmes, Sarah, 185
- Nerves, 393-410
impulses affecting, 406-410
motor, 393, 406-407
sensory, 393, 406-407, 409
vasomotor, 384
- Nervous disorders, 390, 398
- Nervous system, 393, 405-410
- Neurons (See Nerves)
- Newton, Sir Isaac, 51, 122
- Nichomachus, 7-8
- Night blindness, 340

Nitrates, 310
 Nitrous oxide, 285-286, 291
 Nobel, Alfred B., 154
 Nobel Prize, 153-154
 to Adrian, 394
 to Banting, 390
 to Behring, 264
 to Carrel, 417
 to Ehrlich, 269
 to Eijkman, 338
 to Fischer, Emil, 315
 to Fischer, Hans, 320
 to Hill, 403
 to Hopkins, 338
 to Koch, 199
 to Landsteiner, 281
 to Laveran, 208
 to Macleod, 390
 to Mechnikov, 269
 to Meyerhof, 400
 to Morgan, 153
 to Pavlov, 396
 to Ross, 216
 to Roux, 264
 to Sherrington, 394
 to Spemann, 366
 to Szent-Györgyi, 446
 to Warburg, 403
 to Willstätter, 315
 Noguchi, Hideyo, **230-234**, 270
 picture of, 232
 Nonsuch Island, 422, 426
 Novocain, 297
 Nucleus, in plant cells, 58, 60, 65
 in Protozoa, 414-415
 Nutrients, caloric values of, 327,
 329
 necessary for health, 334-336,
 347, 432, 434
 (See also Vitamins)

Nutrition, 331-347
 and chemicals, 342-343
 importance of proper, 346
 problems of, 329, 334-337
 and vitamins, 334, 338-342,
 343-347
 Nutrition Laboratory of Carnegie
 Institution, 331, 332

O

On the Trail of Ancient Man, by
 Andrews, 432
 Ophthalmoscope, 73
 Order, classification term, 28, 29
 Organic chemistry, 300, 313, 315,
 319, 443
 Organic chemists, 319, 320
 Organizers, 365
 Origin of species, 105-125, 250
 Darwin's theory of, 119-125
 Lamarck's theory of, 110-111
 Wallace's theory of, 120-121
 (See also Variation in species)
Origin of Species, The, by Darwin,
 112, 121-122, 275
 Osborn, Henry Fairfield, 429
 Osmosis, 310, 379
 Osmotic pressure, 322
 Osterhout, Winthrop J., 236, 357
Our Times, by Sullivan, 246
 Oxidation, process of, 306, 307-
 308, 325, 372, 390, 418
 Oxygen, discovery of, 305, 306
 named by Lavoisier, 305
 use of, by muscle cells, 402
 use of, in respiration, 305,
 306-308, 372

P

Page, Walter Hines, 249
 Painter, T. S., 153, 159

- Paleontology, 87, 93, 103, 428, 431
 definition of, 80-81
 invertebrate, 104, 109
 vertebrate, 83, 85, 87, 104
- Panama Canal Zone, 216, 227-228
- Pancreas, 375-376, 381, 386-388, 396
- Pancreatic juice, effect of, 384
- Paracelsus, **179-180**
- Paramecia, reactions of, 351
- Parasites, 268
 in digestive tracts, 416
 as insect control, 255-258
 (See also Hookworm, Malaria, Syphilis, and Texas fever)
- Parasitology, 243, 250, 252, 416
- Park, William Hallock, **265-266**
 picture of, 265
 writings of, 266
- Parthenogenesis, artificial, 359, 364
- Parts of Plants, The*, by Aristotle, 12
- Pasteur, Louis, **187-194**, 261, 385
 influence of, on Lister, 201
 pictures of, 188, 191, 193
- Pasteur Institute, 192, 208, 214, 260, 261, 278
- Pathogenic Micro-organisms*, by Park and Williams, 266
- Pavlov, Ivan Petrovitch, 375, **394 400**
 picture of, 398
- Peas, Mendel's experiments with, 135-136
- Pellegra, 345-346
- Pepsin, discovery of, 68
- Peristalsis, 374
- Personal Narrative*, by Humboldt, 113
- Peter the Great, 57, 273
- Pettenkofer, von, Max, 327
- Phagocyte theory, 278-279
- Phagocytes, 269, 277-279
- Phenylhydrazine, 315
- Philip of Macedonia, 8-9
- Philosophie Zoologique*, by Lamarck, 110
- Phipps, James, 184, 186
- Photosynthesis, 299-323
 meaning of, 299
 rate of, 318-319
- Phototropism, 351-352
- Phylum, classification term, 28, 29
- Physiologie végétale*, by Senchier, 308
- Plague, bacillus causing, 199
- Planetary motion, Copernican theory of, 81-82
- Planetesimal hypothesis, 82-83
- Plant and Its Life, The*, by Schleiden, 66
- Plant breeding, 162, 168-174
 by artificial pollination, 135-136, 142, 163, 170, 173
 by grafting, 169, 172
- Plant Breeding*, by de Vries, 140
- Plant geographer, 59
- Plant Hybridization before Mendel*, by Roberts, 142
- Plants, classification of, 26-27, 59-60, 443
 (See also Photosynthesis and Plant breeding)
- Plato, 8, 10
- Pliny, the Elder, **13-14**, 169
 influence of, 14
 writings of, 13, 14, 17, 19
- Pollination, 60, 62, 166-168
 artificial cross-, 142, 170
 in date trees, 163, 165
 in peas, 135-136
 in Shasta daisy, 173
 self-, 162, 163
- Poliomyelitis, 270

Polyneuritis, 336
 Porphyrin, 319
 Priestley, Joseph, 304, **305-306**,
 307, 347
 Primrose, James, 40
 Primrose, mutations of, 140
Principles of Geology, by Lyell, 90,
 114, 115
Principles of Human Physiology, by
 Starling, 379
Principles of Scientific Botany, The,
 by Schleiden, 66
Prometheus, by Jennings, 362
 Protista, 29
 Protoplasm, 46, 64, 70, 78, 403
 irritability of, 350, 351, 352, 353,
 364, 416
 Mechnikov's study of, 276-277
 origin of term, 69
 streaming movement of, 75
 Protozoa, 411-416
Protozoa, The, by Calkins, 414
 Protozoan diseases, 415-416
 malaria, 208, 212-214
 Texas fever, 241-242
 Psychology, Galton's study of, 132
 Ptolemy, 81
 Public Health Service, 246, 250,
 345
 Purkinje, Johannes E., 60, **70-74**,
 77, 312
 pictures of, 71, 74
 Purkyně (*See* Purkinje)
 Pythagoras, 46

R

Raleigh, Sir Walter, 181, 385
 Reactions, 349-353, 356
 of lower animals, to stimuli,
 351, 361, 362-364
 of nerves and muscles, 393-410
 Redi, Francesco, **413**
 Reed, Walter, 217, **218-224**
 picture of, 219
 Reflex arc, 406, 408
 Reflexes, 399-400, 406, 408
 conditioned, 396-398
 natural, 396
 Regeneration, in animals, 364
 in plants, 359, 364
Researches on Fossil Fish, by Agassiz,
 97
 Respiration, 305, 306, 350, 403-404
 in plants, 306-308, 322
 Reuterholm, Nils E., 22
 Richards, Theodore W., 320
 Riley, C. V., 254
 Roberts, H. F., 142
 Rockefeller Foundation, 132, 154,
 345
 Rockefeller Institute for Medical
 Research, 234, 236, 242-243,
 270, 358, 359, 439
 Rockefeller, John D., 249
 Rocky Mountain spotted fever, 258
 Roosevelt Medal, to Park, 266
 Roosevelt, Theodore, 249, 266
 Rosa, E. B., 330
 Rosen, Nicholas, 19, 24
 Ross, Ronald, **209-217**, 220
 picture of, 215
 writings of, 213, 216
 Rothman, Johann S., 19, 20
 Roux, Emile, 260, **261, 263**, 265
 picture of, 262
 Roy, C. S., 405
 Royal Society, 44, 45, 48, **49-50**,
 55, 57, 58, 141, 204, 378, 381,
 400, 405, 443
 Rubner, Max, **327-329**, 347
 picture of, 329
 Rudbeck, Olaus R., Jr., 20

S

- Sachs, von, Julius, 66, 138, **311-312**, 356, 364, 366
 picture of, 312
 writings of, 312
- Saint-Hilaire, Geoffrey, 109, 144
- Salversan, 269
- Sarcode, 63, 64
- Sargassum weed, 341
- Saussure, de, Nicholas, **308-309**
- Scheele, Karl Wilhelm, 304
- Schinz, Johann Caspar, 94
- Schleiden, Matthias J., 62, 64, 65, **66-67**, 69, 77, 412
 picture of, 65
 writings of, 66
- Schultze, Max, 63, 69, **76-77**, 412
 picture of, 77
- Schwann, Theodor, 63, 64-65, **67-69**, 76, 412
 and germ theory of disease, 69
 picture of, 65
 writings of, 67
- Scurvy, early problems of, 334-335
 preventives for, 335-336, 432, 434
 (See also Deficiency diseases)
- "Sea bottles," 426
- Sea urchin, 9, 358
 picture of, 9
- Second Visit to America*, by Lyell, 92
- Secretin, 376, 377, 396
- Sedgwick, Adam, 114
- Segregation, Law of, 136, 138
- Seifriz, William, 70
- Self-pollination, 162, 163
 (See also Pollination)
- Senebier, Jean, 308
 writings of, 308
- Sensory nerves, 393, 406-407, 409
- Sexuality of plants, 164-165
 (See also Pollination)
- Shasta daisy, 173
- Sherrington, Sir Charles, **404-408**
 picture of, 404
 writings of, 406
- Silk-worms, 44, 192
- Simmonds, Nina, 343
- Simpson, Sir James, **294-297**
- Singer, Charles, 14
- "Sky hook," 438
- Skyward*, by Byrd, 435
- Smallest Living Things, The*, by Calkins, 414
- Smallpox, 181-186, 242, 307, 308
 medical victory over, 186
- Smith, Allen J., 245
- Smith, Theobald, **239 243**
 picture of, 241
- Solander, Daniel Charles, 26
- Solution "606," 269
- Species, as classification term, 26-29, 31
 (See also Fixity of species, Origin of species, and Variation in species)
- Spermann, Hans, **364-366**
 picture of, 365
 writings of, 366
- Spices, as medicines, 179
- Spirochaete, cause of syphilis, 234
- Spix, John, 96, 101
- Spontaneous generation, theory of, 11, 69, 189, 412-413
- Stanley, Wendell M., 234, **235-236**
 picture of, 235
- Starfish, cells in larvae of, 277
 reactions of, 362-363
- Starling, Ernest Henry, **375-379**
 picture of, 377
 writings of, 379

- Statistics, in biological study, 129–132, 140
 Stethoscope, 128
 Stiles, Charles Wardell, **243–250**
 picture of, 252
 writings of, 250
 Stobaeus, Kilian, 19
 Stomates, 302, 310, 322
Structure of the Human Body, by Vesalius, 34
 Studnička, F. K., 73
 Sturtevant, A. H., 153
 Subphylum, classification term, 28, 29
 Sullivan, Mark, 246
 Surgery, anesthetics used in, 283–297, 318, 383
 antiseptic methods in, 202–204, 205, 262, 417–418
 early methods of, 201, 283, 284, 383–384
 modern methods of, 36, 287, 417, 445
 (See also *Medicine*)
 Sylvius, Jacob, 33
 Syme, Agnes (Mrs. Joseph Lister), 200
 Syne, James, 200
 Syphilis, 234, 269
Systema Naturae, by Linnaeus, 23, 26, 28
 Szent-Györgyi, von, Albert, 446
- T
- Tachina fly, 254–255
 Taste, sense of, 158
 Taylor, Frances Long, 289
 Tessier, Alexandre-Henri, 84, 86
 Tetanus, 242, 264, 405
 Texas fever, 240–242
Textbook of Botany, by Sachs, 312
 Thaler, Peter Aurelius, 134
 Theophrastus, 12
 Thermotropism, 353
 Thigmotropism, 353
 Thothmes, III, 4.
 Thyroid gland, 342, 369–372
 Thyroxine, 370–372, 375
Thyroxine, by Kendall, 371
 Ticks, 238, 241–242
 Tissues, grafting of animal, 364–365
 grown outside of body, 418, 439
 Tobacco-mosaic disease, 234–236
 Tobacco plants, hybrids of, 168
 Tournefort, de, Joseph, 19, 21
 Toxin, diphtheria, 260–266
 Toxin-antitoxin, 260–266
 Toxoid, 266
Truite d'economie rurale, by Bous-singault, 311
 Transfusions of blood, 279–280
Travels in North America, by Lyell, 90
Trees in Winter, by Blakeslee, 157
 Tropisins, 350–353, 356, 360
 Tschermak, Erich, 137
 Tuberculin, 197–198
 Tuberculosis, bacillus of, 197, 240, 267
 in cattle, 240
Two Bird Lovers in Mexico, by Beebe, 421
 Tyndall, John, 413
 Typhoid fever, prevention of, 199, 257
- U
- Ultra violet light, 340
 Unit characters, Law of, 136
Universe and Life, The, by Jennings, 362.

Urare, 384-385

Urea, 313

V

Vaccination, 184-185, 205, 242,
308, 445

Variation in species, 126, 140

Bateson's study of, 141-143

Davenport's study of, 149

(See also Mutations)

"Vegetable anatomist," 75

Vegetable Statics, by Hales, 303Vegetative propagation (See Graft-
ing, in plants)

Venable, James, 289

Ventilation, Hales's study of, 303

Vesalius, Andreas, **33-36**, 369

picture of, 35

Vinegar fly, 154-157

Virchow, Rudolf, 405

Virus, 230-231, 234-236, 237, 238

Virus theory of diseases, 234-236

Vitamins, 334, 337, **338-347**, 434

vitamin A, 339-340, 446

vitamin B, 340

vitamin C, 343, 446

vitamin D, 340-341, 343, 347

vitamin E, 343-344

vitamin G, 345-346

vitamin P-P (See vitamin C)

(See also Nutrition)

Vivisection, 382-383

Voit, von, Carl, **326-327**, 330, 347

Von Mohl (See Mohl)

Vries, de, Hugo, 137, **138-140**, 149,
156, 172

picture of, 139

writings of, 140

W

Wallace, Alfred R., 111, 120-121
picture of, 121Walter Reed Veterans Hospital,
224Warburg, Otto, **318-319**, 403

Warren, John C., 293

Watanabe, Kanae, 232

Water striders, 423

Wedgewood, Josiah, 115

Weismann, August, **144-147**, 154

picture of, 143

Wells, Horace, 291-292

Whale Hunting with Gun and Camera,
by Andrews, 428

Whales, Andrews' study of, 428

Who's Who among the Microbes, by
Park and Williams, 266Willard Gibbs Medal, to Will-
statter, 316

Williams, Anna, 266

Willis, Thomas, 381

Willow, Helmont's experiment
with, 302Willstätter, Richard, **315-319**

picture of, 317

Wilson, Edmund Beecher, **147-148**

picture of, 148

writings of, 148, 153

Wöhler, Friedrich, 144, **313-314**,
347

Woods Hole Laboratory, 154, 359

Woolly root-louse, 255-256

parasite of, 256-257

Worm, army, 254

Worms, pathogenic (See Hook-
worm)

Wound shock, treatment of, 380

Wyman, Walter, 246

- X
- Xanthophyll, 316
 Xerophthalmia, 340
 X ray, effect of, on vinegar flies,
 156-157
- Y
- Yellow fever, 207, 219, 230, 234
 carrier of, 220-223
 control of, 227, 229
 Yellow Fever Commission, 217
 work of, 220-224
- Yersin, Alexandre Emile, 260-261,
 263
- Z
- Zeiss, Carl, 66
 Zinsser, Hans, 240
 Zoology, 95, 424, 429
 classification in, 3, 27- 29
 invertebrate, 109, 110, 112
 of Pliny, 13
 Protozoology, 411-416
Zoonomia, by Erasmus Darwin, 127

