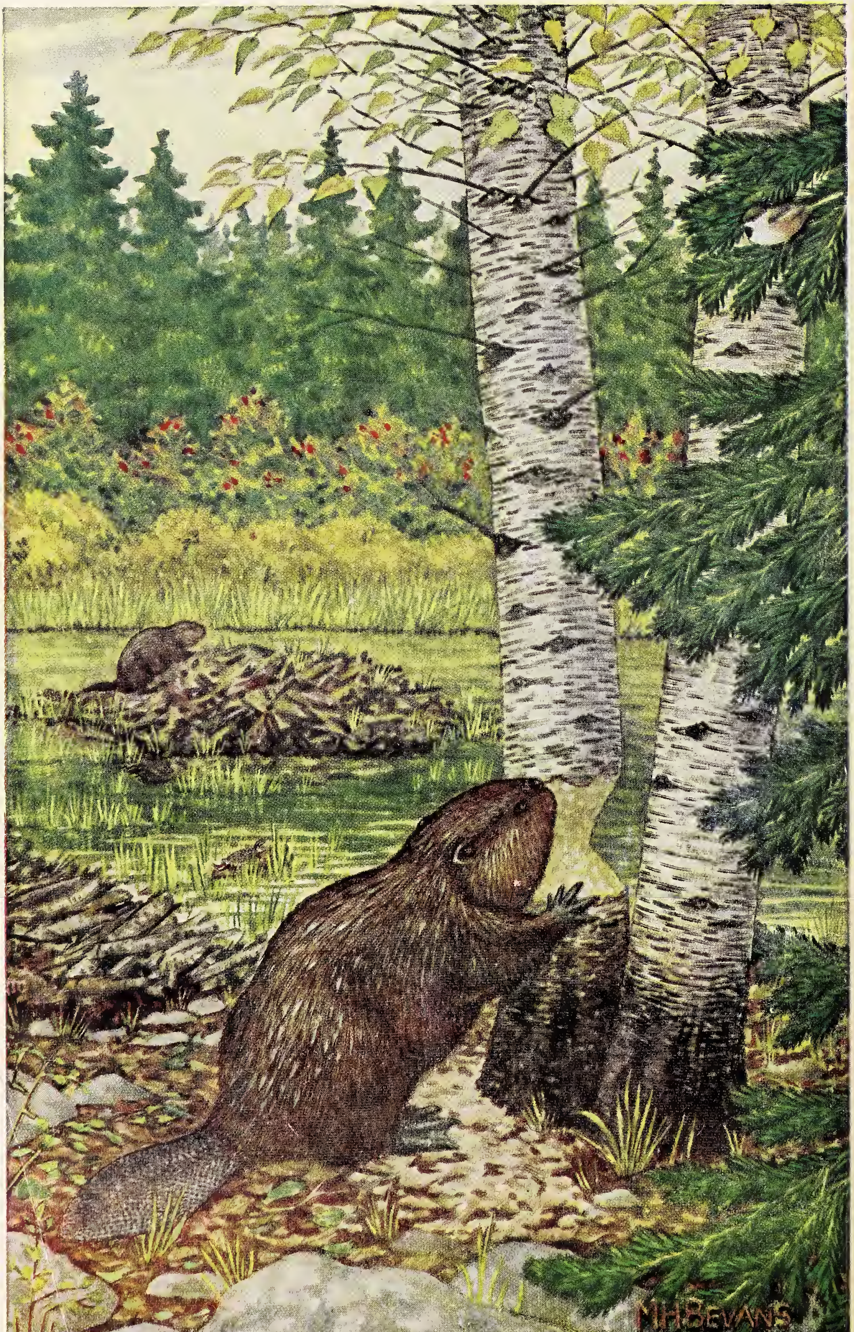
MODERN BIOLOGY

ON

NN

O

P. 365 - VVI — egg laying
- VIV — bring forth
OVOVIV — bring
young


M.H.BEVANS

MODERN BIOLOGY

TRUMAN J. MOON

PAUL B. MANN

JAMES H. OTTO

NEW YORK
HENRY HOLT AND COMPANY

The Authors of MODERN BIOLOGY

Truman J. Moon . . . Late Head of the Science Department, The High School, Middletown, New York

Paul B. Mann . . . Late Deputy Chairman of the Science Council of New York City and Head of the Department of Biology, Evander Childs High School, New York City

James H. Otto . . . Head of the Science Department, George Washington High School, Indianapolis, Indiana

6–48

Preface to Modern Biology

Several years have passed since the last major revision of BIOLOGY. These years have been especially significant in social, political, and scientific progress. As the history of World War II, of the period of reconversion, and of the years following reconversion is written, many of its chapters will emphasize phenomenal scientific development. Scientific progress in recent years has greatly influenced the life of every individual. Recent advances in biological knowledge, of tremendous significance, have been included here as a part of the basic biological training of the high-school pupil.

This revision of BIOLOGY appears under a new title, MODERN BIOLOGY. In one sense, MODERN BIOLOGY is a new book. It contains several entirely new chapters, many rewritten chapters, and a large amount of new material which has been added to the chapters in BIOLOGY. In another sense, however, MODERN BIOLOGY is not a new book, because the general scope of subject matter and the clear and logical plan of presentation which made BIOLOGY FOR BEGINNERS (1933) and BIOLOGY (which appeared first in 1938) so effective have been carefully preserved.

MODERN BIOLOGY remains a text for the beginner. It is designed for the pupil of secondary-school level who has had no previous biological training. His study of biology begins with the most basic principles of life and continues through a series of units, arranged in logical sequence, to more complex concepts of the science of life. Throughout this study, we use specific forms of life to demonstrate biological principles. The pupil becomes acquainted with many forms of plant and animal life which exist about him. As he studies them, he becomes aware of the broad principles which govern the existence of all living things. But the study of plants and animals is not made secondary to a consideration of the principles demonstrated by living things. Nor is the pupil expected to generalize, in the abstract study of comparisons of life forms, from an assumed background of biological knowledge which he may not possess. Rather, he pursues his study of biology much in the manner in which he would learn in the out-of-doors, by getting acquainted with plants and animals about him, observing their life activities, and comparing the life forms he meets.

The general scope and sequence of the material in the previous edition have been somewhat altered in the preparation of MODERN BIOLOGY. We have broadened the introductory unit to include a more thorough presentation of the rise of biology as a science and the development of scientific method. We discuss thoroughly the basic characteristics of living things, the life processes, the physical basis of life, and the chemical basis of life before we consider any specific organisms.

Likewise, the pupil studies the interrelation of all living things before he deals with any particular life forms. This sequence provides a biological background for the study of various plant and animal groups.

Another new feature of MODERN BIOLOGY is the unit dealing with Microbiology. Microscopic plants and animals are studied in the manner in which they live in nature. The unit includes both plant and animal forms which make up the intricately balanced society of the microscopic world of life.

MODERN BIOLOGY is functional in that much of the material it includes applies directly to life situations and experiences of the pupils. Even the more technical discussions of the structure, function, and adaptation of organisms are brought close to the life of the average person through careful selection of the life forms that are used as examples. A new and greatly expanded unit on disease acquaints the pupil with both the curative and preventive phases of modern medicine. The unit on heredity, too, has been expanded to include more information on plant and animal breeding and the application of genetics to problems of the human race. Especially practical applications of the study of plant life are included in new chapters dealing with forestry and economic botany.

We have emphasized conservation, a vital problem in America today, throughout the text. A final unit relates all phases of conservation and discusses the organized program of conservation in America.

While its units are arranged in a logical sequence from simple to complex and from basic principles to more advanced applications, the organization of MODERN BIOLOGY has been made quite flexible. This enables the teacher to rearrange the units to fit a variety of biology courses. Many courses are organized on a seasonal plan of study, the general and animal phases of biology being presented in the fall semester and the plant phases in the spring semester. Units may be shifted to meet these requirements quite readily and without destroying the continuity of the text.

MODERN BIOLOGY is adapted for use in courses which emphasize laboratory and field study of biology. In the field, the pupil deals with specific forms of life and their relation to one another. Given a background of knowledge of life forms, he is then able to comprehend the broad principles which govern the existence of all living things. This same plan of study is incorporated into the units of MODERN BIOLOGY. The text also allows for laboratory experimentation. Since only a limited number of life forms are needed to demonstrate any portion of the text, the teacher may readily provide actual material for direct experimentation and observation. The teacher is not required to have on hand a wide selection of life forms — simple and complex, plant and animal — to be used simultaneously, over and over, in order to provide material directly related to the text. This feature of MODERN BIOLOGY encourages the laboratory and field phases of the biology course. The teacher without laboratory teaching opportunity will find, however, that the use of the text is in no way dependent upon pupil experimentation.

In the preparation of MODERN BIOLOGY, teleological expressions, implying purposeful action on the part of plants and animals which are without ability to apply reason to their problems, have been carefully avoided. We have presented life forms in a purely scientific manner without effort to dramatize biology.

The general content of each unit is presented to the pupil in a short preview before any specific information is given. Each chapter, too, begins with an inviting introduction.

Teaching and learning aids at the close of each chapter are divided into three sections. The section titled *Using Your Knowledge* includes questions relating to chapter content, providing review and consolidation of the material covered. *Expressing Your Knowledge* consists of significant terms which have been used, defined, and, if necessary, pronounced in the chapter and helps the pupil to crystallize his knowledge of their use. In the section, *Applying Your Knowledge,* the pupil's knowledge of the chapter content is used in carrying out suggested activities. These activities are not intended as laboratory exercises and, for the most part, require no laboratory apparatus. They will encourage pupil initiative and an application of biology to situations in his immediate environment. At the close of each unit, a list of selected bibliographical references is included in the section *Increasing Your Knowledge.* The books selected have been found especially suitable as supplementary references for both pupils and teachers.

Grateful acknowledgment is made to all those who have assisted, in one way or another, in the preparation of MODERN BIOLOGY. The comments made by Mr. Thomas D. Bain of Harding High School, Marion, Ohio, concerning the previous edition, have been most helpful in preparing the manuscript for the revision. The many valuable suggestions submitted by Mr. Henry Flury, Eastern High School, Washington, D. C., are also appreciated. The authors are indebted, too, to Mr. H. T. Smolenski, Indianapolis, Indiana, for advice concerning many phases of the book, and to Miss Mildred Campbell of Shortridge High School, Indianapolis, for information concerning bird study and bird migration. Acknowledgment is made, in addition, to Dr. John E. Potzger and Dr. Ray C. Friesner of Butler University, Indianapolis, for suggestions regarding certain portions of the discussion of plant life, and to Dr. J. E. Tether of the Indiana University Medical Center, Indianapolis, for information in regard to the Rh factor of blood.

Our list of acknowledgments must also include the members of the science faculty of George Washington High School, Indianapolis, and, especially, Mrs. Mildred I. Ross, who prepared the references included in *Increasing Your Knowledge* for all units, and Mr. J. C. Nelson and Mr. Allan R. Stacy, who assisted in obtaining material to be included in the revision. Acknowledgment is given also to Mr. Walter G. Gingery, principal of George Washington High School, who made valuable comments concerning *Our World of the Future,* which appears in the opening portion of the book.

Finally, deep appreciation is extended to my wife, Eloise B. Otto, for the rather inglorious but necessary task of typing the greater portion of the manuscript and for her many helpful suggestions which have been incorporated into the text.

J. H. O.

Indianapolis, Indiana
March, 1947

Contents

Acknowledgment for Illustrations

The authors gratefully acknowledge the courtesy and co-operation of the following individuals and organizations who have been kind enough to supply some of the photographs used in this book:

Allen, Dr. A. A., p. 393 (bottom right)
American Museum of Natural History, pp. 4, 75, 299, 335, 348, 349, 350, 351, 367, 387, 420, 421, 436, 620, 627, 630, 650
Bausch & Lomb Optical Co., p. 580
Boy Scouts of America, p. 37
Brooklyn Botanic Garden, pp. 76, 92, 94, 99, 150, 173, 633
Bureau of Water Supply, City of New York, p. 565
Caterpillar Tractor Co., p. 82
Colby, A. S., p. 124
Davey Tree Expert Co., p. 313
Drexler, R. V., p. 235
Ferry Morse Seed Co., p. 73
Funk Brothers Seed Co., pp. 109, 198, 577
General Biological Supply House, p. 370
Good Housekeeping Institute, pp. 3, 442
Hanovia Chemical and Mfg. Co., p. 561
Heinz, H. J. Co., p. 447
Kauffeld, Carl F., p. 369
Koehler, Benjamin, p. 233
Lakeside Press Galleries, p. 27
Leeds and Northrup Co., p. 9
Missouri Botanical Garden, p. 94
National Audubon Society, p. 393 (top left)
National Committee on Boys and Girls Club Work, p. 605
National Education Association, p. 510
National Tuberculosis Association, pp. 557, 558
NYA Photographic Workshop, p. 327
New York Botanical Garden, pp. 58, 59, 61, 62, 91, 95, 97, 100, 123, 125, 127, 133, 152, 170, 172, 173, 224, 225, 230, 600
New York Zoological Society, pp. 373 (top left), 413
Otto, James H., pp. 1, 80, 373 (bottom right)
Parke, Davis & Co., pp. 440, 441, 552, 554, 556
Pfizer, Charles & Co., Inc., p. 232

Rockefeller Institute for Medical Research, p. 569
Science Service, p. 318
Sinclair Refining Co., pp. 23, 361
Society of American Bacteriologists, pp. 242, 544
Tippo, Dr. Oswald, p. 136
Triarch Botanical Products, p. 580
United States Department of Agriculture, pp. 71, 89, 202, 312, 392, 444, 555, 579, 601, 602
  Bureau of Entomology and Plant Quarantine, pp. 77, 286, 312, 313, 315
  Bureau of Plant Industry, p. 234
  Forest Service, pp. 22, 61, 81, 128, 134, 138, 208, 210, 212, 213, 637, 644, 652, 654
  Soil Conservation Service, pp. 61, 195, 641, 642, 645
United States Department of the Interior
  Bureau of Reclamation, p. 647
  Fish and Wildlife Service, pp. 283, 406, 657, 659
United States Public Health Service, p. 572
United States War Department, Signal Corps photograph, p. 314
Westinghouse Electric Corporation, p. 48
Zoological Society of Philadelphia, p. 369

Our World of the Future

The world in which we live today was dreamed of by men long ago — men who never lived to see it, but who played an important part in building it for us. Modern civilization has resulted from centuries of human progress. The knowledge which produced this wonderful age has been passed on and gradually increased, generation after generation over a period of centuries.

Today, we stand on the threshold of a new age — the highest civilization the world has even seen. But in entering this new era we find ourselves at the crossroads of civilization. We have an important decision to make — a decision which may determine the entire future of our civilization and, perhaps, the very existence of the human race.

Modern civilization has been built upon human progress in two important lines. *Scientific progress* has given us power; power to do good, or power to do evil. The manner in which we use this power depends upon *social progress*.

Had man progressed socially and scientifically at equal rates, we would have nothing to fear today. The power which science has given us would be used to build even a better civilization for future generations. But, while openmindedness, freedom from prejudice, and international co-operation have advanced science at a tremendous rate, selfishness, prejudice, suspicion and international jealousy have retarded social progress. As a result, our scientific age is far in advance of our social age.

Recently, the condition of our civilization became critical. World War II brought, within a few years, scientific advances which would normally have required many years to achieve. Scientific power almost beyond comprehension is now in our hands. On August 5, 1945, the most shocking incident of the entire war occurred over Hiroshima, Japan. In a tremendous cloud of dust and vapor, a large portion of a city — its buildings, homes, and human inhabitants — disappeared from the earth. Those who witnessed the explosion of that atomic bomb were filled with awe. Such a spectacle was beyond human imagination. The civilized world was shocked. Some felt joy that such a weapon would bring a hasty end to the war. This enthusiasm was dampened, however, by fear of what such power might do to the human race.

But this atomic bomb meant more than the destruction of a city — more, even, than the end of that bloody war. It ushered in a new age — the atomic age. The significance of this new age is so tremendous that we can almost reckon time from the summer of 1945 when atomic energy was first released upon the earth.

While science was at work discovering the secrets of atomic fission, breath-taking discoveries were being made in other fields. A strange new power called radar made our ships and planes and guns the most effective in the world and hastened the end of the war. Jet-propelled planes, precision bombing instruments, and many other scientific marvels appeared and made obsolete all other devices of their type.

Yet, while we were bending every effort toward self-defense and the production of weapons of war, science was advancing rapidly in other fields. Biologists were making important discoveries destined to save many thousands of lives. Dreaded wound infections and blood poisoning, so costly to soldiers in combat, were nearly stamped out by the wonder drug, penicillin. Through miracles of modern medicine, wounded men were given almost immediate treatment in the front lines and were then flown to specialized hospitals which had been set up in all parts of the world for further treatment and recovery. Knowledge gained in medicine and surgery, as a result of research through the war years, promises to revolutionize much of our medical practice of the future.

Now we must make our choice. Will all of this power be used for good or for evil? Will giant planes of the future deliver visitors of good will or atomic bombs? Will the energy of atomic fission run power plants or demolish cities? Will our knowledge of medicine be used to save lives or to fight future wars with infectious diseases? We have, on one hand, opportunity; on the other, desolation and the destruction of civilization. We must make the decision.

The late Wendell Willkie spoke of "One World." Other informed men of all nations have spoken of our future hope in these terms. We can no longer live unto ourselves to the exclusion of other peoples. Suspicion, jealousy, prejudice, and hatred must no longer hamper social progress. We must understand other nations and co-operate with them. We must live as citizens of a world.

The hope of the future depends, to a great extent, upon the understanding of the principles and ideals of science, by all people. Science is a never-ending search for truth. It is no respecter of nations, of races, or of sects. The bonds of science are greater than any of these. Now, we must learn to *live* scientifically, according to these high principles. If rapid social progress can be made in the manner of science, we have tremendous power to do good. World travel, television, atomic power, control of cancer, even the end of infectious diseases may be ours through science — if we make the right choice.

Practical Pointers for Beginners in Biology

1. Keep your eyes and your mind open. In biology as in all science, conclusions are based on facts. The scientific method and scientific attitudes discussed in Chapter 1 are to be applied throughout your course and should become habits of straight thinking for intelligent living.
2. Your profit from this course, like other undertakings in life, depends directly upon what you yourself put into it — the age-old law of compensation.
3. The more you learn about living things, the more interested you become. Allow your curiosity and special interest to go beyond this textbook. Observe living things and read some of the books that appeal to you from the selected lists, entitled *Increasing Your Knowledge,* at the end of each unit.
4. Immediately after a careful reading of an assignment, check your understanding by glancing over the **boldface** paragraph headings. If you cannot make an accurate statement from what you have just read, reread those paragraphs until you can. When you reach the end of a chapter, answer the questions entitled *Using Your Knowledge.*
5. The visual aids provided in the diagrams and tables of comparison are an outstanding feature of this book. Train yourself to remember and to interpret accurately by seeing as well as by reading.
6. Biology is a laboratory science. Many of the important facts and discoveries can be observed by experimental evidence. If you are so fortunate as to have valuable laboratory equipment available, use it with the intelligence and care of a scientist. Participate in making your classroom a laboratory experience by bringing in specimens for observation and by doing some of the projects suggested in *Applying Your Knowledge* at the end of each chapter.
7. Try to acquire the language of biology in your day-to-day study of the text. You will understand and remember terms best by associating them with their use in the discussions. Each special biological term is printed *in italics* the first time it occurs in the text. Pay particular attention to the meaning given and to the subject with which it deals. The most important biological terms used in each chapter are listed for a quick, check-up review in *Expressing Your Knowledge* at the end of the chapter.

   Later in the text, when you encounter one of these terms whose meaning you have temporarily forgotten, stop to look it up and to refresh your memory. For this purpose, the authors have provided the special device, *Index and Guide to Terms.* Either the *first* page listing for that term or the page listed as "definition" refers you directly to the original definition in the text. The word appears on the text page *in italics* or **in boldface.** You will remember better by reading not just the definition itself, but the whole paragraph which gives you a complete association picture. Now return to your reading. You are not likely to forget that term again. If you use the *Index and Guide to Terms* correctly, you will find that you will develop a working knowledge of the language of biology.

Unit 1 ~~

Biology: The Scientific Study of Living Things

You may have seen a magician pull a rabbit out of a hat, and wondered what sleight of hand trick he used to do it. You certainly have seen plants and animals grow, but did you ever wonder how it happened? In nature, leaves and roots are really changed into rabbits. Did hocus-pocus, sleight of hand, and other magician's trappings do this? Certainly not! This is all part of an orderly growth which we take for granted. Actually, there is no magician as clever as nature, no trick so complex as the growth which takes place in all living things.

How does nature work these apparent miracles? We don't know all the answers, but biologists know many of them and are constantly searching for more. Biologists know that a wonderful substance called protoplasm is the living material of all plants and animals. They know that the basic units of all forms of life are cells. Skin, bone, muscle, and blood; roots, leaves, flowers, fruits, and wood, as well as many other parts of living things, are alike in two respects: they are made of protoplasm and cells.

Chapter 1

The Science of Life

Have you ever collected leaves or insects? Have you watched tadpoles turn into frogs or birds build a nest and raise a brood of young? Or have you hiked through the woods in autumn and wondered what makes the leaves turn red and yellow and orange? If so, you have studied biology.

Probably your study of plants and animals has been limited because of lack of direction. You now have an opportunity to study life in the manner of science. You will learn what our scientists have found out about living things and how they have used this knowledge in developing the science of biology.

What is biology? A definition of biology should begin with an understanding of science, for biology is but one of the several sciences. Science is a method by which men search for truth. It is a vast knowledge based upon proved facts.

Much of the classified knowledge which constitutes science concerns life and living things. We call this branch of learning *biology*. The word biology comes from two Greek words, " bios " which means " life " and " logos " meaning the " science " or " study of." Thus, the two parts make a perfect definition: " the science of life or living things."

Biology is the study of plants and animals, including man. It deals with the principles which govern all living things. The relation of plants and animals to their surroundings and to each other is another phase of biology. It deals with farming and gardening, conservation, pest control, disease and hygiene, and numerous other fields which involve life and living things. So you see, the field of biology is extremely broad.

Why do we study biology? Long before man began his study of mathematics, astronomy, physics or chemistry, he began to study living things. There are several reasons for this interest in plants and animals.

As living organisms ourselves, we must live in close relationship with other living things. We depend directly upon plants and animals for food, clothing, shelter and countless other necessities of life. We have found it good business to study these living things upon which we are so dependent. Much of our biological study has been directed toward improvement of the plants and animals which supply these necessities of life. Through scientific breeding, we have developed more productive cattle, hogs, sheep, corn, wheat, and other plants and animals capable of supplying our needs.

Another reason for the development of biology is man's curiosity about life. It is natural that we, as living beings should wonder about ourselves and about all other living things. Life has always been somewhat of a mystery to us. We enjoy studying the make-up and activity of the numerous plants and animals around us. We are intrigued by nature and the delicate balance which she maintains in her realm of life.

Biology has served another great de-

FOOD TESTING LABORATORY. Good health is maintained because foods are constantly being tested in modern laboratories.

sire of man. We naturally look forward to a long and healthy life. Disease looms as a constant threat to this desire. Through biology, we have discovered the causes of most diseases, ways of aiding the body in its fight against disease, and methods of preventing disease. Extensive study of our own bodies has provided further means of maintaining health through medicine and hygiene.

How did biology develop as a science? In one sense, biology is the oldest branch of science. The study of living things is older than civilization. But biology, as an organized science, is much more recent. Man has not always applied science to his problems of living.

While biology began with the Greeks, its development from that time to the present has been neither gradual nor steady. Most of our knowledge of living things has been acquired since the seventeenth century. During the past three hundred years, biology has developed rapidly, and the past twenty-five years have seen almost unbelievable progress.

The history of biology is similar to the history of the other sciences. It concerns not only the development of the science itself, but the gradual acceptance by men of a method of thinking and reasoning based upon observed facts and an attitude of open-mindedness and desire for truth which constitute the method of science. The history of biology is really, then, a story of the development of man's ability to use reasoning in the solution of his problems.

The eras of biology. The history of biology covers four principal eras. These eras are not just periods of time necessary to build our knowledge of science. Rather, they are steps in the development of the methods and attitudes of science.

1. Primitive man and the era of magic and superstition.

2. Greek medicine and the dawn of biology.

NAVAJO INDIAN TRIBE. The witch doctor drives away evil spirits and thus cures the patient of his disease.

3. The dark ages of science.
4. The rebirth of science.

Primitive man and the era of magic and superstition. Primitive man lived at the mercy of nature. To obtain food, clothing, and shelter and to defend himself from the countless dangers around him was a tremendous struggle. He was constantly confronted with problems which he could not understand. Famine, disease, floods, droughts, and storms were continual threats to his existence.

Primitive man had not learned to reason. Lacking the intelligence to study his problems, he turned to his imagination. What he could not understand, he imagined to be controlled by supernatural forces. He feared these controlling spirits greatly and developed practices of magic and witchcraft as a means of winning their favor.

Nothing frightened primitive man more than disease. The cause of disease was beyond his comprehension. Sickness was attributed to demons or evil spirits which entered the body of the victim, causing a curse to fall upon him. Cure for sickness was carried on by the witch doctor or medicine man of the tribe. This strange person was thought to possess supernatural power capable of driving the spirits of sickness away. In keeping with his mysterious ability, the witch doctor painted his body and wore a strange costume of feathers and fur. His looks were made more impressive with a headdress made to resemble demons or wild animals. Waving rattles and magic charms, this creature danced wildly around the patient until the possessing demons of sickness were frightened out. Fortunately, the witch doctor kept no vital statistics and the natural recovery of a few victims of disease kept him in good standing in the tribe.

In similar manner, primitive man appealed to supernatural forces for aid in solving other problems of his existence. For success in finding food, protection from beasts and preservation of his home and family, he appealed to spirits through strange practices of magic.

Wherever you find primitive people, you find magic and superstition. Even today explorers and missionaries who have been able to reach the deepest parts of Africa and the unexplored regions far up the Amazon river in South America, find strange and primitive tribes performing rituals of magic as an effort to win favor with imaginary demons and spirits. This condition seems somewhat strange to us who live in the realm of civilization.

GREEK MEDICINE. The practice of medicine was based on an appeal to gods and spirits.

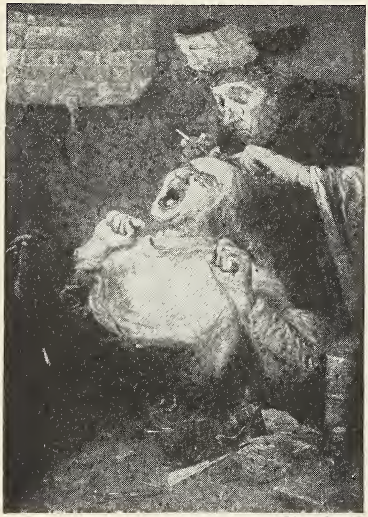
Greek medicine and the dawn of biology. The belief that disease and other human catastrophes were due to supernatural forces continued through long periods of history. Among the early Greeks, certain cults of priests devoted their lives to the service of a god of healing. The entire practice of medicine was based upon appeal to gods and spirits.

Among the early Greek physicians, the name of Hippocrates [*Hip pock' crat eeze*] will always be remembered as the one who first separated medicine from the god of healing. Hippocrates, who lived from 460–359 B.C., was the most famous physician of his day. His wisdom in first applying scientific reasoning to the treatment of disease marks him as the *father of medicine.*

Little is known about Hippocrates except through his writings, which were brought to Europe during the fifteenth century. His ideas about the structure of the human body are, today, rather amusing. Among other things, he thought the brain was a radiator to cool the blood and that food was cooked in the digestive system. Regardless of these mistaken ideas about the body, Hippocrates applied sound judgment and scientific reasoning to his practice of medicine. He emphasized the importance of proper diet, rest, and fresh air as a means of aiding the body in its fight against disease. He kept accurate records of his patients, the nature and symptoms of their ailments, the sort of treatment he used for each case and the results of treatment, whether successful or unsuccessful. The name of Hippocrates became famous throughout Greece and the neighboring countries. His work established a new era in the practice of medicine. His influence remains today in the Hippocratic oath taken by young doctors at the time they receive their M.D. degree — an oath to uphold the high ethical standards of the medical profession.

Following Hippocrates, another famous Greek thinker, Aristotle (384–322 B.C.) began the scientific study of plants and animals which marks him as the *father of biology.*

Having studied under the great philosopher, Plato, in the Academy of Athens, Aristotle began his career of scientific study about 347 B.C. He studied many plants and animals carefully and made observations which were based upon discovered facts rather than upon the superstitions of his day. Probably his greatest contribution to biology was in



Monkmeyer Press Photo Service

MEDIEVAL MEDICINE. A clumsy barber performing surgery on a patient.

grouping and classifying animals. He studied and described over 500 species of animals and grouped them into classes based upon structure. While this number seems small in comparison with the many thousands of animals known today, it was a remarkable achievement in those days.

In addition to his work in classifying animals, Aristotle learned much about anatomy or body structure. He dissected more than fifty different animals and studied similarities and differences in their internal make-up.

The views of Aristotle were far ahead of his age. It is little wonder that his influence has remained alive two thousand years after his death.

The dark ages of science. If the influence of Hippocrates and Aristotle had continued to serve as the basis for scientific work, the history of science would have been quite different. However, much of the influence of these Greek thinkers was dimmed by Claudius Galen [*Gale'len*], who lived from A.D. 131–201. Galen was the most famous of the Greek physicians of his day. Much of his medical practice was carried on in Rome and among the Roman armies.

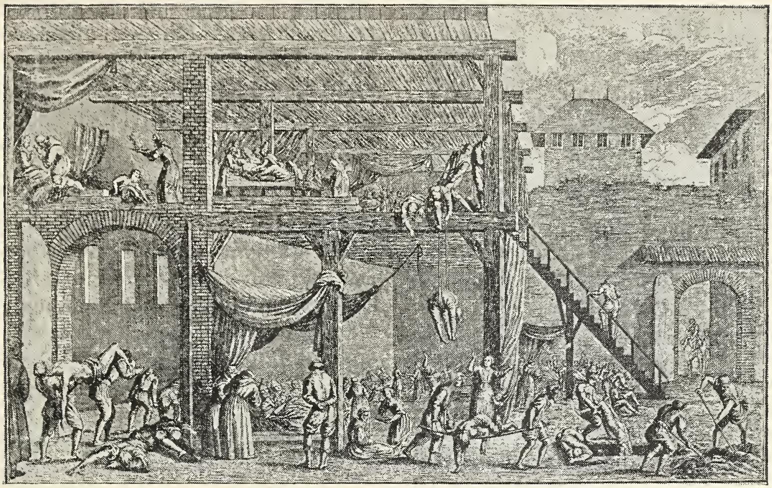
While Galen was considered the absolute authority on medical matters, many of his views were incorrect. He was greatly influenced by Hippocrates and Aristotle, but did not hesitate to modify their teaching to suit his views.

Galen's work included dissections of many animals. His knowledge of human anatomy was gained largely through the treatment of Roman soldiers wounded in battle. With his limited knowledge of the human body and his observations from animal dissection, he spoke with authority on all medical matters. Where he lacked proof from firsthand observation, he substituted his own ideas and no one doubted them.

Galen published his beliefs and the ideas of Hippocrates and Aristotle, often incorrectly interpreted, in writings which served as the basis for medical practice until the sixteenth century. For nearly 1,500 years, the word of Galen was considered the final "authority of science."

The period which followed the death of Galen and lasted through the Middle Ages is famous in history. Smallpox swept through Europe, taking a tremendous toll of life. Carts, piled high with the bodies of victims, were wheeled through the streets to the edges of cities where the bodies were burned. Thousands, fortunate enough to recover, were disfigured for life. The sight of a face unmarked by smallpox was a rarity.

During these dark ages of science, physicians prepared "cures" consisting of leaves and herbs, animal livers, human skull preparations, and other nau-



Monkmeyer Press Photo Service

PESTILENCE HOSPITAL IN VIENNA. Plagues and epidemics of the Middle Ages were treated in such places as this.

seating concoctions described by Galen. Patients were bled in doctors' offices in an effort to remove "poisoned blood" from their systems. Indeed, medical practices were so crude and unscientific that civilization would have benefited had there been no physicians.

The rebirth of science. It was Vesalius [*Vess sale'ee us*], a young physician born in Brussels in 1514, who first dared to overthrow the "authority of science." Coming from a family of physicians, Vesalius possessed an inherited tendency toward scientific pursuits. He was keenly interested in anatomy. He dissected many animals, including dogs and rabbits and learned much about their plan of structure.

It is little wonder that Vesalius rebelled against the mere discussion of anatomy by his professors in medical school. The quotations of Galen and the other ancients on matters of anatomy did not satisfy Vesalius. He wanted to find out for himself — to experiment!

Following his graduation from medical school in Brussels in 1537, Vesalius became a teacher of anatomy. Prior to his time, crude demonstration dissections were made before the classes by clumsy barbers while the professors quoted Galen on the subject of anatomy. This procedure soon disgusted Vesalius, who dismissed the barbers and carried on his own dissections before his classes. In the course of his demonstrations, he discovered that the dissections frequently did not agree with the word of Galen. In the true spirit of science, Vesalius discarded the teachings of Galen in favor of proved and observed facts before his eyes.

Much of Vesalius' work was published in 1543 in a book entitled "Fabrica." This book included illustrations of the skeleton and muscles of man and various other organs accurately drawn from his dissections.

One might suppose that the work of Vesalius was praised by the men of his

Monkmeyer Press Photo Service

ANDREAS VESALIUS

day. But such was not the case. Even the medical men who benefited most from his careful study of anatomy turned from him. Vesalius had dared dispute the word of Galen and was bitterly condemned by all. Nevertheless, Vesalius introduced a new era — a return to scientific observation and experimentation as a means of problem solving. In his footsteps were to follow other great scientists who further provided the basis for modern biology.

The rise of modern biology. After Vesalius and the overthrow of the "authority of science," biology continued to develop on a scientific basis. The famous English physician, William Harvey (1578–1657), conducted a series of experiments to demonstrate the circulation and direction of flow of blood. As Vesalius had provided the methods for the study of anatomy, Harvey opened the field of experimental physiology, or the function and operation of living parts.

The work of Sir Joseph Lister, Louis Pasteur [*Pass tur'*], Edward Jenner, Gregor Mendel, and other famous biologists led to the development of biology as we know it today. In your study of biology, you will become acquainted with many of these famous men as you learn about the contributions which they made.

The scientific method. When men began to apply reason to problem solving, science was born. The names of Aristotle, Hippocrates, Vesalius, and Harvey will always live in biology, not so much for the knowledge they contributed as for their attitudes and manner of thinking. The rise of science brought with it a revolution in thinking, based upon reason rather than superstition, and facts rather than ideas.

Today science is universal. Scientific attitudes and methods are not limited to the scientist. They are part of the thinking of everyone who understands and accepts the spirit of science.

A scientific *attitude* leads to the practice of scientific *method*. If we analyze the scientist we find that his thinking conforms to a definite pattern. The following characteristics constitute the attitude and method of science:

Scientific Attitudes

1. *Open-mindedness.* The scientist must keep his mind free from prejudice. He must be willing to accept a new idea and not be blinded by preconceived notions about things.

2. *Tolerance.* The scientist must respect the opinions of others, even though they may not agree with his own.

3. *Cautious judgment.* A scientist must not jump to conclusions. In making a decision, he must consider all the facts and information carefully and

make sure they are reliable before forming an opinion.

4. *Desire to learn.* Every scientist is driven by a tremendous desire to learn. He wants to know the why of things. Through study and experimentation, he constantly increases his knowledge.

Scientific Methods

1. *Recognition of a problem.* The study of science reveals numerous problems yet to be solved. Solution of one problem introduces another. The scientist, through his study and investigation, is constantly discovering new problems which require a solution in the interest of expanding knowledge.

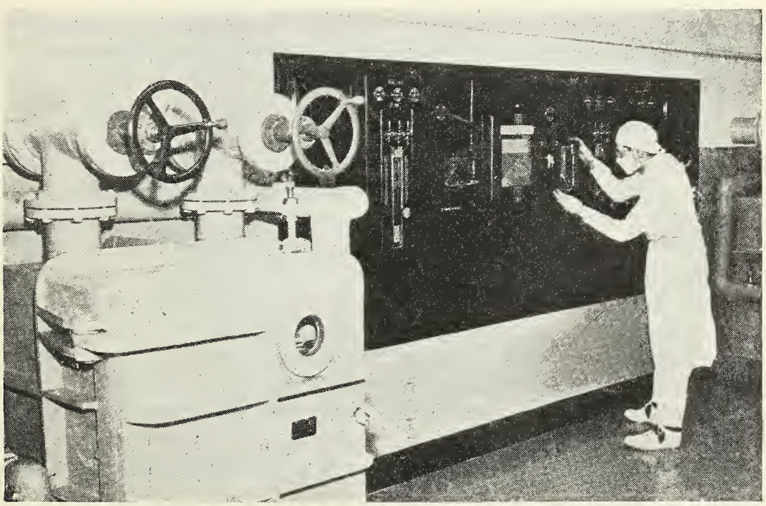
2. *Clear understanding of a problem.* In selection of a problem, the scientist is certain that he understands exactly what he is attempting to prove. The *aim* of the problem must be clearly defined.

3. *Application of scientific knowledge to problem solving.* Proved facts lead to the discovery of more facts. In this manner, science grows. The scientist makes use of scientific facts which he believes to be correct. By applying knowledge to new situations, the known can be used to help solve the unknown.

4. *Experimentation.* The solution to many scientific problems lies beyond the attained knowledge of science. Here, the scientist turns to experimentation. He carefully decides what is to be proved and devises experimental methods of proving it. The aim of the experiment must be definite.

5. *Observation.* Accurate observation of the results of an experiment is as important as the experiment itself. The scientist must observe his experiment carefully to learn exactly what results.

6. *Drawing conclusions.* After an experiment has been conducted and observed carefully, the scientist must be able to draw proper conclusions. These



PROCESSING PENICILLIN. A micromax temperature and vacuum recorder used with a low-temperature high-vacuum drier in processing the drug.

conclusions must be based *only* upon proved facts. He must guard against false conclusions, based upon ideas or opinions instead of the facts demonstrated by the experiment.

7. *Checking the correctness of conclusions.* Conclusions drawn from experimentation must be checked several times before they are accepted as truth. Experiments must be repeated to see if results are always the same. Scientific knowledge before it is accepted must be thoroughly tested.

8. *Application of proved facts to new situations.* Frequently, facts discovered by experimentation become much more important when applied to situations other than those which the original experimenter had in mind. Here, a scientist must have vision. He must be able to apply his knowledge. Often, simple discoveries grow into revolutionary scientific advances when facts are applied to new situations.

For example, Dr. Alexander Fleming, a British bacteriologist, discovered in 1929 that a mold called *Penicillium notatum* retarded or stopped entirely the growth of bacteria in culture dishes. Dr. Fleming established the fact that this fungus was active against certain bacteria, but it remained for other investigators, both British and American, to develop present uses of the wonder drug, penicillin, so important in medicine today.

Biology and You

Who are scientists? The preceding section has presented several outstanding pioneers of science upon whose contributions the foundation of biology is laid. These, and many other contributors, have given much more than knowledge to science. They established a pattern of reasoning based upon proved facts which we term the scientific method. We may term a *scientist,* then, anyone who accepts the attitudes and methods of science and practices them in his thinking.

Producer scientists. In our laboratories, biological companies, hospitals, research foundations, universities, and other scientific centers we find men and women engaged in scientific work. They are the professional scientists. They have devoted their lives to scientific study. We may also refer to them as *producer scientists,* since they have selected science as a career or profession. We look to these producer scientists for our future scientific achievement. We look to them to safeguard our health and happiness and to provide the means for better living through advance in scientific knowledge.

Consumer scientists. But science is not confined to the laboratory. Nor does one need to be engaged in scientific work to be called a scientist. The nonprofessional, nonproducer scientist we term a *consumer scientist.* In this great scientific age, we may all be consumer scientists. We may live scientifically, learn scientifically, and think scientifically.

You and your course in biology. In a single year, the biological progress of centuries will be reviewed in your biology course. One lesson may represent a lifetime contribution of some great scientist. Biology is such a broad field of study that no one individual could learn all that is known about it in a lifetime. Yet, in a single year, you will get a glimpse into most of the major fields of study which biology includes.

Much of your knowledge of biology will be gained from reading. This information will constitute a background for laboratory and field study. As you carry on experiments or watch demonstrations, you will have an opportunity to apply the scientific method of problem solving. You probably will find nothing new to biology in the course of your experimenting, but the things you learn will be new to you. You should experience the same thrill in finding out things that the professional scientist feels when he discovers something new to science.

Completion of your biology course should accomplish certain definite objectives. Through the study and application of biological facts which you will learn, your thinking and attitude toward life and living things should be changed. With this change you should become a *consumer biologist.*

Goals and objectives of the biology course. The following are some specific objectives of the biology course. These should be your principal reasons for studying biology.

1. *To become familiar with living things.* Few subjects add so much to the general culture of an individual by giving him more objects of interest and more information than biology. Living things are all about us. To one with an understanding of biology, a woods or field or swamp, far from being desolate and lonely, provides opportunity to observe the many wonders of nature.

2. *To develop, through the study of organisms, an understanding of the basic principles of life.* As you study biology, you will learn that all living things, whether plant, animal or human, operate according to the same principles of life. These principles are fundamental. Without a knowledge of them, you cannot understand the fascinating life activities of organisms.

3. *To develop, through understanding, an attitude of respect for living things.* No organism has exceeded man in ruthlessness and wanton destruction of living things. Much of the natural heritage of America has been needlessly destroyed. Birds, game animals, fish, forests, marshlands, and even the soil itself are threatened by the inroads of civilization. But civilization need not destroy our wildlife. We must learn to live with nature. As you become better acquainted with plants and animals through the study of biology, you should develop an appreciation of living things.

4. *To develop in every individual a co-operative attitude toward our conservation programs.* National, state and local conservation organizations are working to protect and to restore our valuable plant and animal resources. These organizations need your help. The study of conservation in biology will acquaint you with many of our problems and will show you ways of co-operating with and participating in our conservation programs.

5. *To acquire, through practice, the scientific method of observing and reasoning.* Few people really *see* very much in the things about them — they lack the ability to observe properly. Accurate observation is a rare but valuable trait, and the study of biology will greatly increase the powers of observation, as well as emphasize the most interesting things to look for.

Mere observation of facts is not enough, however, for one should be able to draw correct conclusions from what he sees. The ability to think and reason is one of the chief aims of the laboratory work in biology or any other science.

6. *To improve our general standards of health through a better understanding of ourselves and the problems of disease.* In a more personal way, biology deals with the health and care of our

bodies — *hygiene.* It includes the study of our bodies as well as the cause and prevention of disease, the work of bacteria, and means of maintaining healthful surroundings. At least half of the human deaths caused by germ diseases could be prevented by proper knowledge of hygiene and sanitation. This in itself would be sufficient to enlist our interest in biology.

7. *To provide opportunity for recreation in the out-of-doors and to introduce worth-while leisure time pursuits of a biological nature.* Biological knowledge will enhance the enjoyment of every hike, trip, or sojourn in the country and thus be of value in enjoying leisure time throughout life. Nothing relieves the pressure upon a tired mind as much as a trip into nature. An early morning bird hike, a fishing trip, a camping trip, or a drive through the country — these are the things for which most of us long. Nature offers the best relief to one worn out with the complexities of everyday life. Miles of paved highways lead to forests, lakes, state and national parks and other opportunities for outdoor recreation. In nature you will find the plants and animals you learn about in biology.

8. *To improve our knowledge of biological occupations.* The average person deals with the principles of biology in his everyday life much more than he realizes. Flower growing; vegetable gardening; care of the lawn; tree growing; breeding and raising of dogs, cats, and other domestic animals, all represent common biological hobbies and occupations. The student of biology should be able to grow better flowers or raise better vegetables because of his knowledge of the biological principles involved.

9. *To acquaint us with some of the outstanding contributors to biological knowledge.* Every phase of modern living has benefited in some way by the contributions of great biologists. We who enjoy these benefits should become better acquainted with the men and women whose tireless efforts led to such discoveries.

10. *To present biological science as an opportunity for lifetime study and activity.* Some of you will become the scientists of tomorrow. We look to you for a cure for cancer, better methods of combating tuberculosis, better strains of corn and wheat, and new methods of destroying insect pests. Some of you may find the answers to these and numerous other unsolved problems as the producer scientists of tomorrow. To most of you who will not become professional scientists, biology offers opportunity for lifetime study of interesting plants and animals around us as consumer biologists.

The scope of biology. Although biology is a single science based on the study of all living things, it is so broad in scope that it includes many special branches. These branches are really sciences dealing with specialized phases of study. The biologist, after gaining a knowledge of biology in general, usually becomes a specialist in one or more of these branches.

Just as living things are separated into groups, so biology may be divided into areas of study.

1. *General biology* includes the study of living things in general, the principles of life and the relationship of organisms to their environment and to each other.

2. *Plant biology,* or botany, is the specialized study of plant life and the relation of plants to other living things.

3. *Animal biology,* or zoology, centers around the study of animals and their relation to other living things.

4. *Human biology,* or physiology, is a part of animal biology. However, the biological knowledge concerning man is so extensive that it really constitutes a special area of biology.

These general areas are, in turn, divided into further fields of specialized study. There are numerous sciences dealing with different phases of the study of plants and animals.

Your study of living things will take you into these and other special fields of biology. You will learn what each of these sciences has contributed to the study of life.

Summary

Biology is the branch of science which deals with life and living things. The development of biology from the Greeks to the present day has been neither gradual nor steady. Biological progress was halted during the Middle Ages because of the replacement of scientific study with a so-called " authority of science " based upon the views of Galen. With the work of Vesalius, however, biology was reborn and in the past 300 years has grown to be an extremely broad field of organized science.

With the advance of biology and other sciences, a new type of thinking, based upon observation of facts and truth rather than superstition arose. This scientific method characterizes all scientific work. One who accepts this method of thinking and reasoning is a scientist.

The pupil, in his study of biology, has an opportunity to develop this method of science and to enrich his life through the study of living things.

Using Your Knowledge

1. In what respect is biology different from the other sciences?
2. Why do you think primitive man turned to the supernatural world to account for disease?
3. In what way did Hippocrates first introduce science into the practice of medicine?
4. What evidence do we have of the influence of Hippocrates in the training of doctors today?
5. Why is Aristotle called the father of biology?
6. Explain the " authority of science."
7. Account for the fact that the " authority of science " retarded scientific progress throughout the Middle Ages.
8. List some of the ways in which the work of Vesalius resulted in the re-birth of science.
9. Name four attitudes characteristic of a scientist.
10. List the steps used by a scientist in solving a problem.
11. Distinguish between producer and consumer scientists.

Expressing Your Knowledge

magic	open-mindedness	objective
superstition	tolerance	attitude
witch doctor	experimentation	method
Hippocrates	observation	general biology
Aristotle	application	botany
Galen	producer scientist	zoology
Vesalius	consumer scientist	human biology

Applying Your Knowledge

1. Make a list of some superstitions in common practice today. See if you can find out how some of them originated.

2. List the steps a doctor uses as he applies the scientific method to the diagnosis of illness.

3. See what information you can obtain about a tribe of primitive people in a remote region of the earth which still practices magic and superstition in the treatment of disease.

4. Enumerate some of the procedures you would use in preventing and treating disease in a scientific manner.

5. Using the steps of the scientific method, devise an experiment to prove that plants must have light for normal growth. (Use potted plants in the experiment.)

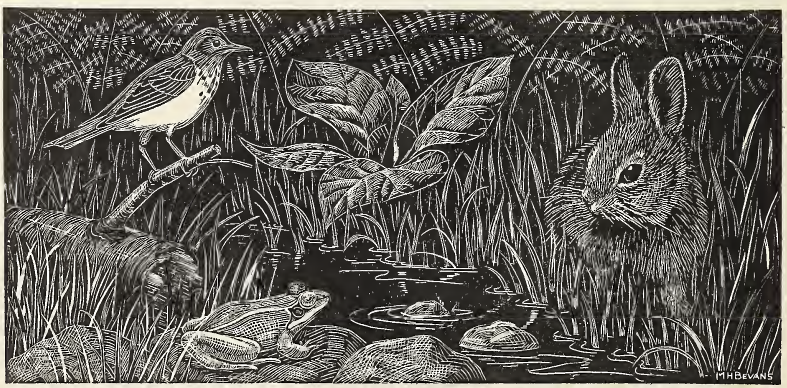
Chapter 2

What It Means to Be Alive

Biology is the study of all living things, and living things include plants, animals, and human beings. These forms of life may appear to be quite different from each other. Actually, they are all very much alike. Human beings cannot be separated from animals, biologically, and even plants and animals are similar in many more ways than they are different. All living things behave in much the same way. They carry on the same life functions and are faced with the same fundamental problems in order to remain alive.

Living and nonliving things. What do trees, shrubs, frogs, birds, and insects have in common that rocks, water, and minerals do not have? The simple answer is *life*. All of the things found on the earth may be divided into two great groups or categories — living and nonliving. Individual plants and animals are referred to as *organisms*.

Living things differ fundamentally



LIVING AND NONLIVING THINGS

An Animal and a Plant. They look quite different, but biologically they are much alike.

from nonliving things. The marvelous condition which we call life gives to the plant and animal definite characteristics which we recognize in distinguishing the living from the nonliving. While we cannot determine exactly what life is, biology can tell us what life does.

Living things are fundamentally alike. The properties of life which distinguish the living from the nonliving also make all living things similar. Life seems to be a condition of matter which forms plants and animals. It is universal. Things are either alive or they are not. Life is expressed in countless forms of living things — from the lowliest bacteria to the complex human being.

Look at the picture of the cat and the geranium plant. They are so different in appearance that no one could mistake the plant for the animal. You can name many ways in which they seem to be different. The cat can run and jump, make sounds, see and hear, and do many other things which the geranium plant cannot do. Yet, is the cat any more alive than the geranium? Your difficulty in making a comparison is that you know much more about the cat than about the geranium. As you learn more about both plants and animals, you will come to see that the fundamental make-up and processes of all living things are the same. The cat and the geranium plant are similar in many more ways than they are different.

Characteristics of living things. Let us now consider some of the characteristics of all living things which make them similar and distinguish them from nonliving things. These characteristics of plants and animals are some of the remarkable properties of life.

1. *Living things have a definite form and size.* If you were asked to describe a tree, a cat, a geranium plant, or a horse, you could probably give a reasonably accurate description of any one. This is because all living things have a definite form and size. Furthermore, your description of a cat would, with some variations, fit all cats. The geranium plant is like all other geranium plants. Shape and size distinguish a walnut tree from an elm tree, and a crow from a sparrow.

Monkmeyer Press Photo Service

Litter of Puppies. They will grow up to be dogs, with all the fundamental qualities and characteristics of dogs.

While two plants or animals of the same kind are never identical in appearance, they are of the same form as all others of their kind. A tiny salmon will become an adult salmon. It will grow to be like all other salmon and will develop certain coloring, shape, and size. It cannot become a bass, a herring, or a mackerel.

Nonliving things, on the other hand, may exist in a variety of forms and sizes. How large is a stone? What shape is a piece of glass? While some nonliving things, such as crystals, do assume definite shapes, the size of crystals may vary. Nonliving things lack the predetermined form and size which characterize all plants and animals.

2. *Living things have a definite life span.* The life span of a plant or animal is its period of existence — the time between its beginning and its death. Like its form and size, the length of life of a living thing is limited. No form of life can exist indefinitely. Beginning of life, growth, maturity, and death are steps in the life of every plant and animal. Even though all living things repair and maintain themselves for considerable periods of time, the matter of which they are composed seems to break down in time, and to lose its characteristic of remaining alive.

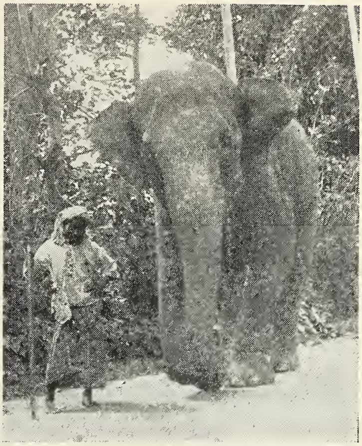
The life span of any particular plant or animal, barring disease or accidental death, is like all others of its kind. The average length of life of man is today about 60 years. Some individuals live to be much older, while some die younger, but the average person can expect to reach that age. The life spans of plants and animals vary from a few weeks in the case of certain insects to several thousand years, as illustrated in the Big Trees of California.

The period of existence of nonliving things is not predetermined. Much of the nonliving matter of the earth has existed in its present form for great periods of time. Some of it is changing constantly. Existence of these nonliving things is determined by outside forces. They do not have a definite period of existence as do living things.

3. *Life is a state of constant activity.* Living things cannot just exist. Life depends upon a continuous activity of living matter. When activity ceases, life also ceases.

Life activity does not refer just to visible signs of life, such as moving around. A tree may show no outward appearance of being alive, yet its living parts are in a constant state of activity.

Life depends upon a constant supply of energy. Energy, and the forms of energy, will be discussed in another chapter. At this point we need say only that energy gives us the power to move, to think, to grow, and to perform the other activities of life. The energy which gives life to living things is called *vital energy.*



Philip D. Gendreau, N.Y.

An Elephant. This is an animal with a very long life span.

Activities of plants and animals are called *life functions* or *processes.* These processes are universal in that they are carried on by all living things. Thus, they make all organisms fundamentally alike and different from nonliving things.

Life Processes

All plants and animals carry on, at least to some degree, the following ten *life processes* or *life functions.*

1. Food getting or production
2. Digestion
3. Absorption
4. Assimilation
5. Respiration
6. Excretion
7. Secretion
8. Motion
9. Sensitivity
10. Reproduction

Food getting or production. We stated that life depends upon a constant supply of vital energy. This energy is taken from food. Food is necessary to the plant and animal in supplying the materials for growth and maintenance of their bodies. It is evident that food is essential to all living things.

Food is supplied to living things in two ways. Being animals ourselves, we are familiar with the process of eating. A more scientific term is *ingestion* [*in-jes' chun*], which is the process of taking in food which already exists. Ingestion is common to all animals and to some plants. Bread mold, mushrooms, and bacteria are forms of plant life which grow directly upon a food supply which they absorb into their bodies.

A second way occurs *only* in green plants. They contain certain substances, about which we shall learn in a later chapter, which enable them to manufacture their own food from raw materials absorbed by them from the soil and the air. They do not ingest food which is already in existence. They make their own food. Animals and nongreen plants are totally unable to do this, but depend upon green plants for their own food supply.

Digestion. After they ingest or manufacture food, both plants and animals must change its character so that their bodies may make use of it. Our food is carried in blood to all parts of the body. The food which is sent to our brains or hearts or muscles is quite different from that which we ate as a meal. We apply the term *digestion* to the process of altering food to make it suitable for use by the body.

Absorption. Digested food passes through the plant or animal by a process called *absorption*. In animals, food passes through the walls of the digestive tract into the blood and into all parts of the body. In plants, also, digested food reaches the roots and stem from the leaves in fluids and by the process of absorption.

Assimilation. Much of the digested food which is carried by our bodies is used for growth and maintenance. By a process called *assimilation,* digested food can be converted into living matter. This new living matter may be used for *growth* or to replace injured or worn out matter to *maintain* our bodies. By means of assimilation, the materials contained in milk may become cat; and substances composing meat, potatoes, and lettuce may become human matter.

Respiration. In addition to the supply of materials necessary for growth and maintenance, digested food supplies the energy necessary to maintain life. Food so used is called fuel food. Energy is released from food by a chemical process called *oxidation*. During oxidation, oxygen is combined with the food, thus breaking it down and setting energy free. As a result of oxidation, waste materials, including carbon dioxide are left in the body. Organisms must receive a constant supply of oxygen to carry on oxidation and, at the same time, must continually eliminate carbon dioxide resulting from oxidation. The exchange of these gases by living matter is termed *respiration*.

All living matter carries on respiration. Frequently, living things have special methods of exchanging these gases between the body and the atmosphere. We have lungs with which to *breathe in* air containing oxygen and *breathe out* air containing waste carbon dioxide. Fish and other animals have gills for carrying on respiration in water. Plants, too, exchange gases through openings in the leaves but do not breathe in the sense that we do.

Excretion. As plants and animals carry on their body processes, certain waste products form which must be eliminated. The process of waste removal is called *excretion*. Many animals excrete wastes by means of lungs, skin, intestines, and kidneys. Plants eliminate wastes chiefly through the leaves.

Secretion. Plants and animals require many special substances to carry on their activities. These substances cannot be taken in like food and must, therefore, be produced within the organism. The substances are called *secretions* and the process by which they are produced is called *secretion*. Many animals possess special glands for supplying these secretions. For example, fluids which carry on digestion are secreted in the mouth, stomach and other parts of the digestive

Monkmeyer Press Photo Service

Horses on a Wyoming Ranch. Their locomotion is both rapid and graceful.

tract. Secretions for other purposes are secreted by glands in other parts of the body, such as the thyroid gland in the neck.

All living things secrete essential substances, although plants, compared with animals, have very little secretion.

Motion. Perhaps the most obvious of the life processes is motion. In comparing living and nonliving things, we are inclined to think of the ability to move as a characteristic of life.

We must be sure that we understand the different types of movement. Many lifeless things move. Water flows in rivers, glaciers move through valleys or over continents, and automobiles travel over highways. Yet we cannot say that these lifeless things possess ability to move. Rather, they are moved by outside forces.

Living things, on the other hand, possess the power of motion; movement is accomplished from within. This independent motion is called *spontaneous movement* and is characteristic of all plants and animals.

Animals possess the greatest ability to move. The muscles of animals accomplish such rapid forms of movement as walking, running, swimming, or flying. This ability to move from place to place is usually called *locomotion.*

Movement in most plants is not so obvious. Yet they move much more than we realize. A plant bends its leaves and branches toward light and its roots toward moisture in the soil. Plants grown in windows bend toward the light and must be turned regularly to prevent them from growing crooked. Time lapse photography, in which pictures are taken at intervals over a period of time and then shown as motion pictures, reveals movements in plants that are almost startling.

Another type of motion in animals results in *circulation.* The movement of heart muscles pumps a flow of blood to all parts of the body. Likewise, the digestive organs and other parts of the body carry on various forms of movement.

Sensitivity. One of the most remarkable properties of living matter is its ability to react to its surroundings. This response of a plant or animal to environment we call *sensitivity* or *irritability.*

Both plants and animals, in a general way, respond to touch, heat, light and other forces outside themselves. Plants react to light and water. Stems naturally grow upward and roots downward. Vines twine around an object or send out tendrils which clasp firmly.

The highest expression of specialized senses is to be found in animals. Consider to what a great degree our own senses are developed. We are capable of hearing, seeing, smelling, tasting, feeling, and sensing heat and cold. These abilities are merely properties of living matter.

Reproduction. For the continuance of plants and animals, there must be another life process, that of *reproduction.* Since no organism can live indefinitely, life must be continually passed on to new individuals.

Reproductive processes are associated with life and serve further to distinguish the living from the nonliving. Some nonliving things increase in number, but they do not reproduce. A large stone may be broken into several smaller ones by freezing and thawing through the winter. Yet this increase in the number of stones was accomplished only by destroying the original one. Each new stone is smaller and can never become like the original one of which it was once a part. A small plant or animal, on

Comparison of Live and Dead Engines

	A living organism	A steam engine
Requires	Food	Fuel
To unite with	Oxygen	Oxygen
By means of	Breathing	Draft
To produce	Heat and " vital " energy	Heat and mechanical energy
Leaving	Unused food	Ashes
Waste	Carbon dioxide (in breath), water, etc.	Carbon dioxide (in chimney gas), water, etc.

DIFFERENCES

A living organism	A steam engine
Is alive	Is not alive
Grows in size	Does not grow
Repairs wear	Wears out
Reproduces	Cannot reproduce

the other hand, will grow up to be just like its parent and is, therefore, a result of living reproduction.

Live and dead engines. A living organism is often compared with a steam engine. Both need a supply of food (fuel) and operate on the energy set free by oxidation (burning). Both require oxygen in the process of oxidation and produce waste products which must be carried off. In both, heat is produced and changed into motion.

But an engine is not a living thing. It cannot get its own food, it does not assimilate or grow, and it cannot reproduce. The only ways in which it resembles a living thing is that it depends on the energy which is released when fuel is oxidized and turns this energy into motion.

Conditions Necessary for Survival

All organisms, though they may not be aware of it, are constantly facing difficult conditions. Existence is no problem for nonliving things, but life can exist only if certain critical conditions are met. All plants and animals are faced with the following conditions of living:

1. Satisfying the organic needs.
2. Finding a suitable environment.
3. Surviving in the struggle for existence.
4. Reproducing their kind.

Satisfying the organic needs. Organic needs of organisms are those things upon which life itself depends. *Food* must be found, though some animals seem to endure long periods without it. Plants which produce food must obtain the materials necessary for food manufacture from the soil and air. *Water* is essential to all living things. Both plants and animals succumb quickly if deprived of water. Most organisms, especially plants, require considerable *light.* If deprived of *air,* both plants and animals soon die.

The needs of living things, though fundamentally the same, vary with each different kind of plant or animal. Some organisms find food where others perish. In like manner, the amount of air and water required by a plant or animal may vary considerably. These variations in organic needs have resulted in the distribution of living things to all parts of the earth in search for particular requirements.

Finding a suitable environment. Living things find their organic needs in their environment, or surroundings. The environment must supply, also, a suitable place to live. Factors of environment include temperature, rainfall, humidity or water vapor in the air, winds and air currents, topography of the land, and many others. Environmental conditions differ in various localities. Desert plants and animals cannot survive in a moist woods nor can prairie life survive in swamps. Sudden changes in the environment such as a great storm, sudden cold, drought, loss of homes or nesting places through fire or other kinds of destruction of plants or trees, bring vital problems to hundreds and thousands of individuals.

Surviving in the struggle for existence. Even after satisfying its organic needs and finding a suitable environment, an organism still has a third great condition to meet. It must compete with other living things in the struggle for existence. Plants and animals must live in competition with each other. Sometimes the struggle is a competition for the needs of life; other times it is a fight against enemies. A small tree growing from the forest floor must race with nu-

Devastated Forest Land. This area once was covered with a magnificent stand of Douglas fir. But a sudden change in environment due to fire, has made the region practically a wasteland.

merous other trees to find a place to grow. If the tree can overpower its competitor, it can mature; otherwise it must give way to a stronger individual. Often species of plants and animals perish, being unable to meet new hardships. Sometimes they migrate to places with better living conditions, or remain at home and become adapted to the difficulties. Such is the struggle for existence.

The relation of living things to their surroundings is so important that two later chapters will be devoted to it. The manner in which specific plants and animals meet their environmental conditions will be discussed throughout our study of organisms.

Reproducing their kind. Finally, a plant or animal must be able to *reproduce* successfully if its kind is to continue on the earth. Methods of reproduction are strange and interesting. Fruits may have tempting pulp or hairs to disperse the seeds. Animals frequently migrate long distances to find conditions suitable for the production and rearing of young. The plant or animal must be able to reproduce at a rate at least equal to the mortality rate of its kind. Plants usually produce large quantities of seed that compensate for the many young plants which fail to grow or are destroyed. Likewise, animals such as insects produce large numbers of young, many of which are destroyed. In cases where fewer young are produced, their chances of living are greatly increased by parental care.

The degree to which plants and animals meet these conditions, then, means success or failure. The organism which fails to meet its organic needs or to find a suitable environment soon perishes. If problems of survival are not met, the organism is destroyed by other forms of life. If reproduction is not accomplished, the race becomes extinct.

Unsuccessful organisms. The study of biology reveals that numerous organ-

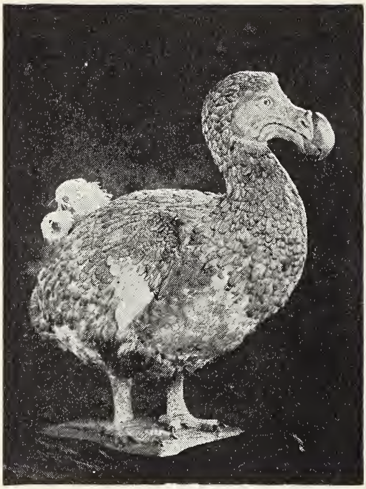
Giant Reptiles. These dinosaurs are now extinct because they were unsuccessful organisms.

isms which once flourished upon the earth are now gone forever. They are now classified as extinct forms. The giant dinosaurs are now gone, and only their remains are left to tell us of this once powerful race of reptiles. Perhaps these giant creatures failed to meet their food problem or could not withstand the gradually changing environment. Undoubtedly great numbers of them were destroyed by more successful and more intelligent beasts of the time. Similarly, the extensive fern forests which once covered parts of North America were unable to withstand the changing environment and perished, to be known to us only in the great deposits of coal which we are now unearthing. The curious turkey-like Dodo was too stupid to fear its enemies (Dodo means simpleton in Portuguese) and was soon driven to extinction by those who hunted it for food. The Heath Hen, Passenger Pigeon, and Great Auk likewise are known today in name only, for they are all extinct. Unless man intercedes, other kinds of organisms may also become extinct.

Man, the supreme form of life. As living organisms, human beings face the same problems of life which confront plants and animals. But one superiority of the human race has placed man far above plants and animals in the ability to meet these problems. Man is the most intelligent living thing. What we lack in instinct and physical ability we more than compensate for in intelligence.

We learned long ago that food could be grown in cultivation, thus removing much of the uncertainty of food supply which the plant and animal must face. True, human beings still experience famines at certain times, but even this problem will some day be solved.

Man has spread his civilization over the entire face of the earth — not because of greater ability to endure the heat and cold and other factors of environment which limit other forms of life, but due again to his superior intelligence. We can modify our environment to suit our



Monkmeyer Press Photo Service

Dodo Bird. This turkey-like bird was too stupid to fear its enemies which soon drove it from its natural environment. It is now extinct.

needs. Clothing, shelter, and heating facilities enable us to live in cold climates which we could not otherwise endure. Intelligence has enabled man to become the most widely distributed form of life upon the earth.

Intelligence, again, has allowed man to remove himself from the struggle for existence, so difficult for all other living things. We would be quite helpless if we were forced to match strength with the animal world, but through our own ingenuity, weapons made us the physical master of all we survey.

Our offspring are guaranteed a better chance of survival than the young of any other form of life through man's intelligence expressed through science. Continuation of the human race is much more of a certainty than continuation of any other form of animal or plant life.

In fact, man has become so supreme in the world of life that he has become his own greatest danger. Much of biology is now directed toward teaching us to live in the biological world without destroying it.

In later chapters, we shall return to a discussion of these conditions which living things face, and find out how various plants and animals solve them.

Summary

Life gives to plants and animals certain characteristics which set them apart from all of the nonliving substances of the earth. Plants and animals possess a definite form, a limited period of existence, and maintain throughout life a state of constant activity.

The life activities of organisms are referred to as life processes. While we frequently think of plants and animals as quite different from each other, actually they are much alike. All forms of life perform the same basic life processes.

All living things are similar, also, in that they must solve the same problems of existence. A successful organism must satisfy its organic needs, find a suitable environment, survive in the struggle for existence, and be able to reproduce its kind. Failure of a race of organisms to meet any of these conditions results in its ultimate extinction.

Man, because of superior intelligence, has been the most successful form of life. Science has shown us how to solve many of our life problems and thus has established our race as supreme among living things.

Using Your Knowledge

1. Explain how living things may be distinguished from nonliving things on the basis of definite form.

2. Define the term " life span " and indicate the approximate life span of several common plants and animals.

3. Explain the relation between vital energy and life.

4. List and define the life processes.

5. Define the term " organic need " and enumerate the organic needs of organisms.

6. Plants differ from animals in many ways. Enumerate some of the ways in which they are similar.

7. Enumerate some of the important varying factors which compose the environment of an organism.

8. Why, do you think, organisms struggle with each other for existence rather than live entirely independent of one another?

9. List some of the ways in which man has been more successful than any other organism in meeting the problems of his existence.

Expressing Your Knowledge

organism	respiration	locomotion
life span	oxidation	sensitivity
vital energy	breathe	irritability
life function	excretion	reproduction
environment	secretion	ingestion
digestion	motion	organic need
absorption	spontaneous	extinct
assimilation	process	intelligence

Applying Your Knowledge

1. List at least three extinct organisms and see if you can determine possible causes for the disappearance of each.

2. Place a bean or corn seedling in the window. Observe it daily and make notes of responses the plant makes to light.

3. Make a list of plants and animals which require a desert environment and a similar list of plants and animals which live in swamps, bogs, or marshes.

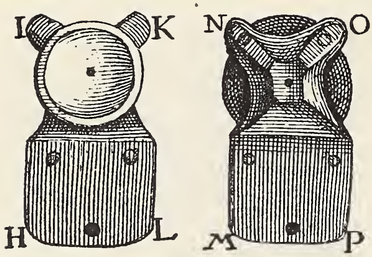
4. Enumerate the ways in which you benefit from human ingenuity in meeting your problems of existence. Then comment briefly on each item in your list.

Chapter 3

Protoplasm—the "Bios" of Biology

The invention of the microscope made possible one of the most exciting discoveries in biology, that all parts of plants and animals are composed of tiny units called cells. The microscope has revealed further that each cell is a little world of wonderful structures and functions. This chapter discusses cells and how they work together for the good of the whole organism.

You will learn, also, about the construction and use of the microscope. As you become skilled in operating this instrument, you can learn from first-hand



ONE OF LEEUWENHOEK'S MICROSCOPES

observation about these wonderful tiny units of life which we call cells.

The preceding chapter discussed several characteristics of living matter. In showing the similarity of all plants and animals and how living things differ fundamentally from nonliving things, we spoke mostly about functions and processes. The structure, or make-up, of organisms is as striking as their processes. In the study of structure, we will find further similarities between all plants and animals as well as further distinctions between living and nonliving things.

The microscope, a fundamental tool of biology. The structure of living organisms was never really understood until the invention of the microscope. This was true because the units or cells which compose the living parts of all plants and animals are not visible to the naked eye. For example, a leaf appears to be made up of a thin, green portion or blade, threadlike veins, and a stem, or petiole. These are all general parts, visible to the naked eye. But under the microscope, many more wonders of the leaf are revealed. The blade is composed of several parts, and the veins and petiole contain conducting tubes of different sorts. The remarkable activities of a leaf become much clearer when the microscopic structure of the leaf is fully understood.

The microscope has served, further, to reveal worlds of tiny plants and animals which were never known to exist until its invention. Many of these microscopic forms of life are of extreme importance. Much of our knowledge of disease is based upon the discovery of bacteria and other disease-causing organisms, which can only be seen clearly under a microscope.

Since so much of the study of biology is based upon the microscope, you will want to become familiar with its parts, its proper use, and some of the history of its invention.

Van Leeuwenhoek and the invention of the microscope. The invention of the microscope cannot be attributed to any one person. Yet, Anton van Leeuwenhoek [*Lu'wen hoke*] contributed so much to the perfection and early use of the microscope that its invention is often credited to him.

Van Leeuwenhoek, a Dutch lens grinder, was born in 1632. He ground and mounted his own lenses, capable of magnifying from 40 to 270 diameters. Each of his microscopes consisted of a single lens, much like the magnifying glasses of today, but more powerful. The lenses were fastened to a special kind of device which held the object to be viewed.

One of Van Leeuwenhoek's microscopes, built to view a small fish, consisted of a tube in which the fish was placed, and a frame around the tube which held a small magnifying lens. When the eye was placed close to the lens, the tail of the fish was magnified sufficiently to show blood vessels with blood circulating through them. With other microscopes, Van Leeuwenhoek was able to study the minute structure of muscles, parts of plants, and even bacteria.

One disadvantage of the simple microscopes of Van Leeuwenhoek's day was the special nature of their construction. Each different type of material to be studied required a special microscope. The instrument used to study the fish was not suitable for examining pond water. Furthermore, each microscope used only one lens and thus could not magnify beyond the enlarging power of a single lens.

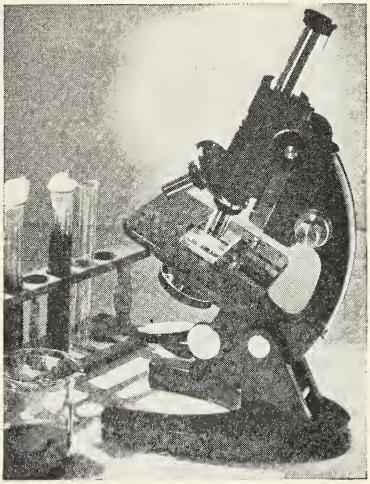
The modern compound microscope. From the simple microscope of Van Leeuwenhoek's day, a long series of improvements and perfections have resulted in the modern microscope.

The most commonly used microscope for biological study is a compound microscope. It contains several lenses mounted permanently in relation to each other. Delicate adjustments and movable parts make it an extremely efficient piece of apparatus.

Proper use of the compound microscope requires considerable skill. Study carefully the illustration in the photograph and locate each of its parts. Be sure that you understand each part and its function before attempting to use the instrument.

The microscopic structure of living things. Two great discoveries, made by means of the microscope, revealed the plan of structure of all living things. One of these discoveries was the cell, the smallest unit of plants and animals. The other was a substance called *protoplasm* [*pro' toe plazm*] which occurs in all living cells and is considered to be the physical basis of all life.

Cells and protoplasm may be studied from any living part of a plant or animal. Roots, stems, leaves, flowers, muscles, bone, skin, heart, and any other part of an organism may be used as a subject for cell study. Some materials



MODERN COMPOUND MICROSCOPE

show cells and protoplasm much more readily than others. Your introduction to cell study will, therefore, probably be from specially selected subjects.

Protoplasm, the basic substance of life. We defined biology as the study of living things. We might have defined it as the study of protoplasm, for to study plants and animals is to study the protoplasm of which they are made.

The word protoplasm is derived from two Greek words, "*protos*" (first) and "*plasma*" (substance). It is well named, for protoplasm is the first or primary substance of all life.

Protoplasm is unlike any other substance in the world. While the materials which make it up are not alive, this unique material is able to exist in an active, living condition. It is little wonder that scientists have long marveled at this strange substance of life. While much is known about protoplasm, the properties which make it live are still not entirely understood.

The nature and composition of protoplasm. Living, active protoplasm appears as an almost colorless or grayish substance. It is neither entirely solid nor liquid, but jellylike in texture. It is frequently likened to white of egg in appearance. Some forms of protoplasm are almost clear, while other forms appear to contain tiny bubbles or grains. Protoplasm in any particular plant or animal may vary in color and texture. Depending upon the amount of water present, it may be thin and watery or almost solid.

Analysis of protoplasm shows that it contains about seventy per cent *water*. The water composes the liquid portion of the substance. Aside from water, about one half of the material in protoplasm is a substance called *protein* [*pro' teen*]. *Sugars, starches, fats,* and *salts* also are present. All these solid substances, associated with water, form a solution called a colloid [*koll'oid*]. A colloid is a substance which never forms crystals. Protoplasm is a good example of such a substance.

Cells, the units of protoplasm. You may wonder why plants and animals do not appear like the protoplasm of which they are composed. If leaves and flowers and wood are alive, why do they not resemble protoplasm? Why do not we ourselves appear as masses of grayish, living jelly, for protoplasm composes a large part of our bodies?

The answer to these questions is revealed under the microscope. A portion of any living thing, highly magnified, will be seen, not as a continuous mass of matter, but as a mass of tiny units called *cells*. Each cell includes a small quantity of protoplasm.

The discovery of cells and protoplasm. During the same period in which Leeuwenhoek was experimenting with his microscopes, another biologist, Robert Hooke, made a startling discovery. While examining various objects with a crude microscope in 1665, he chanced to use as a subject a piece of cork. To his surprise, he found the cork to consist of a mass of tiny spaces or cavities. Each space was enclosed by walls, reminding him of the cells in a monastery. Accordingly, he named these tiny cavities *cells*.

Hooke did not realize, however, that the most important part of these cells was lacking. Unfortunately, he saw only the empty shells or walls of cells which had once contained active, living protoplasm.

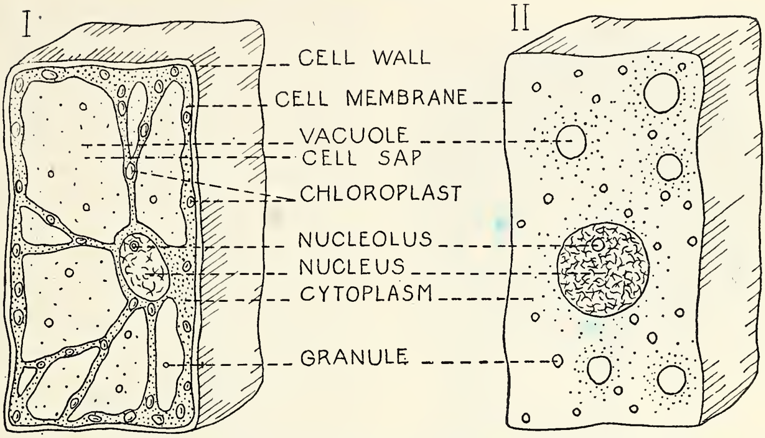
More than a hundred years later cells were found to have a living content. In 1838, two scientists, Schleiden [*Schly'den*], studying animal cells, and Schwann, working with plant cells, discovered protoplasm almost at the same time. Together, they worked out the *cell theory,* which states that all living things are composed of cells, that all cells come from previously existing cells, and that the cell is the unit of structure of all living things.

The parts of a cell. Close examination of cells under a microscope reveals that they are composed of many distinct parts. Certain of these parts are composed of protoplasm and therefore are living, while others are made of nonliving materials. Furthermore, while all cells are somewhat alike, certain structures present in plant cells readily distinguish them from animal cells. The parts of a cell, both living and nonliving, as shown in the illustration on the next page may be grouped as follows:

1. The *cell wall,* which is formed by plant cells but not by animal cells.

2. The *protoplast,* which includes all of the protoplasm or the living content of the cell.

3. The *inclusions* of nonliving substances contained in the protoplasm.



LIVING CELLS. I represents a typical plant cell; II represents a typical animal cell.

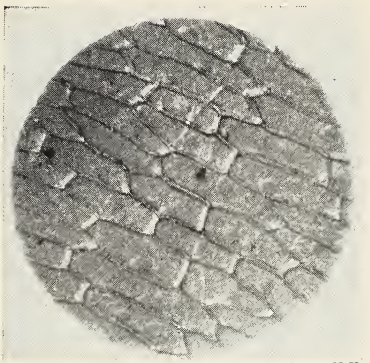
The cell wall. Cell walls are peculiar to plant cells and readily distinguish them from animal cells. The wall is a nonliving case surrounding the living portion of the cell. It is composed, largely, of a substance called *cellulose,* which is produced and formed into a wall by the cell protoplasm. Cell walls may be extremely thin and delicate, forming such plant parts as flower petals, pulp in fruits, or leaves. On the other hand, cell walls of wood and plant fibers, or the shells of nuts, are very thick, giving these plant structures tremendous strength.

The protoplast. All of the living content is included in the *protoplast.* We discussed protoplasm as though it were a single substance and all alike. Actually, the protoplasm of a cell forms several distinct parts. The principal divisions of a cell protoplast are the *nucleus* [*noo'klee us*] and the *cytoplasm* [*cy'toe plazm*].

Cytoplasm is usually jellylike in texture and somewhat grayish. It fills most of the cell outside of the nucleus. It frequently appears to contain grains or tiny bubbles. The outer edge of the cytoplasm is slightly hardened to form a thin skin or membrane, called the *cell membrane* or *plasma membrane.* In plant cells, the membrane lies just within the wall and is difficult to distinguish from the wall. In animal cells, which lack a wall, the membrane forms the outer boundary. Since the cell membrane is thin and flexible, animal matter is usually soft and pliable and lacks the rigid texture which walls give to plant matter.

Cytoplasm of plant cells often includes living bodies called *plastids.* These plastids are of several sorts and have special uses. Perhaps the most common type of plastid is the *chloroplast* [*klo ro'plast*] which contains the green coloring found in leaves and other plant parts.

The *nucleus* appears as a spherical mass of protoplasm, frequently near the center of the cell. The nucleus can usually be distinguished from the cytoplasm by its protoplasm, which is denser. Special stains or dyes, frequently used to color cell contents for microscopic study,



Philip D. Gendreau, N.Y.

CELLS OF ONION SKIN

can be used to stain the nucleus darker than cytoplasm and make it very distinct.

The nucleus is the center of most of the activity of a cell. Its removal or destruction results in the death of the cell. In addition to controlling cell activities, it is the center of cell reproduction.

The outer edge of the nucleus is a living membrane called the *nuclear membrane*. Within the membrane lies the *nucleoplasm* [*noo'klee o plazm*], a dense gelatinous form of protoplasm. The nucleoplasm contains a small spherical body called a *nucleolus* [*noo klee'o lus*] which appears as a tiny nucleus within the nucleus. Frequently, several nucleoli may be present. Special staining and preparations reveal ribbonlike strands of *chromatin* [*krome'at tin*] within the nucleus. Chromatin is of extreme importance since it carries the hereditary characteristics of the plant or animal.

The inclusions. These are nonliving parts found in the cytoplasm and the nucleus. Scattered through the cytoplasm are spaces or bubbles known as *vacuoles* [*vack'u oles*]. These vacuoles contain a lifeless, watery fluid called *cell sap* which contains various dissolved food substances, especially sugar. Vacuoles of plant cells are frequently quite large. Similar cavities in the nucleus are filled with *nuclear sap*. Other lifeless granules of food substances such as starch and droplets of oil or other liquids are also contained in the protoplast.

The principal parts of a cell may be grouped as follows:

- I. Cell wall (nonliving and found only in plant cells)
- II. Protoplast (living protoplasmic structures)
  1. Cytoplasm
     - a. Plasma membrane
     - b. General cytoplasm
     - c. Plastids (only in plant cells)
  2. Nucleus
     - a. Nuclear membrane
     - b. Nucleoplasm
     - c. Nucleolus
     - d. Chromatin
- III. Inclusions (nonliving)
  1. Vacuoles of cell sap or nuclear sap
  2. Droplets of oil or other lifeless granules of food substances

Cell study. The parts of a cell may be seen in various plant and animal materials prepared for microscopic examination. Certain types of cells have been found especially good for this purpose, and the beginner will do well to use these subjects first.

The thin skin of an onion which peels out of the inner surface of each scale is an ideal subject for typical plant cells. Onion cells show cell walls, cytoplasm, vacuoles, and nucleus very distinctly. Inclusions in the cytoplasm in the form of oil droplets are usually abundant. A drop of iodine on the section will stain cell contents yellowish and brownish and make them much more distinct.

The leaves of *Elodea*, or waterweed, may be mounted whole to show typical leaf cells with chloroplasts. Thin potato sections reveal numerous starch grains stored within large angular cells. Iodine colors these starch grains blue-black.

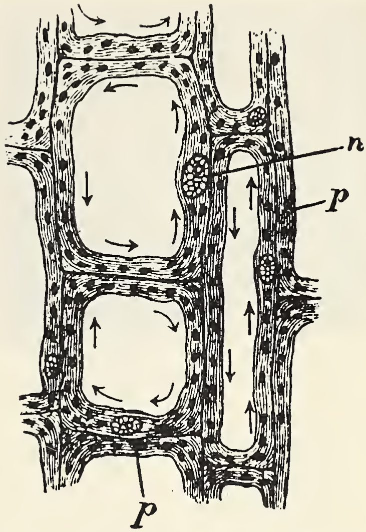
Animal cells may be studied from thin sections of beef muscle, heart muscle, or many other sorts of material. Stains, such as methylene blue, make the cells much more visible under the microscope. An interesting study of human cells may be made by gently scraping the inner surface of the cheek and mounting the slimy material which you gather. A drop of iodine or methylene blue reveals many irregular *epithelial* [*ep i thee' lee al*] cells from the lining of the mouth.

The cell as the unit of structure. The unit of structure of anything is the smallest part of which it is composed. The unit of structure of a building may be a brick, a stone or a board, depending upon its type of construction.

In the same way, the cell serves as the unit of structure of all living things. We think of our bodies as being composed of skin, muscle, bone, and various other parts. Actually, we are composed of a vast number of human cells and these cells make up skin, muscle, and the other parts. Similarly, a tree is a great mass of cells formed into roots, trunk, branches, and leaves.

The simplest plants and animals consist of only one cell. Since they never become larger, we consider the one tiny cell to be the complete body. Thus, a plant or animal may be formed by one cell or by a mass of millions of cells. The size of a plant or animal is determined not by the size of its cells but by the number of cells. The cells of an elephant are no larger than those of a mouse — there are simply more of them.

The cell as the unit of function. Not only is the cell the unit of structure in plants and animals, it is also the unit of function. We think of an organism as eating, digesting, growing, and reproducing. However, none of these functions would be possible to the animal or plant as a whole if its cells were not capable of performing these activities.

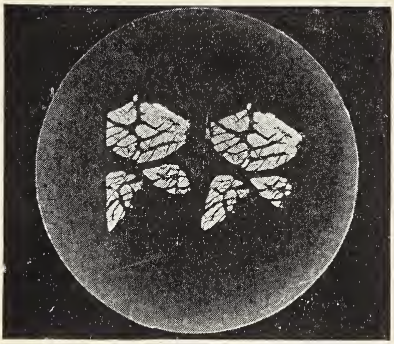


CELLS OF *ELODEA*. The arrows indicate the direction of the flow of protoplasm. *n* is the nucleus; *p* is the protoplasm.

Each cell is, in a sense, a tiny living thing. It is composed of protoplasm and performs all the activities of which protoplasm is capable. When great numbers of cells are arranged together, as in the case of our own bodies, each cell leads its own existence and, at the same time, serves as a small part of that greater whole which we call the human body.

The wonderful abilities which we possess, then, are really abilities of the cells which compose our bodies or, more specifically, remarkable properties of the protoplasm which our cells contain.

The life activities of cells. To some degree, every cell carries on the following ten basic life functions:



Ewing Galloway, N.Y.

CELLS FROM STRIATED MUSCLE OF MAN

1. Food getting or production
2. Digestion
3. Absorption
4. Assimilation
5. Respiration
6. Excretion
7. Secretion
8. Motion
9. Sensitivity
10. Reproduction

We have already learned how organisms perform these processes. We shall now study briefly the manner in which each cell performs its life activities.

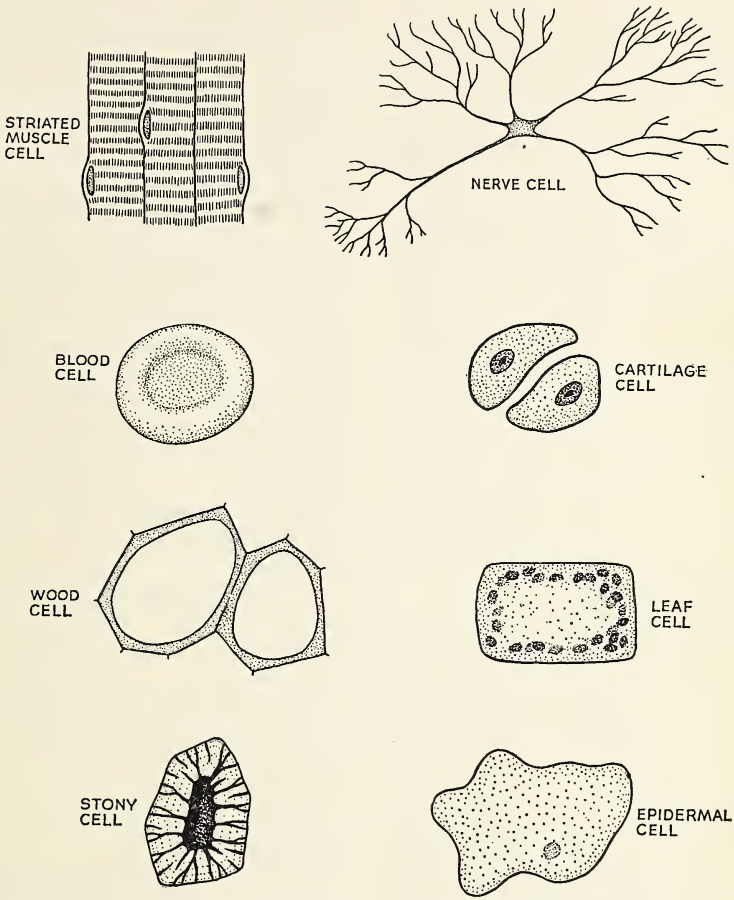
Food materials must be *taken into* the protoplast of the cell through the wall and the membrane, or must be *produced* within the cell. Food or raw materials pass into the cell by a process called *absorption*. The protoplasm *digests* food within the cell by means of digestive fluids which it secretes. Oxygen must, likewise, pass through the wall and membrane continually, to oxidize digested food and release energy needed for all cell activities. Oxygen enters the cell and carbon dioxide from oxidation is discharged by the process of *respiration*. Some digested food is converted to protoplasm by the process of *assimilation,* resulting in cell growth. Waste products, formed from assimilation and other processes, are removed from the cell during *excretion*.

Cells exhibit *motion* in various ways. Cytoplasm frequently flows or streams through the cell in a circular course. Many cells, such as muscle cells, may lengthen or shorten by bending their elastic membranes. One-celled organisms such as bacteria possess special hair-like strands of protoplasm called *cilia* [*sill'ee ah*], which propel the cells from place to place. Cells also exhibit sensitivity in various ways. The protoplasm reacts to heat, light, moisture, touch, and other factors outside of the cell.

Cell *reproduction* is especially interesting and will be discussed in more detail in later chapters. The size which a cell may become is definitely limited. Since the absorption of food, water, oxygen, and other necessary materials and the discharge of waste materials occurs through the wall and membrane, the bulk of any cell is limited by the exposed surface. Indefinite growth would result in a mass of protoplasm too large to be supplied by the surface exposed.

Consequently, when a cell reaches its maximum size, growth must cease, unless the cell can reproduce. If reproduction is possible, growth may be continuous, for reproduction of a cell involves splitting of its contents into two approximately equal parts.

The first evidence of cell division is the splitting of the nucleus and the pulling apart of the halves. A cell in this condition possesses, for a brief time, two nuclei. Soon after division of the nucleus, the cell divides through the middle to form two cells, each containing half of the original content. In this manner, many cells reduce their size at regular intervals and, thus, may continue their growth processes until attainment



ANIMAL AND PLANT CELLS FROM VARIOUS TISSUES

of maximum size results in another division. The complete story of cell division, which is called *mitosis* [*mite toe′sis*], will be discussed in Unit 10.

When plants and animals consist of many cells, cell division results in growth of the organism. However, among one-celled plants and animals, splitting of a cell results in two individuals instead of one and constitutes reproduction of the organism. We shall learn later about special cells formed by cell division which carry on the reproductive process of complicated plants and animals.

Special cells for special functions. While all cells must carry on all of the life processes, various types of cells forming the body of a complex plant or animal become fitted for special purposes. In this manner, plants and animals are composed of large numbers of specialized cells. These specialized cells become extremely efficient in performing particular functions but become dependent upon other cells for their existence. For example, a nerve cell is specialized for sensitivity. If removed from the body it soon dies because it depends upon other cells for food, oxygen, waste removal, and all of the other factors necessary for life. Similarly, muscle cells are specialized for motion, cells of glands for secretion, and cells of the stomach for digestion.

Cells and the organization of tissues. A group of similar cells, devoted to a single use, is called a *tissue*. Like the cells which compose them, tissues are specialized to perform particular functions. Animals are composed of numerous tissues. Our bodies contain such tissues as bone, muscle, and nerve. Plants contain such tissues as pith and wood. In all of these tissues the cells are alike and work together.

Tissues are grouped to form organs. In most plants and animals, tissues are grouped together to form a more complex part, or *organ*. Like the tissues of which it is composed, an organ is a specialized part of the plant or animal with some important general use. The stem of a tree, for instance, which supports the leaves, flowers, and fruit, consists of wood, pith, and other tissues, all working together. The leg of a cat is made up of bone, muscle, nerve, and other tissues. The muscle is used for motion, the bone for support, and the nerve for carrying impulses, and so on. Working together, they make possible locomotion in all its forms.

Organs may be grouped into systems. In the higher forms of life, especially among animals, several organs often perform related functions. Such groups of organs working together are referred to as *systems*. For example, the digestive system performs the functions related to preparation of food for the body. It is composed of numerous organs, including the stomach, liver and intestines. The circulatory system includes the heart, arteries, veins, capillaries, and blood all united together in the work of circulation.

Complex organisms. The complex plant or animal is organized, then, in the following way:

1. Protoplasm composes all of its living parts.
2. Protoplasm is organized into units called cells.
3. Cells are grouped into specialized tissues for definite purposes.
4. Tissues, working together, are grouped into organs.
5. Organs, performing related functions, form systems.
6. Systems grouped together form the *organism*, or the plant or animal as a whole.

Summary

The microscope has revealed cells and protoplasm, thus explaining the physical basis of all life. Protoplasm differs from all other substances in that it is active and alive. The cell is a basic unit of protoplasm.

The cell is the unit of structure of living things since all plants and animals are composed of cells. Organisms may consist of only one cell, or they may include billions of cells. The size of an organism is determined not by the size of, but rather by the number of, its cells.

The cell is also the unit of function. Life processes are really the properties of protoplasm. Since a cell is a unit of protoplasm, it carries on, individually, all these processes. Specialized cells in the make-up of complex plants and animals make such organisms extremely efficient in carrying on their life activities.

Specialized cells working together form tissues. Tissues are grouped into organs for particular purposes and related organs form systems. The systems together with the cells, tissues, and organs form the complex plant or animal.

Using Your Knowledge

1. Explain why the microscope is essential to the study of biology.
2. Account for the fact that the modern microscope attains much greater magnification than any of Van Leeuwenhoek's.
3. Why is protoplasm called the basic substance of all life?
4. List the different substances contained in protoplasm.
5. Explain why Robert Hooke, even though he discovered cells, had no conception of protoplasm.
6. Name the parts of a cell.
7. Why are the cell wall and inclusions segregated from the protoplast in enumerating the parts of a cell?
8. Discuss the cell as the unit of structure of plants and animals.
9. Define the term tissue and explain how tissues are specialized.
10. Define the term organ and explain the relation between cells, tissues, organs, and systems.

Expressing Your Knowledge

microscope	cytoplasm	membrane
Van Leeuwenhoek	plastid	vacuole
protoplasm	chloroplast	unit of structure
Hooke	nucleus	unit of function
protoplast	nucleolus	cell
inclusions	chromatin	tissue
cell wall	nuclear sap	organ
cellulose	droplet	system

Applying Your Knowledge

1. Prepare a report on Anton Van Leeuwenhoek and include his work with early microscopes.
2. Prepare a report showing how Hooke, Schleiden, and Schwann contributed to the progress of biology by their studies on the cell and its contents.
3. Examine several different plant and animal parts with a microscope and see how many different kinds of cells you can find.
4. Sketch a large cell and fill in all of the cell content you can.
5. Make a collection of all of the plant and animal tissues you can obtain. Your collection might include small pieces of muscle, brain, wood, cotton, bone, and skin.
6. Make a series of sketches to show the organization of a complex animal. Start with a drop of protoplasm, then show a cell, a tissue, an organ and, if possible, some of the organs included in a system.

Chapter 4

The Chemical Basis of Life

Have you ever visited a chemical laboratory? If so, you probably were impressed with an array of bottles containing chemical substances of many forms and colors and with the odor of various gases, characteristic of such a laboratory. When certain of these substances are brought together, chemical reactions occur and new substances are produced. Such are the marvels of chemistry.

But have you considered that chemical reactions may play a large part also in the formation of a plant or animal? Many of the same chemicals found on the shelf in the laboratory are found in living things.

The study of life reveals many strange things, but the manner in which living organisms are formed from what appears to be only the earth, air, and water about them is, perhaps, the most amazing thing in the world.

By marvelous chemical processes, soil, air, and water may produce a forest, a field of grass, or a garden crop. By further processes, grass may become a cow, and vegetables, a man. Unlike Topsy, we did not " jist grow," but were formed from chemical matter in a most amazing way. Your introduction to the chemistry of life will explain some of the manners in which nature forms her plants and animals from the chemical raw materials of the earth.

Why is chemistry necessary to the study of biology? The phase of science dealing with the composition of things is termed *chemistry*. Thus, if you study the composition of a plant or animal and the manner in which various substances are united to form its tissues, you are really studying chemistry. The biological phases of chemistry are given the special name, *biochemistry*.

What are energy and matter? Anything which occupies space and has weight is termed *matter*. Thus, plants and animals are composed of matter. *Energy* is the ability to do work or cause a change. It is not a form of matter, but expresses itself through activity of matter. Life depends upon energy, expressed through activities of a plant or animal. Biology is really a study of matter and energy, or the make-up and life activities of living things.

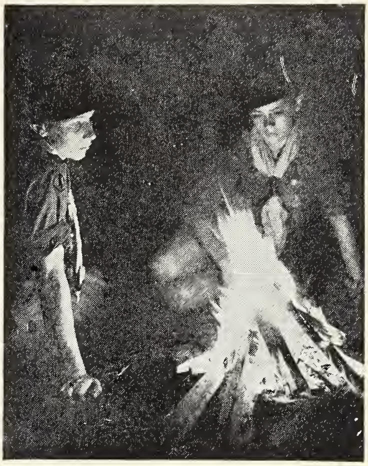
Characteristics of energy. We cannot see energy. It has no weight, nor does it occupy space. We can only observe its effects. It shows itself in the form of heat, light, electricity, and mechanical activity, and in chemical changes. Energy, of whatever form, is expressed through matter. By various means, energy may be transformed from one form to another.

Transformation of energy may be illustrated in the case of a steam boiler, where we start with chemical energy stored in such fuels as coal, oil, or wood. Oxidation, or burning, of the fuel releases energy in the form of heat, which sets water particles into motion resulting in steam, containing force. The energy of steam is converted into mechanical energy in turning a dynamo. The dynamo converts mechanical energy into electrical energy. Electricity, wired to our homes, may be converted to other forms of energy, such as light from an incandescent bulb, heat from a toaster, or motion by means of a motor. Thus, the original energy contained in fuel in the boiler has been changed in form many times by means of various devices.

Energy is used by living organisms in much the same manner as in the boiler. We use fuel in the boiler and food in our bodies. In each case, energy is converted into different forms to do work in one way or another. The steam from the boiler may operate a machine; the body, likewise, produces movement and activity. Energy is involved in both cases, though something more than mere chemical energy is needed to produce life. Not only in the simple cases just referred to, but in all other activity on the earth and throughout the universe, matter and energy depend on each other for complete expression.

Properties of matter. All substances of the earth are termed *matter. Matter occupies space and has weight.* We are accustomed to thinking of all *solids* and *liquids* as matter since we can see them and measure them readily. But *gases* such as oxygen and nitrogen, composing most of the atmosphere, occupy space and have weight just as do solids and liquids, and are, therefore, forms of matter.

Matter, like energy, may be changed from one form to another. Such a change may be *physical* as illustrated in the melting of ice to form water and the converting of water into steam, both resulting from temperature variations. Ice, water, and steam, though they appear quite different, actually, are the same substance. Similarly, a piece of iron may be changed physically from a solid to a liquid by applying heat.



A Campfire. Burning wood seems to disappear in the process of burning, but actually only changes form.

During *chemical* changes, matter changes from one substance to another. Such a chemical change occurs when wood burns to form water vapor, carbon dioxide, and ash.

Scientists used to teach that during chemical and physical changes, matter was neither created nor destroyed but only changed in form. Burning may appear to destroy a substance, but actually this is only a chemical change resulting in new substances which may be invisible. Likewise, they taught that energy was not created or destroyed as it changed from one form to another. This phenomenon, which still holds true for chemical and physical changes, is called the Law of Conservation of Matter and Energy.

Until recently, science believed that matter could never be destroyed and that energy could not be created. We know now that this is not the case. In fact, one may be changed into the other. A piece of radium, a form of matter, disintegrates slowly to produce rays, a form of energy. This change of matter into energy was demonstrated on a much larger scale in the disintegration of uranium to release tremendous amounts of energy during the explosion of the atomic bombs. We know also that matter is destroyed and that energy is created constantly on the sun resulting in heat and light which are given off into space. Scientists tell us, however, that we need not worry lest the sun consume all of its matter and cease to give off energy since only one hundredth of one per cent of the sun's total mass has been destroyed since the earth was formed.

What are the two classes of matter? The matter of the earth is in a constant state of change. Certain forms of matter combine with other forms to produce a wide variety of substances. These changes may occur naturally or may be the result of body activities of plants and animals. The materials of the physical earth we call *inorganic,* while substances produced by living things are termed *organic.* The distinction between organic and inorganic is more than the origin of a substance, for the power of life involved in the formation of organic compounds gives these products of plants and animals distinct properties.

Inorganic substances include minerals, water, oxygen, metals and other similar forms of matter. Science tells us that the earth was once entirely inorganic. Conditions were unfavorable for life. The vast number of organic substances so essential to us today were entirely lacking because there had never been life to produce them. But with the appearance of life upon the earth, living organisms began to use the inorganic substance of the physical world in the production of organic substances.

Organic substances include all living matter, matter which has lived at some time and nonliving products of plants and animals. Wood, paper, leather, and meat are readily recognized as organic. Coal and oil are organic remains of plants of past ages. Other substances such as sugars, starches, vitamins, and alcohols, while never alive, are products of living things and are organic.

Elements, the alphabet of matter. All the words of our language are formed from twenty-six letters in various combinations. When we look through a large dictionary we realize what an enormous number of combinations may be formed from so few letters. In somewhat the same way, all the matter in the world is composed of ninety-two * basic substances called *elements.* These we might think of as the letters in a chemical alphabet which spell all the substances — both organic and inorganic — that are in existence.

Elements are composed of tiny units called *atoms.* Atoms are basic units of matter and may be altered only by extreme physical means. We have witnessed the smashing of atoms of certain substances such as uranium, but only as a result of extreme physical means. Under ordinary circumstances, atoms or the elements they represent are pure forms of matter and, like letters of the alphabet, cannot be simplified.

Compounds and mixtures. When an element exists by itself, it is termed *free.* Usually, however, elements unite with each other and thus exist in *combined* form. Two or more elements combined chemically form a *compound.* For example, iron is a free element. Oxygen in the air is also a free element. When these two elements unite chemically,

* Ninety-two elements are known to exist naturally, although seven additional elements have been produced in experimental work with atom smashing.

they form a compound which we call iron oxide or iron rust.

Compounds are composed of tiny units called *molecules.* Molecules are composed of two or more atoms, linked together chemically. The molecule bears the same relationship to the compound as the atom bears to the element. As elements unite to form compounds, so atoms unite to form molecules. A compound such as iron oxide results when atoms of oxygen combine chemically with atoms of iron.

Mixtures, on the other hand, have properties quite different from compounds. They may be formed from different elements or compounds, but are the result of physical union of the substances rather than a chemical combination as in the case of a compound. In a mixture, the substances forming it show their individual characteristics, while in a compound they lose their identity, the compound showing entirely new properties. The elements in a compound always unite in definite proportions, that is, a definite amount of each, whereas a mixture may be formed in any proportions. Furthermore, the elements in a compound may be separated only by chemical means, while mixtures may be separated by physical means.

For example, we can mix powdered iron and powdered sulphur in any proportions we wish. Having mixed them, we can take a hand lens and see the separate particles of iron and sulphur just as they were before mixing. We can pick out the iron with a magnet or remove the sulphur by means of substances which will dissolve it and leave only the iron. So far we have only a mixture, produced by a physical change.

Now if we put this mixture into a test tube and heat it strongly, a glow will spread through the mass; and after it cools, a different substance will be found in the tube. Heating caused the iron and sulphur to combine chemically to form a compound called iron sulphide. When we examine the substance with a magnifying glass, we can no longer see iron and sulphur as we did before. The heat has produced a chemical change forming a new substance which has properties different from both the iron and sulphur. So closely are they united that chemical means would now be needed to separate them.

In living things, the elements are found most often united in compounds, seldom in mixtures. Some of the compounds are simple, such as water with two parts of hydrogen and one part of oxygen. Other compounds, such as those composing protoplasm, are so complicated that it is very hard to state their composition.

Elements, compounds, and organisms. Plants and animals, like all other forms of matter, are formed from chemical compounds composed of elements. Of the total ninety-two elements, living things require only eighteen, with minute traces of four or five more. That is, if we analyze any plant or animal and reduce it to the elements it contains, various quantities of eighteen elements will be found.

The manner in which plants and animals obtain these elements is most remarkable. Few of the necessary elements exist in pure form in nature. Instead, they are combined with other elements to form various inorganic compounds. From these sources, living things obtain their necessary elements and rearrange them, by the power of life, to form complex organic compounds which build their living structure and supply the needs of life.

The relation of elements and com-

Philip D. Gendreau, N.Y.

A CROCUS. This plant could not grow without soil, air, and water which supply its necessary elements.

pounds to living things may be summarized as follows:

1. Eighteen chemical elements form the substances of which all living things are composed.

2. These essential elements are obtained by organisms from inorganic compounds of nature.

3. By the power of life, organisms rearrange the elements to form complex organic compounds.

Thus, during life, the organism is continually building. Simple compounds supply foundation substances for complex products. After death, however, these processes are reversed. Complex organic compounds are broken down to simple, inorganic compounds, to be used again by other forms of life.

The chemical relations of plants and animals. Plants and animals depend upon each other in many ways. But nowhere in the world of life is there a closer relationship than the chemical dependence of living things upon each other.

Without plant life there could be no animal life. Perhaps you question this statement. Using ourselves as examples, let us see why this is true. Like all other living things, the human body is formed from the eighteen essential elements. These elements are derived from three inorganic sources, *carbon dioxide, water,* and *mineral compounds.* Yet surrounded by an abundance of these substances, we are powerless to use them as sources of elements. True, water and mineral compounds are essential to us, but not in forming compounds. We cannot make chemical use of them in supplying the elements which they contain.

Green plants, however, possess a remarkable ability to use these substances in the formation of organic substances usable by protoplasm. All of life depends upon the green leaf, for here the inorganic and organic worlds are linked. Carbon dioxide and water supply the elements required by the green tissues to form an organic compound, sugar. During this process the organic world is born.

Roots of green plants remove minerals from the soil, thus introducing other necessary elements. By complicated processes, these elements are added to organic compounds produced in the leaf to form *proteins.* With protein formed, *protoplasm* may be produced and life may build its substance.

Sugars and starches, which are called *carbohydrates,* fats and oils, and proteins are familiar organic compounds produced in plants. These substances are used by animals and serve as our source of food. Certain plants such as molds and bacteria lack the foodmaking ability of green plants and must nourish themselves upon manufactured organic substances like animals.

Thus, until human ingenuity duplicates the marvelous foodmaking processes of the plant, we must continue to live as organisms entirely dependent upon the leaves of green plants.

Essential elements and compounds and what to learn about them. Our study of biology will deal much more fully with the chemical relations of living things. We shall discuss the eighteen essential elements, the inorganic compounds which supply them, and the organic compounds formed from them. For the present, we need to know four things about these elements:

1. their names
2. where they are found
3. enough of their characteristics or properties so that we can recognize them
4. their use to living things

Essential Elements

Oxygen (O). We already know that oxygen is part of the air, but it is also part of water, rock, and many other things. It may be hard to understand how a gas can be part of a liquid, like water, or of a solid, like wood; but this is true. Oxygen, united in compounds, loses all of the properties it has as an element. Oxygen is found in all plant and animal substance. It is the most abundant element in the world and, in the form of compounds, is contained in about one half of the solid material of the earth's crust.

In referring to oxygen, the scientist uses a *symbol* "O." This system of abbreviation for elements is a chemical shorthand. When elements unite to form compounds as in water (H_2O), symbols of elements, showing the number of atoms combined, are indicated in a *formula,* representing a molecule of the substance. Thus, O is a symbol representing one atom of oxygen as an element. H_2O is the formula for one molecule of water containing one atom of oxygen and two atoms of another element, hydrogen, in chemical combination. As we study other elements, you will want to learn their chemical symbols.

Oxygen is a colorless, odorless, tasteless gas. It is denser than air. It dissolves in water, thus becoming available for aquatic plants and animals.

The use of oxygen to living things is twofold. Oxygen as a gas enters living matter during respiration, where it is used for oxidation. During this process, food materials unite with oxygen; and energy, which was stored in the foods, is set free. This energy is used for performing the life processes.

Oxygen is necessary, also, in the formation of protoplasm. This oxygen is obtained from water and carbon dioxide taken from the soil and air and built into organic substances from which protoplasm can be formed.

Nitrogen (N). Nitrogen is another important element. It makes up four fifths of the air. It is found combined with several minerals in the soil and exists in the living tissue of all plants and animals.

Nitrogen is a gas which resembles oxygen in being colorless, odorless, and tasteless. It is, however, lighter than oxygen. It is the exact opposite of oxygen in that it will not cause oxidation or burning and will not combine readily with other elements to form numerous compounds.

Nitrogen is found in the active living

Ewing Galloway, N.Y.

COTTON FIELD. The plants on the left are growing in soil which is deficient in nitrogen. Those on the right have adequate nitrogen in the soil.

substance of all plants and animals and is essential to their life. Its various compounds are among our most necessary foods such as meat, milk, eggs, and beans.

Since nitrogen composes four fifths of the atmosphere, one might assume that plants have an abundant supply at all times. Such is not the case, however. Nitrogen essential to production of foods and living matter must come from soil minerals called *nitrates*. These compounds are an essential part of plant fertilizers. A plant may die for want of nitrogen and yet stand in an atmosphere containing an abundance of it. With the exception of certain bacteria, to be discussed later, plants are unable to use the pure nitrogen of the atmosphere.

Hydrogen (H). Hydrogen occurs combined in water, plant and animal tissue, wood, coal, gas, and all acids. It resembles both oxygen and nitrogen in being a colorless, odorless, tasteless gas. It will not cause things to burn, but in the presence of oxygen burns itself or even explodes when brought into contact with fire. It is the lightest substance known.

Hydrogen is important to the biologist because of many important compounds. Plants take hydrogen from water and use it, combined with oxygen and another element, carbon, to form a series of compounds called fats, sugars, and starches. It is also an essential ingredient of all plant and animal tissues.

Carbon (C). Carbon is an element with which we are all familiar, for we see it in coal, charcoal, and wood. Lead pencils do not contain lead, but carbon in another form called graphite.

Carbon is usually a black solid substance, though the diamond, a form of carbon, is an exception. It is usually quite inactive and does not unite readily with other elements to form compounds. If heated in a flame, a piece of carbon becomes red hot and seems to disappear. Actually, it combines with oxygen to form carbon dioxide, a colorless gas.

The importance of carbon to biology is due to the fact that it is a part of all organic substances, combining with hydrogen, nitrogen, oxygen, and other elements to form the protoplasm of plants and animals and many of their foods.

We know that any partly burned plant or animal substance turns black. This, in every case, is carbon. Sugars, starches, fats, and other organic substances likewise show carbon when burned. Complete burning causes the carbon to disappear as carbon dioxide.

Plants *alone* are able to obtain their carbon from the carbon dioxide of the air. Animals depend entirely on plant foods for the carbon compounds necessary for their life.

Sulphur (S). The element sulphur, like carbon, is familiar to most of us as a yellow, solid substance. We frequently see it as a finely powdered solid called flowers of sulphur, or in a roll form. Pure sulphur and sulphur compounds are common in nature, especially in the Southwest, from which much of our sulphur is obtained.

Sulphur itself has no odor, but when burned, unites with oxygen to form sulphur dioxide (SO_2), with the suffocating odor which we incorrectly associate with sulphur itself. Another sulphur compound, hydrogen sulphide (H_2S), has the unmistakable odor of rotten eggs. Hydrogen sulphide is sometimes found dissolved in water in sulphur springs. Sulphur water has a disagreeable odor and flavor but is thought to be beneficial to the health of those who drink it.

The biological importance of sulphur is the fact that like nitrogen, it is part of the living substance of all plants and animals. Sulphur and other elements are combined chemically to form complex compounds which are grouped together in the formation of protoplasm.

Certain plant and animal products such as mustard, onions, and eggs contain especially large quantities of sulphur. The blackening of silver by these substances is due to chemical reaction of sulphur with silver.

Animals obtain sulphur from plant substances included in their diets. Plants, in turn, draw upon sulphur compounds in the soil. Minerals containing sulphur, called *sulphates,* are absorbed by roots and are carried to other regions of the plant where they are converted into complex organic compounds.

Phosphorus (P). It seems strange that phosphorus should be essential to living things, for pure phosphorus is an extremely dangerous element. It exists as a yellow, waxy solid with a peculiar "phosphorescence" or glow and in a deep red solid form. Yellow phosphorus is the most active and dangerous form. When taken internally it is extremely poisonous and, when contacted, produces severe burns which are slow in healing.

Yellow phosphorus burns fiercely in air, forming an oxide with a choking odor. In the laboratory, yellow phosphorus must be kept under water to prevent this reaction with oxygen. Red phosphorus ignites when rubbed or heated, bursting into flame and forming the familiar smoke of a burning match. One of the most common uses of red phosphorus is in match manufacture.

Strangely enough, our bodies and those of all other living things contain phosphorus compounds. Naturally, we never deal with pure phosphorus. Plants remove mineral compounds of phosphorus, called *phosphates,* from the soil. Animals utilize plant products as a source of phosphorus essential in the formation of bone and nerve tissue.

Iron (Fe). We are familiar with iron as a heavy, solid, gray metal which unites slowly with oxygen to form iron oxide or rust. Iron is found as ore in deposits in the earth and is contained in spring water frequently in the form of mineral compounds.

We should hardly expect our bodies to contain iron, but it is necessary to both plants and animals. Iron is associated both with the green coloring of plants and with the red blood cells of animals. Iron is essential, also, in the formation of chromatin, which carries the factors of inheritance in the nucleus of the cell. Although iron constitutes only 1/25,000 of the body's weight, it is essential to life and inheritance. Later we shall learn the remarkable services which its compounds perform in the bodies of plants and animals.

Calcium (Ca). This very active metal resembles silver but is much more brittle. Pure calcium is never found in nature because it reacts rapidly with water and oxygen to form compounds. While pure calcium may be seen only in the laboratory, calcium compounds are common in the form of limestone, marble, and shells.

Calcium is essential to our bodies in the formation of bone, teeth, and blood.

Sodium and Potassium (Na and K). These elements are light metallic substances which are extremely active and are therefore dangerous to handle. Both react violently with water, sodium bursting into a yellow flame and potassium producing a violet flame. Neither element exists in pure form in nature due to this reaction with water which is ever present in the ground and the air.

Both sodium and potassium, combined with other elements, form common mineral salts. Sodium chloride, more commonly called table salt, is the chief source of sodium in the diet. Potassium compounds, taken from the soil by plant roots, provide this element essential to normal growth.

Other elements essential to living things. *Iodine* (I) constitutes only about 1/3,000,000 part of the body, but is essential in the secretion of the thyroid gland. The importance of this element in the regulation of body processes will be discussed more fully in the section on human biology.

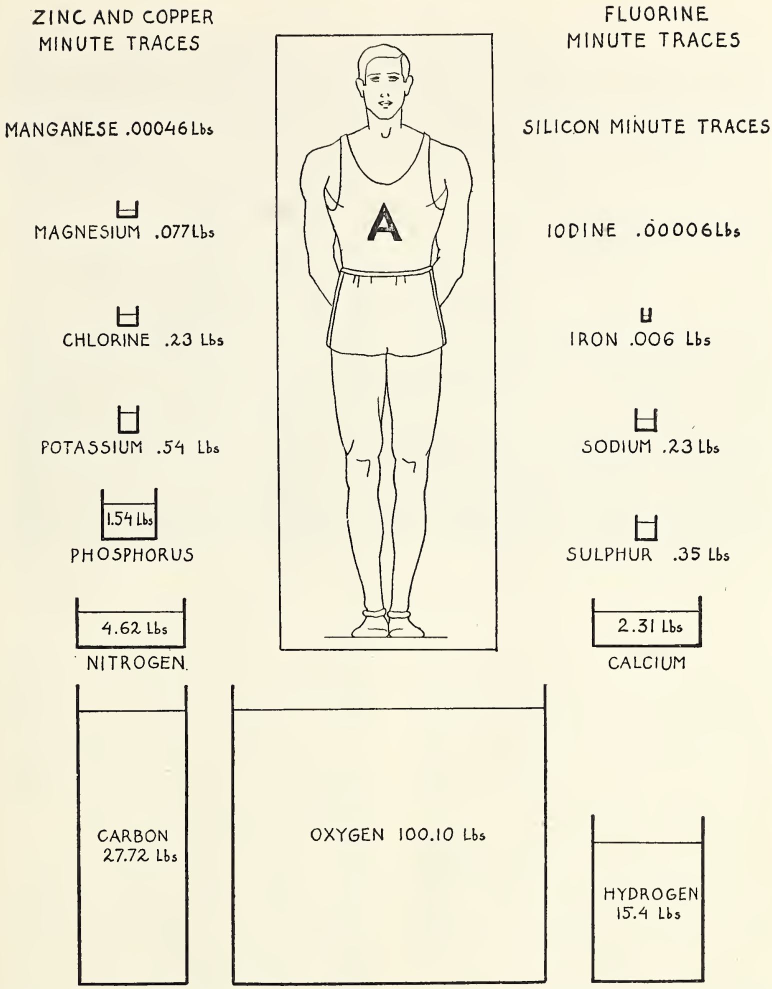
Chlorine (Cl), a heavy, greenish, poisonous gas is rarely to be found outside the chemical laboratory. The element chlorine could not be used by plants and animals. Yet, combined with sodium to form common salt or sodium chloride, we eat it daily.

Magnesium (Mg) is an active metal commonly seen as flash powder or as the metallic foil in photo-flashbulbs. Though living things require only small amounts of magnesium, it seems to be essential for health and, like many other elements, is taken from the soil by plants in the form of magnesium compounds.

Manganese (Mn) is rarely seen as an element, but is commonly used in making a hard form of steel called manganese steel and in potassium permanganate, a purple crystalline solid which forms a deep purple solution in water.

Manganese seems to be essential to the growth of the body and to the processes of reproduction. In small amounts, manganese is essential to the growth of plants.

Other elements, including *silicon* (Si), *fluorine* (F), and *zinc* (Zn) are present in the body in various com-



THE EIGHTEEN ESSENTIAL ELEMENTS. This athlete is 5 feet, 8 inches tall, and weighs 154 pounds. The eighteen elements, if separated and placed in containers, would be represented by the amounts given.

pounds and play an important part in maintaining good health. Like manganese, these elements are found in plants in small quantity and seem to be essential for growth.

Although we have spoken of eighteen elements as essential to life, we must not assume that organisms deal with these elements as pure substances. Compounds, containing these elements, are the building materials of living things and are also the waste products. Our study of the chemistry of life, then, turns to compounds.

Inorganic Compounds

In obtaining the elements necessary for life, plants turn to three common sources, *water, air* and *soil*. All the essential elements exist in compounds in one of these three sources.

Water, a common inorganic compound, may be taken from the soil or, as water vapor, from the air. *Air* also contains a gaseous compound, *carbon dioxide,* which serves to supply other elements. Most of the elements are obtained from the soil in the form of *mineral compounds.*

Thus, a plant supplied with sufficient air, water, and minerals may obtain the elements necessary for life and by organizing them into plant substances may supply all other living things.

Carbon dioxide (CO_2). When carbon unites with oxygen, it forms a colorless, odorless, tasteless gas called carbon dioxide. Both oxygen and carbon are used in large amounts in the formation of both plant and animal tissues, and in the production of numerous substances essential for life. The element, carbon, taken from carbon dioxide is the basis of all organic compounds.

Carbon dioxide is a source of plant food. Plants have the power to take this gas from the air into their leaves and stems, where it is combined with other substances to form plant tissues and other products.

The presence of carbon dioxide may be readily detected by the use of clear limewater. Mixed with limewater, it forms a milky substance. The fact that we exhale carbon dioxide may be easily proved by blowing into a tube of limewater through a soda straw.

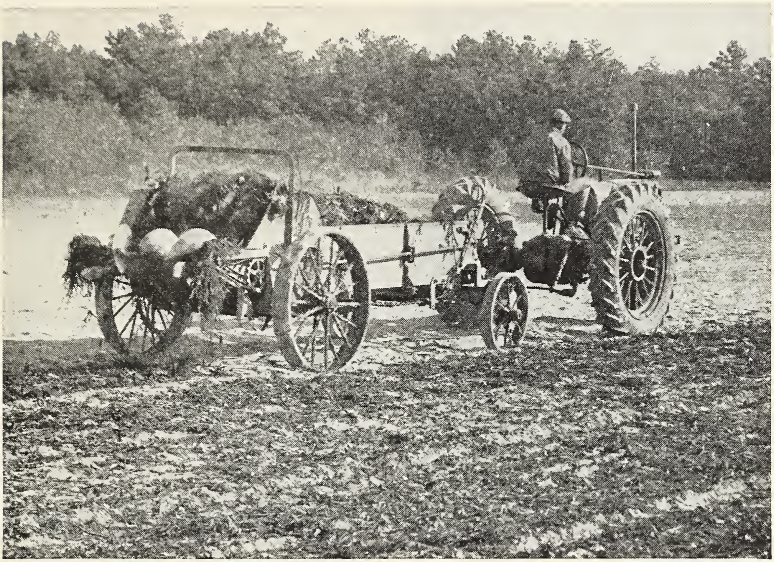
Water (H_2O). Our most abundant compound, water, is essential to living things in many ways. Chemically, water supplies the elements hydrogen and oxygen. Water, combined in plant leaves with carbon dioxide, is used in the forming of numerous compounds essential to all plants and animals. In addition to the supply of hydrogen and oxygen, water constitutes over one half the weight of all organisms. It serves further as a transporting medium in both plants and animals. The study of biology will reveal many other ways in which water is essential for life.

A simple test for water in a substance is to heat the substance in a tube and drive the water off as vapor. The vapor will condense as moisture on the inside of the upper part of the tube. A more exact test for water consists of weighing the substance carefully, heating it, and then reweighing it. Loss in weight represents the original amount of water.

Mineral compounds. The mineral compounds include numerous substances which supply all the essential elements except carbon, hydrogen, and oxygen. Many elements taken from minerals are required by living things in small quantities only. Nitrogen, sulphur, phosphorus, iron, calcium, sodium, and potassium are the most important elements derived from minerals.

Many mineral compounds supply several necessary elements. Calcium sulphate supplies both calcium and sulphur while calcium phosphate supplies calcium and phosphorus. Both compounds, in addition, contain oxygen. Likewise, sodium nitrate supplies both sodium and nitrogen.

Soil normally contains these necessary mineral compounds. Some soils may lack certain minerals, however, resulting in a deficiency of necessary elements. If the mineral deficiency is not



Ewing Galloway, N.Y.

MANURE SPREADER ON A FARM. By means of machines like this, lost minerals are restored to the soil, which is thus kept in a fertile condition.

too great, a plant may survive though the effects may be noticeable. Serious mineral deficiency may prevent certain plants from growing at all.

Crop plants grown in quantity exhaust the mineral content of soil, making artificial fertilization necessary. Fertilizers are intended to replace exhausted minerals. Consequently, minerals containing nitrogen, sulphur, phosphorus, and potassium are important parts of fertilizers. Nitrates, sulphates, phosphates, and potash are familiar mineral ingredients in commercial fertilizers. These names frequently appear on the bag as a part of the fertilizer formula. Often a formula such as 10:4:4 is used to designate the nitrogen, phosphorus, and potash or potassium content.

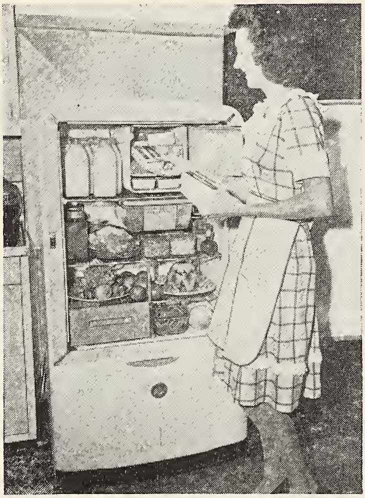
The supply of mineral compounds to animals is entirely through plants. While we use some salts such as table salt (sodium chloride) in our diet, we use the salt only as a body regulator, not as a food. Just as plants vary in mineral requirements, they vary, also, in mineral content. By using different plants for food, we can regulate our supply of necessary minerals elements.

Minerals in substances are usually grouped together and called mineral matter or mineral salts. Complete burning of a substance will reveal its mineral content as an ash.

Organic Compounds

These compounds represent the products of living things. They differ from inorganic substances in that they are formed only by living things. They are present in food, clothing, and shelter.

Plants, alone, may produce organic



Essential Foods. The daily menu should contain adequate amounts of carbohydrates, fats, and proteins.

compounds from inorganic substances. Animals, using plant products, form many organic substances by means of chemical changes within their bodies. As living things ourselves, we eat organic food and develop organic matter in the form of the many tissues and organs which compose our bodies.

Fortunately, the complicated compounds which both plants and animals use for food and growth can be grouped into three great classes: (1) carbohydrates, (2) fats, (3) proteins. These are sometimes grouped together and called *organic nutrients.*

Carbohydrates. The building of the organic compounds essential to living things begins with the formation of carbohydrates. Within the leaves of plants, water and carbon dioxide are rearranged chemically to form *sugar.* Sugar contains the elements carbon, hydrogen, and oxygen, with twice as much hydrogen as oxygen and varying amounts of carbon.

Sugars may be of many different types and may be converted from one form to another by various plants and animals. Some of the more common types of sugars include:

Cane sugar	from sugar cane	(sucrose)
Beet sugar	from sugar beets	(sucrose)
Grape sugar	from fruits	(glucose)
Milk sugar	from milk	(lactose)

Starches constitute another group of carbohydrates closely related to sugars. Starches differ chemically from sugars, although the same elements compose both. Starches are insoluble in water, while sugars, being soluble, dissolve readily in water. Plants frequently convert sugar to starch for storage purposes and later change the starch back to sugar.

Familiar forms of plant starches are:

Corn starch	from corn
Potato starch	from potato
Flour starch	from wheat
Tapioca starch	from cassava root

Although most starches are associated with plants, many animals form a carbohydrate, *glycogen,* or "animal starch," in the liver. It seems to be stored there for later use.

A third group of carbohydrates, the *celluloses,* include many familiar plant substances such as wood, cotton, linen, and other fibers. To plants, cellulose is essential in the formation of much of the plant body. The bulk of woody plants such as trees is cellulose. Commercially, cellulose is important as the substance forming numerous products such as lumber and paper.

Carbohydrates as fuel foods. Sugars and starches are important to all living things as the greatest source of the energy necessary for life. Not only in plants which produce them, but in animals which use them as food, carbohydrates serve as fuel for living tissues. It would be a cheap diet if we could produce these important fuel foods from carbon dioxide and water. But we must depend on plants for this wonderful process and begin where plants leave off, using the plant-made carbohydrates for food.

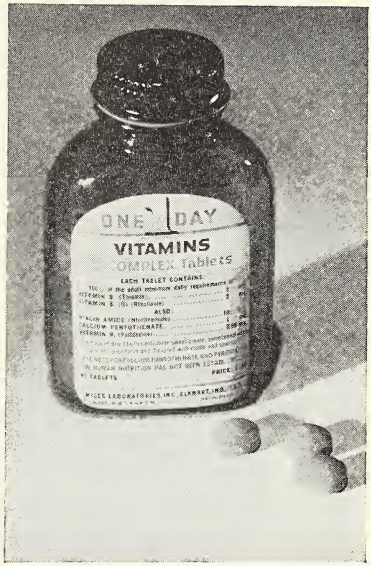
Tests for carbohydrates. No one test can be used for all the carbohydrates, but we can see whether cells contain starch by adding iodine. If it is present, the cell contents turn a blue-black color. It is frequently better to boil the substance before, since boiling bursts the starch grains, making a surer test possible. The iodine starch test is delicate and reliable, since no other substance will produce the characteristic blue-black color in the presence of iodine.

Another reliable test for a carbohydrate is the *Fehling test* for simple sugar. This test is commonly used to distinguish glucose from cane or beet sugars and to detect glucose in plant or animal tissues.

Two solutions are used in the Fehling test, one colorless and one blue. When these are added in equal amounts to a similar amount of substance to be tested, a deep blue color results. As the mixture is heated, the color becomes green, then yellow, and finally brick red. The final red color results only when glucose is present. Cane or beet sugar will not act in this way.

Fats. Similar in many respects to carbohydrates, the fats, oils, and waxes constitute a second great class of organic compounds. They are composed of carbon, hydrogen, and oxygen, but contain less oxygen than do carbohydrates.

Fats, oils, and waxes are familiar plant and animal products. Plant oils are frequently stored in seeds in such products as peanut oil, cottonseed oil, corn oil, soy-



Ewing Galloway, N.Y.

PREPARED VITAMINS. These are taken only when the daily diet lacks sufficient quantities of vitamins, and usually on the advice of a physician.

bean oil, or the all-too-familiar castor oil. Animals, too, store food in the form of fat. A diet containing excess sugar and starch results in storage of this excess in fatty deposits. Animal fats such as butter and lard serve as important items in our diet.

Like carbohydrates, fats are oxidized in tissues. This process releases energy and fats are a valuable source of fuel.

Proteins. This great class of organic nutrients contains numerous substances used in the formation of plant and animal tissue. Protein forms much of living protoplasm and is, therefore, essential to growth of the organism.

Chemically, protein usually contains six elements: carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. The first three elements are contained also in carbohydrates. By complicated chemical processes, plants add nitrogen, sulphur, and phosphorus to these to form the protein. These latter elements must be derived from minerals. Thus, the plant, while able to build its carbohydrates and fats from air and water, must rely upon soil minerals for other elements necessary for protein.

Worn-out soil, deficient in protein building minerals, may produce plants rich in sugars and starches. Yet, animals feeding upon such plants fail to grow because of protein deficiency.

The proper diet should consist of a balance of all nutrients; carbohydrates and fats for heat and vital energy necessary for life, and proteins for growth and repair of tissues through the formation of protoplasm.

Vitamins. A fourth class of nutrients, the vitamins, are complex organic substances found in foods and essential to plants and animals in various ways. The discussion of vitamins will be reserved for a later chapter on foods.

Summary

All forms of matter, living and nonliving are composed of certain of ninety-two chemical elements. These elements combine to form numerous compounds.

The compounds concerned with living things are formed from eighteen elements. These elements are obtained from nature in combination with each other to form the inorganic compounds, carbon dioxide, water, and minerals.

Plants alone have the remarkable ability to use these inorganic substances as a source of the elements used in the manufacture of organic compounds. As animals, we live in a purely organic world, turning to plants for our supply of life-giving substances in the form of carbohydrates, fats, proteins, and vitamins.

Thus plants link the physical and biological worlds and, through their remarkable chemical abilities, make possible the organization of such a chemical marvel as a human body.

Using Your Knowledge

1. Explain how energy differs from matter.

2. Enumerate some of the devices used to measure energy.

3. Why do scientists believe that the moon is composed entirely of inorganic substances?

4. How do you explain the fact that organic substances usually turn black when they are partially burned?

5. Consider that a log burns to ashes in ten hours. Compare the amount of heat given off in such rapid burning with the amount which would be given off over a period of ten years during the process of natural decomposition.

6. Why does paint prevent rusting?

7. Explain why some substances burn with a hotter flame than others.

8. List ten of the essential elements and indicate whether each is obtained from water, carbon dioxide, or minerals.

9. Name three classes of organic compounds or nutrients and indicate a test for each.

10. Why are carbohydrates called fuel foods?

11. Explain why an organism could not grow on a diet consisting of carbohydrates alone.

12. Where does the plant get its necessary minerals for protein formation?

Expressing Your Knowledge

matter	inorganic	carbon dioxide
energy	element	mineral
solid	compound	carbohydrate
liquid	mixture	fat
gas	proportion	protein
physical change	property	vitamin
chemical change	atom	formula
organic	molecule	symbol

Applying Your Knowledge

1. Weigh a piece of wood carefully, then burn it completely and weigh the remaining ash. Account for the difference in weight.

2. Trace the light energy given off from the lights in your schoolroom to the source with which your power company started.

3. See if you can find out what new elements have been discovered during the experimental work in connection with the atom bomb.

4. How can you prove easily that air is a mixture rather than a compound? Outline an experiment to prove this.

5. Bring in examples of each class of organic compounds you can obtain and, if possible, run a test for each.

6. Find out which vitamins are now prepared commercially in tablet or capsule form.

Increasing Your Knowledge of This Unit

CLENDENING, LOGAN. *Behind the Doctor.* Alfred A. Knopf, New York. 1933

DAMPIER, SIR WILLIAM. *A History of Science.* The Macmillan Co., New York. 1943

DARROW, FLOYD. *Masters of Science and Invention.* Harcourt, Brace and Co., New York. 1923

DARROW, FLOYD. *Story of Chemistry.* Blue Ribbon Books, Inc., New York. 1930

DEKRUIF, PAUL. *Hunger Fighters.* Harcourt, Brace and Co., New York. 1928

DIETZ, DAVID. *The Story of Science.* The New Home Library, New York. 1943

DITMARS, RAYMOND L. *Confessions of a Scientist.* The Macmillan Co., New York. 1934

DITMARS, RAYMOND L. *Making a Scientist.* The Macmillan Co., New York. 1934

DOBELL, CLIFFORD. *Antony van Leeuwenhoek and His "Little Animals."* Harcourt, Brace and Co., New York. 1932

FLEXNER, J. T. *Doctors on Horseback.* The Viking Press, New York. 1937

FURNAS, C. C. *The Next Hundred Years.* Reynal and Hitchcock, New York. 1936

HALDANE, J. B. S. *Adventures of a Biologist.* Harper and Brothers, New York. 1937

HARVEY-GIBSON, ROBERT J. *Two Thousand Years of Science; The Wonders of Nature and Their Discovery.* The Macmillan Co., New York. 1929

HAWLEY, G. G. *Atomic Energy in War and Peace.* Reinhold Publishing Corp., New York. 1945

HYLANDER, CLARENCE J. *American Scientists.* The Macmillan Co., New York. 1939

LOCY, WILLIAM A. *Biology and Its Makers.* Henry Holt and Co., New York. 1915

LODGE, OLIVER. *Pioneers of Science.* The Macmillan Co., Ltd., London. 1926

NORDENSKIOLD, ERIK. *History of Biology.* Tudor Publishing Co., New York 1942

PEATTIE, D. C. *Green Laurels.* Simon and Schuster, New York. 1936

RATCLIFF, J. D. *Modern Miracle Men.* Dodd, Mead and Co., New York, 1940

Sedgwick, William T. and Tyler, Harry W. *Short History of Science.* The Macmillan Co., New York. 1939

Singer, Charles. *A Short History of Medicine.* Oxford University Press. New York. 1928

Snyder, Emily Eveleth. *Biology in the Making.* The McGraw-Hill Book Co., New York. 1940

Thomas, Henry and Dana Lee. *Living Biographies of Great Scientists.* Blue Ribbon Books, Inc., New York. 1946

Thouless, Robert. *How to Think Straight.* Simon and Schuster, New York. 1939

Woodruff, L. L. *The Development of the Sciences.* Yale University Press, New Haven, Conn. 1941


R. I. Nesmith and Associates

Unit 2 —
The Relationships of Living Things

You would hardly expect to find a cactus thriving in a marsh, or a pond lily in a desert, but do you know why? Both are plants, composed of very similar protoplasm and carrying on identical life processes. They require air, water, and soil for life and produce similar products for growth and energy. Fundamentally, cacti and pond lilies are similar, yet they require nearly opposite surroundings.

All plants and animals have definite requirements which determine the places in which they may live. Deserts and marshes are extremely different kinds of surroundings. Yet, such similar surroundings as hillsides and hilltops, valleys and ravines, or uplands and lowlands offer conditions so different that only certain kinds of plants and animals can occupy each locality.

Biology will point out many of these differences and will explain the close relationship between living things and their natural surroundings.

Chapter 5

Vital Factors of Environment

Our study of life has centered, thus far, around two general topics — the composition and basic structure of plants and animals and the activities and functions characteristic of all living things. We learned that organisms are formed from the chemical supplies of the surroundings in which they live. These surroundings must afford, also, conditions suitable for the maintenance of life and the carrying on of all life activities. No organism is sufficient unto itself. Living things are products of a set of complicated conditions in nature which we term *environment.*

The importance of a knowledge of environment and its relation to the organism has led to the development of a special field of biology called *ecology*. In one sense, ecology is nature study, since only in nature can we observe a plant or animal responding to the conditions around it. But ecology is nature study of a most serious sort and has led scientists to all parts of the earth in their study of the many kinds of environments in which plants and animals live. Yet any woods or pond or field — even your own yard — is a part of the great out-of-door laboratory of the ecologist.

Environments in nature. Those who have taken hikes have noticed the variety of conditions under which plants and animals live. A woods, a field, a deep ravine, or a marsh all provide environments totally different from each other. Some of these differences are very obvious, while others are more hidden. Still, they all have a direct effect upon the organisms which come into their influence. Our study of ecology begins with a consideration of some of the conditions of environment which are found in the woods, the field, the ravine, or the marsh.

The conditions or influences which compose an environment are called *factors* by the ecologist. An environment is made up of many such factors, each exerting its own influence upon life and, in addition, operating as a part of the whole or total environment. Some of these factors are *physical* and include such influences as soil conditions, temperature, light, water, atmospheric conditions, and land formation or topography. These forces, and others, make up the physical environment. Equally important are *biological* factors or the living surroundings of the organism. A plant or animal lives under constant influence of other living things. The individual organism is a part of a large society of life, closely bound to the nonliving influences of its surroundings.

The relationship of organisms to each other is of such importance that the next chapter is devoted to its study. For the present, we shall consider only the physical factors of the environment.

Environment and the distribution of life. The earth offers a wide variety of conditions for life, and over its surface organisms have spread gradually until all regions support life in some form. Due to changes in their characteristics, which may occur from time to time, plants and animals have become varied in their requirements. Otherwise, living things would be forced to crowd themselves into small areas of favorable surroundings and much of the earth would be unpopulated.

Thus, our study of environment must include not only the factors which form it, but the adaptations which make an environment suitable to certain forms of life.

Soil, a basic factor of environment. To many, soil is just the dirt which covers the earth. But to the biologist, soil is one of the most important factors of an environment. Careful examination of soil shows that it varies greatly in different localities and that the life it supports varies accordingly.

The study of soil is very complex. Yet, very obvious differences are apparent even to the casual observer. Its texture varies from place to place. Some soils are heavy with clay, while others are loose and sandy. Some, we classify as loam; others, as clay loam or sandy loam. To say that plants prefer any particular type of soil would be incorrect, for adaptations have varied their requirements. Sandy soils may support a forest of pine in Michigan, New Jersey, Georgia, or east Texas while heavy loam supports a beech and maple forest in Ohio or Indiana. Water-logged soils of bogs and swamps provide ideal conditions for larch, white cedar, and cypress forests, while the rocky, shallow soils of mountain slopes produce luxuriant forests of redwood, yellow pine, and Sitka spruce in our western states.

Soils vary likewise in chemical nature. They may be acid or alkaline or, to use the terms of the gardener, sour or sweet. Fertility and richness which are governed by mineral content and decayed organic matter, likewise alter conditions of soil.

Philip D. Gendreau, N.Y.

COASTAL PLAIN FOREST. Sandy soils support pine forest growth in these regions.

The character of any soil is constantly changing. In one place, additions are being made because of the breaking down of rocks into tiny particles, due to the action of weather and chemical disintegration. In other places, the mineral content of the ground is being weakened because of the quantities of salts taken into plants by their roots. Certain soils may be building up through the decay of successive layers of vegetation allowed to return to soil, while other soils become impoverished due to heavy crop production and failure to replenish the exhausted mineral supplies. Much useful farm land is ruined by bad soil care.

As soils change, plants and animals must migrate. In civilized countries, these soil changes may become vital problems. Our crop plants and natural vegetation upon which we build our economy must have suitable soils. The study of soil and its relation to plants and animals is a major problem of the ecologist.

Temperature, a controlling factor of environment. Temperature is a part of a group of weather conditions which we include in the term *climate*. In the temperate regions of the earth, including most of North America, temperature changes range from the narrow fluctuations between day and night to the much more extreme differences in summer and winter temperatures. Even greater variations are found in comparing geographical regions of the earth and at different elevations on mountains.

All of these temperature conditions have an effect upon plants and animals. Any organism must be able to withstand the slight variations between day and night. However, seasonal variations between winter and summer present a much greater problem. Since seasonal temperature changes are only temporary, plants and animals cannot adapt themselves to either extreme. The manner in which organisms meet these seasonal problems is indeed interesting.

Most trees and shrubs in temperate regions flourish through the warm weather of spring, summer, and fall and enter a dormant or inactive period through the colder months. Leaves may fall and sap may move to parts of the plant which are not injured by freezing. Or, like the pine, spruce, and other evergreen trees, leaves may remain green throughout the winter, even though most activity in the plant has ceased. Plants which are not woody may die to the ground and then reappear from dormant roots or from seeds, in the spring.

Animals, likewise, meet these seasonal temperature changes in many interesting ways. They may remain active all winter, seeking shelter only during the most severe periods. Others *migrate* to warmer regions and return with the coming of more favorable weather. Still others, like the bear, just sleep out the cold weather, or to use a more scientific term, *hibernate*.

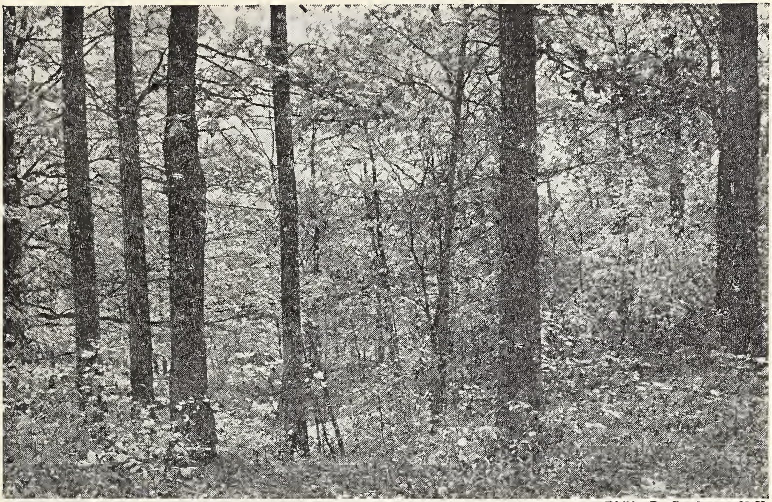
The effect which temperature has upon plants and animals in different geographical regions is even more pronounced. Other factors of climate such as water supply, play an equally important role in the geographical distribution of living things. These great climatic differences are met by adaptations of the body structure and activities of plants and animals.

North America is situated in three great climatic regions, and thus has a wide variety of vegetation and animal life. From the frigid wastes of Alaska and northern Canada, through the plains, prairies, and forest lands of the temperate zone, to the semi-tropics of southern Florida and the hot, dry deserts of the Southwest and Mexico, plants and animals thrive because of adaptations to temperature. A knowledge of biology offers wonderful opportunity to appreciate the great variety of living things which inhabit the various regions of North America.

Sunlight and life. Light is a critical factor in the environment of living things. We cannot say that light is essential to all living things, but we can say that without light there could be no life.

Light is essential to all green plants in food manufacture. This is because light supplies the energy which all foods must contain to nourish the organism.

We find many plants and animals living in complete absence of light. Blind fish with undeveloped eyes have been found in underground streams and rivers in the Mammoth Cave of Kentucky. Likewise deep sea fishes live at depths to which light cannot penetrate. We are



Philip D. Gendreau, N.Y.

Deciduous Forest. Few evergreen species are present in this type of forest.

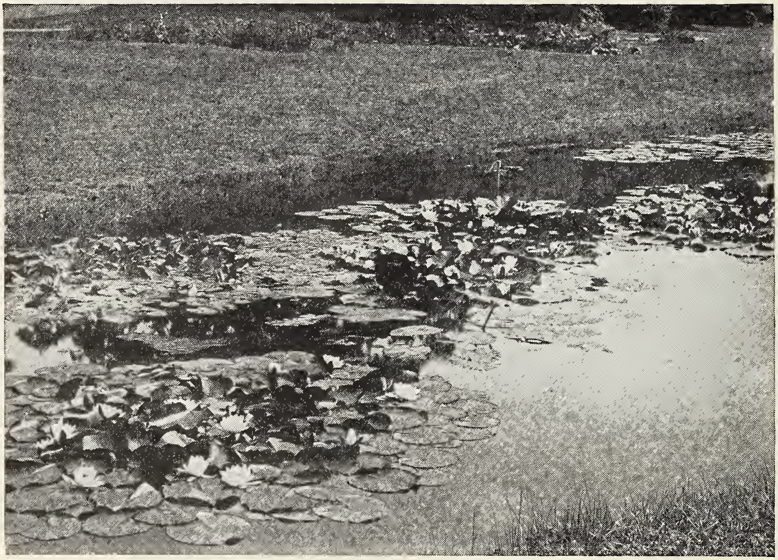
all familiar with molds which thrive in total darkness. Many bacteria live without light and are killed by long exposure to direct sunlight. Yet, careful study of all of these forms which live in darkness shows that they depend indirectly upon light for their existence. They all require food and its stored energy for their activities — food which can be traced back to the green plant and its food-making processes which are dependent upon light.

Like temperature, light conditions vary from place to place. Anyone who has used a light meter in taking pictures is well aware of these variations in light intensity. Deep ravines or valleys, the floor of a forest or the north side of a hill offer places of reduced light to ferns, hepatica, mosses and many other plants which require these conditions. Here, we find also the snails, toads and salamanders which prefer a cool, shaded environment.

Open fields, southern slopes and other exposed places offer ideal situations for plants which require intense sunlight. Associated with these plants which require light, one finds rabbits, groundhogs, coyotes, badgers, prairie dogs, ground squirrels, and many other animals which populate typical communities in exposed places.

Water and life. Probably no factor of the environment has a more pronounced effect upon living things than the water supply. To meet their critical water requirements, plants and animals range from purely aquatic forms living in a complete water environment, to those which thrive in sun-parched deserts. All living things require water. But the manner in which this demand is met by varied plants and animals is a subject of never ending interest to the ecologist.

The oceans, lakes, streams, and ponds contain plants and animals which require a constant water environment. To the *aquatic* organisms which live in these surroundings, water supply is, nor-



WATERLILIES. These aquatic plants require a water environment in which to perform their life functions.

mally, no problem. But the body structure of these organisms is such that they must perform all of their functions in water. Removed to land, even in the wettest surroundings, they soon die.

Plants and animals of the swamps and bogs show a modification for life both in the water and on land. Here we find the *semi-aquatic* forms such as cattails, pond lilies, bull rushes, cranberries, frogs, turtles, and muskrats.

Organisms which live on land require less water than aquatic and semi-aquatic forms, but must depend on water supply nevertheless. Rainfall operates as a powerful factor in controlling the lives of these land or *terrestrial* plants and animals. So with variations in rainfall and atmospheric moisture, land dwelling organisms must find areas of moisture suitable to their individual requirements. The relation between rainfall and life is so critical that a biologist need only examine the plant and animal life of any region to judge accurately the annual rainfall and amounts of moisture normally present in the atmosphere.

Abundant rain and a warm, moist atmosphere brings about a riot of growth in the impenetrable jungles of the tropics. Here plants produce large leaves and require relatively small root areas since water is abundant. Many plants, like the tropical orchids, require no contact with soil moisture at all, and grow on the branches of trees, with their roots hanging in the warm, humid air.

As rainfall decreases and the air becomes more dry, plants face a greater problem of water supply. Root areas become larger and leaf areas smaller. This results in an increased absorbing power and in a reduction of evaporation of water from leaf surfaces into the atmosphere. In regions of moderate rainfall, plant distribution becomes most interesting. Here we find plants occupying lowlands, or moist uplands, or dry hillsides and ridges, depending upon the requirements of the plant and its adaptations for obtaining water.

Grass-covered plains occur where rainfall is low and hot, dry winds produce periods of drought. The great grasslands of our Midwestern states, while not suitable for forests, provide ideal moisture conditions for cereal crops, and have become the grain belt of the nation.

The extreme drought-enduring organisms inhabit the very dry desert regions. Nature has modified these organisms so that they can withstand long periods of rainless weather in a dry, hot atmosphere which parches the soil in which they live. Plants in these regions have little or no leaf area and extensive, shallow root systems which capture the water that is provided during a brief rainy season. The greatly enlarged stems of such plants as the cactus provide storage room ample to hold a supply of water sufficient to last many months until another rainy season. One might suppose that cacti and other desert plants would thrive if they were supplied with more water. But certain modifications to withstand drought have so altered them that excess moisture kills the plant, as all of us have found when we have given too much water to the potted cactus plants which we grow in sunny windows in our homes.

The rather sparse animal population of the desert has its water problem, too. Such animals as the kangaroo rat, gopher, rattlesnake, bullsnake and many others, inhabit this area. Being able to move about, they may escape the killing heat of day by burying themselves or seeking shelter under plants. Their rather small water requirements must be satisfied, directly or indirectly, from supplies stored in plants.

Orchids in the Crotch of a Tree. These tropical plants require no contact with the soil. Their roots hang in the warm, humid air from which they obtain their necessary minerals dissolved in rain water.

The atmosphere, a factor of environment. Even the air about us has a direct effect upon all living things. We learned that oxygen composes about 20 per cent of the volume of the air at sea level. With the exception of certain bacteria, all living things must have oxygen for life. This oxygen may be taken directly from the atmosphere or, as in the case of fishes, may be taken as a dissolved gas in water.

Plants and animals living on the earth's surface normally receive abundant oxygen, but those living in the air, in water, and within the earth itself meet critical oxygen problems.

Air travel has brought with it oxygen problems, since oxygen content decreases with altitude. Even mountain climbers experience breathing difficulty in reaching altitudes of only a few thou-

A Barley Field. This important cereal is grown in the Midwestern states where the rainfall is adequate for grain crops.

sand feet above sea level. Pilots flying above 20,000 feet experience serious oxygen shortage and in reaching higher altitudes must depend entirely upon reserve oxygen supplies carried in tanks.

Life in the deep sea has even a greater oxygen problem. Water receives its supply of oxygen from air. Hence, the oxygen content decreases with depth. The ocean reaches a depth of over 35,000 feet in the Mindanao Deep off the Philippine Islands. Yet, even the deep sea fishes cannot reach those depths. In fact, most deep sea fishes live less than a mile below the surface and no life has been found below 23,000 feet.

Plants and animals which live in the soil are most abundant near the surface. Partly because of food supply, and certainly because of oxygen supply, life is limited in the depths to which it can penetrate the soil.

Air pressure, likewise, has a direct influence upon living things. Storms may destroy plants and drive animals to shelter. Air currents and winds have a much greater effect upon life than most of us realize. Air causes water to evaporate, and winds greatly increase the rate of evaporation. Plants and animals of windy plains and prairies must not only survive the wind itself, but also the accompanying loss of water by evaporation. We have all seen, through first-hand observation or from pictures, the timber line on mountains where high winds force trees to grow close to the ground and to form their branches only on the protected side.

Land formations provide varied surroundings. Land is ever changing. Changes in the surface or *topography* [*toe pog′graphy*] of the earth usually occur slowly, but have a profound effect upon plants and animals.

Due to stresses within the earth, huge

Giant Cacti. These desert plants live only where the rainfall is low. Their greatly enlarged stems provide space for the storage of water.

One-Sided Tree Near Timberline. Why are the branches developed only on the protected side of this tree?

A Pitcher Plant. This unusual plant grows only in the acid soils of a bog.

masses of rock and soil rise, forming mountains. Rivers cut channels and gorges, and form broad, fertile plains with the soil which they transport. Wind and water, through forces of erosion, carry soils from one area to another. Alternate freezing and thawing during the winter months loosens the soil, and produces cracks in the rocks. These slow processes gradually form new soil.

During the glacial period about 25,000 years ago, huge masses of ice pushed slowly south from northern Canada, leveling hills and filling valleys with great deposits of transported soil and rock. With the melting of the great ice sheets, hills of soil or glacial drift were left behind in the form of moraines, so characteristic of glaciated country.

These changes in the surface of the earth, though slow, are constant. As the earth changes, plants and animals must migrate to new and more favorable areas, to be replaced by other organisms more suited to the changed conditions.

Adjustment to surroundings. Plants and animals vary widely in their ability to endure different environments. Certain plants like the willow, the cottonwood and the dandelion range over wide areas because of the ability to adjust to many types of environments. Frequently, plants and animals capable of making such adjustments readily become pests. The crow, the English sparrow, and the starling are able to vary their diets and living conditions to fit numerous environments and, consequently, occur over a very wide area.

Other organisms are much more critical in their needs and are limited, therefore, to specific environments. The pitcher plant requires the acid peat soil of a bog, while the rhododendron and mountain laurel flourish only on the moist hillsides of our eastern mountains. Moist canyons within the fog belt of the Sierra mountains of California supply the critical needs of the Big Trees (Sequoia). These organisms are thus limited by environment. Their range of distribution is small.

Summary

Plants and animals live in close association with their natural surroundings. The various factors which form an environment have a direct and critical influence upon life.

Physical factors of the environment include soil conditions, temperature, light, water, atmospheric conditions, and earth changes. Any variation of these factors results in the different sorts of environments which are found in nature. Each environment supports particular kinds of plants and animals especially adapted to it. This results in a general distribution of living things according to certain special types of environments.

As environments change due to variation in certain physical factors, so life in the environment must change accordingly. The extent to which plants and animals must shift with a changing environment depends upon the extent to which they can endure the new surroundings.

The relationship of the organism to the surroundings and the effect of each environmental factor upon life are subjects of never ending interest to the ecologist.

Using Your Knowledge

1. Distinguish the physical factors of environment from biological influences.
2. Explain how environment controls the distribution of life forms.
3. List some of the variable characteristics of soil.
4. What factors of the environment are included in the general term climate?
5. Explain several different manners in which organisms meet the problem of seasonal temperature variations, giving an example of each type of adjustment.
6. Explain how organisms which live in total darkness actually depend, indirectly, upon sunlight for life.
7. Why are plants such as the tropical orchids restricted to moist, warm regions of the earth?
8. Explain how glaciers alter the environment of plants and animals.
9. What reason can you give for the fact that the Big Trees are restricted to certain areas of California?
10. In terms of adjustment to surroundings, explain why the crow and English sparrow have become pests.

Expressing Your Knowledge

ecologist	hibernate	glacier
factor	environment	drift
distribution	aquatic	evaporate
acid	semi-aquatic	drought
alkaline	atmosphere	jungle
climate	humid	ravine
variation	Mindanao Deep	critical factor
migrate	erosion	fluctuation

Applying Your Knowledge

1. Select a particular place on your school grounds or near your home and make a list of the environmental conditions which influence a plant growing there. Include both physical and biological factors.
2. Select a hill in your community and make an analysis of the plants growing on the north side and compare them with those of the south side. Account for the difference in terms of environmental factors.
3. Visit a stream or pond and notice carefully how the plants and animals in aquatic surroundings differ from land forms.
4. Using an outline map of the United States, shade in the principal forest areas, grasslands, and deserts which compose our land. Use a different color for each kind of vegetation and indicate each with a key in the margin of the map.
5. Keep records of the climatic conditions in your area for a week. Include daily high and low temperatures, average temperature for the week, amount of rainfall, hours of sunlight, wind direction, and wind velocity. The data can be found on the weather map in your daily newspaper.

6. Obtain weather data for various areas of the country, including annual rainfall and average temperature. See if you can correlate climatic conditions with the vegetation of each area.

7. Prepare a report on the glaciation of North America. Include the period of glaciation, the location of the glaciers, and the effect of glaciation upon the topography of North America.

Chapter 6

Balance in the World of Life

The phenomenal progress of the human race has given many of us the impression that man is rapidly becoming a self-sufficient organism. Many, no doubt, wonder if the achievements of science will not, some day, make man entirely independent of nature.

It is true that human ingenuity has overcome most of the hardships and problems imposed upon other forms of life by physical factors of environment. We can regulate the temperature in our homes to suit our needs, provide light as desired, supply adequate water, and even alter the face of the earth with our power shovels, bulldozers or blasting powder.

But with all of his knowledge and inventions man still cannot isolate himself from his living environment. We are a part of a world of life — a balanced world in which organisms perform their functions in close association with other living things. Our lives are part of this intricate balance. We are supreme among living things — yet dependent for our very existence upon even the lowliest of organisms.

Life is a series of processes. The processes of one organism depend upon those of another. Plants depend upon animals, and animals upon plants.

Life depends upon constructive processes. It depends, equally, upon destructive processes. Construction must equal destruction. Food is produced by life and is broken down by life. Living things store energy and use energy. Oxygen is used up and oxygen is given off. Throughout life, plants and animals grow through construction processes, only to be destroyed, after death, by other living things.

Such are the cycles of nature — cycles involving many organisms — cycles without which there could be no life. Such is the balance in the world of life.

Nutritional relation of living things. Nowhere is the interdependence of living things more obvious than in the study of their food relations. Here, we see an absolute dependence of living things upon each other.

Food is a critical need of all organisms, for it must supply the materials for forming protoplasm as well as the energy for maintaining life. To serve as a food, a substance must possess certain properties which make it usable by living protoplasm. Protoplasm alone can give it these properties. In other words, foods are the result of the constructive processes of life. Nature supplies only those materials which form foods. The foods themselves are products of life.

Food requirements bring about a

close dependence of living things upon each other. Only green plants possess the remarkable ability to form organic food materials from inorganic materials in nature. The leaves and stems of green plants perform the task of preparing this food for the entire world of life.

The food making ability of the green plant makes it an *independent* organism. Organisms which must derive prepared foods directly or indirectly from plant life are nutritionally *dependent.* To this latter group belongs the entire animal kingdom and large numbers of non-green plants including such familiar forms of life as molds, bacteria, yeasts, mushrooms, and a host of other plants. To remove himself from this group of dependent organisms, man would have to devise some method of duplicating the chemical processes of a green leaf. Perhaps this seems simple in view of our advanced knowledge of chemistry. Perhaps we will eventually learn the secret. Until then, we must reserve high regard for our neighbors, the green plants. To them we owe our very existence.

The food producing role of the green plant is only half of the story, however. Nature operates in cycles. Food formation is a constructive process and must be balanced by equal processes of destruction. Plants must receive a constant supply of the materials with which to form foods; else food making would in time exhaust these necessary supplies. At this point, all life enters into the food cycle. Dependent as well as independent organisms destroy food within their bodies and release, through excretion, the very substances required by the plant in food manufacture.

Foods used for growth undergo further processes of construction and are, thus, temporarily " lost " from the cycle. But this " loss " is only temporary, as life is temporary. After death, destructive processes are carried on to a great extent by bacteria and other fungus plants. These reduce the organism to the simple substances used by the green plant in forming more food to supply new generations of living things.

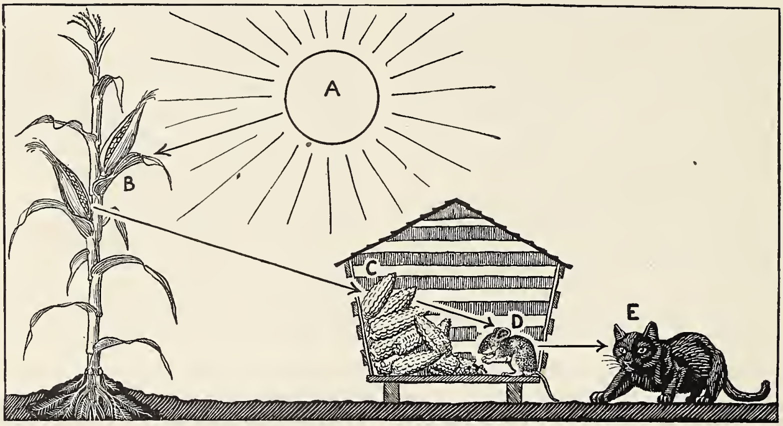
Such is the complex cycle of food and nutritional relations in the world of life. All organisms enter into some phase of it. Some carry on the constructive processes and others the equally important destructive processes. All make constant use of the food supply.

Energy relations of living things. The supply of energy for life is closely bound to the food supply, for foods serve as the storehouse for energy.

The sun is the original source of all energy and the direct source of energy for life. Actually, all organisms run on sunshine. But, while sunlight is everywhere, its boundless energy is available only as it may be released from food within the body.

Again, all life is dependent upon the green plant which absorbs light energy and locks it into molecules of food substances. In this form it may be taken into organisms where it is released for life activity during food destruction in the cells, or stored for future use.

Energy may be passed on from organism to organism in an almost endless cycle. As animals feed upon plants, energy contained in the plant substance is transferred. Some energy will be used in activity but much will be retained in the substances composing animal matter. Should the animal fall prey to another animal, energy will again be transferred. As an example of this cycle, consider what happens when a field mouse eats grains of corn which are stored during the winter in a farmer's corn crib.



THE ENERGY CYCLE. Trace the energy in the body of the cat back to its original source.

The energy stored in the grains of corn was obtained from the sun by the green corn plant when it was growing in the field. Then, when the mouse ate the grains, the same energy was transferred to his body. A cat belonging to the farmer was prowling around the corn crib one night, and spied the mouse which he caught and ate. The energy in the mouse was then transferred to the body of the cat.

The oxygen-carbon dioxide balance. We are all aware that we breathe oxygen into our bodies and exhale carbon dioxide as a waste gas. But perhaps we have not realized that our respiration is a part of another of nature's cycles. Our breathing activity involves the elements carbon and oxygen. We use oxygen in the oxidation of food materials in our tissues. This oxygen combines with carbon contained in food to form carbon dioxide. This process is reversed in food making in the plant, where carbon dioxide is required as a source of carbon and oxygen is released as a waste product. Thus food manufacture and respiration form a cycle; one process using carbon dioxide and releasing oxygen while the other uses oxygen and releases carbon dioxide.

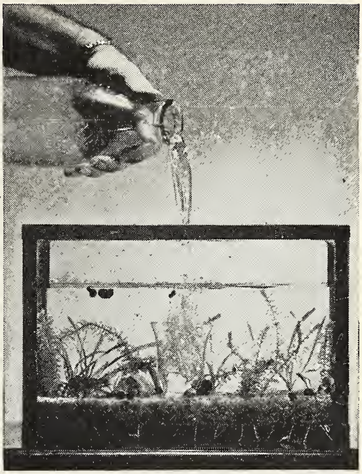
Balance in an aquarium. The relation between plants and animals in one type of environment may be shown in a small way by examining two types of aquariums. In one type only plants will be found. These grow quite well by themselves, and live for indefinite periods of time without the presence of any form of animal life. In the other type, animals such as fish, snails, or salamanders are also present. The plants furnish the food which the animals need because the animals could not live in pure water without some source of food. It is probably true that the presence of the animals in the aquarium does somewhat improve the environment of the plants, by increasing through their waste products the organic matter needed for food manufacture by the plants. But the plants can live without the animals, and very often do. The important observation is that the plants are the immediate source of food for the animals, and without the plants the animals could not live.

The nitrogen cycle. In a discussion of the cycles of nature, nitrogen is of such critical importance to plants and animals that it can hardly be omitted. Not only is nitrogen an ingredient of all protein foods; it is essential for the formation of protoplasm. Plants obtain nitrogen compounds from the soil, mainly as soluble nitrates. They use them in making their living tissues, which, in turn, furnish to animals their only source of nitrogen-containing food for growth.

One might suppose that plants would exhaust soil nitrates, but nitrogen contained in living matter is not permanently out of reach. After the death of plants and animals, protoplasm is reduced during decay to simple nitrogen compounds which return to the soil to be re-used by other plants. Life exhausts soil of nitrogen during constructive processes, but the destructive processes of decay replenish it.

Further dependence of life upon life. Nature is full of examples of the intimate relation and interdependence of organisms. Man uses both plants and animals not only for food, but for clothing, fuel, and shelter as well. He has been called a " parasite on the cow," and when we think of all the products we obtain from this useful animal the expression seems justified. Without the milk, meat, leather and other products which the cow provides, life would be more difficult.

Birds depend upon plant life in many ways. Without plants, many birds would be deprived of nesting places and necessary cover for protection from numerous enemies. Plant life feeds great numbers of birds in the form of seeds and fruits. The birds are just as necessary to plants because they destroy large numbers of harmful insects, distribute seeds, and render other services.



Monkmeyer Press Photo Service

A BALANCED AQUARIUM. What do the plants furnish which the animals need? What do the animals furnish that the plants need? A tumbler placed at the bottom of the glass tank permits the rapid pouring of water without disturbing the living organisms within.

The soil shows many interesting ways in which plants and animals depend upon each other. Earthworms get their living from organic matter deposited in the soil in the form of decaying plant and animal matter. They, in turn, serve future plants by loosening and turning the soil due to their habit of carrying subsoils to the surface as they burrow. While the activity of any one worm may seem insignificant, the entire earthworm activity in any given area may affect all of the plants of that area.

Even those lowly molds which thrive in soil may affect other plant life to a remarkable degree. Foresters tell us that the American beech tree requires certain molds living among its roots. Without these molds, the tree cannot live normally. If such a tree is transplanted, soil containing these essential molds must be carried to the new location. Imagine the

Birds Nesting in a Tree. Of what value to birds are trees?

giant beech tree depending upon a mold for its very existence!

Orchid growers have found, similarly, that many of the orchid plants require an association with a form of mold. Certain orchid seeds, often almost impossible to germinate, produce abundantly when sprouted among the threads of certain types of mold plants.

The activities of bacteria in the soil are so important that they will be discussed at length in a later chapter. These tiny organisms, through a series of chemical activities, form substances in the soil without which plant life could not exist. Thus, since we depend directly upon plants for our existence, and plants depend upon soil bacteria, we may go so far as to say that human life is dependent upon the lowliest of organisms — the bacteria.

Nature's checks upon living things. A rather strange form of interdependence of life is shown in the checks upon organisms maintained in nature. Any organism, uncontrolled, would soon become so abundant that the balance between living things would be endangered or even destroyed. In this way, one organism could become a hazard to all others. Fish in a stream are an essential part of the balance in such a community but, unchecked, could become so numerous as to destroy the plants and animals which they require for life; thus, it would easily be possible for them to destroy themselves.

Living things are held in check by other living things called *natural enemies*. Birds prey upon insects and insects upon plants. Even such predatory animals as wolves, foxes, and coyotes, considered pests by many of us, play an important part in maintaining the proper balance in nature. Destruction of all of these creatures might bring disastrous results when the animals upon which they feed became too numerous.

Ewing Galloway, N.Y.

A Barn Owl Entering Her Nest with a Rat. Predatory birds kill large quantities of rats and other undesirable animals.

Man and the balance of nature. Most organisms live entirely according to natural laws. Under these conditions all plants and animals live in the proper relations of interdependence and the natural cycles operate normally.

Man, however, has sufficient intelligence to challenge this balance for the sake of his own betterment. In so doing, he has dangerously altered many of the cycles vital to his own existence. Now he must pay the price or restore the balance with which he has tampered.

For example, let us consider the soil. In the normal cycle, plants absorb soil minerals and build them into foods — food for the plant, and food for animals and dependent plants. The plants flourish for a time and then return to the soil from which they grew. The animals and dependent plants likewise eventually return to the soil. Normal soil in the forest is rich in decaying matter from the leaves and stems and roots of trees and other plants returning to soil. Grasslands support very fertile soil because no minerals are permanently removed.

Man has greatly altered this condition, however. We cultivate soils to grow crops and then remove the crops from the fields. Later crops prove less valuable because of a lack of minerals. Finally, we begin to pay the price in vitamin and mineral deficiencies. We must rebuild our soils or suffer bitter consequences.

Civilization has upset much more than soil balance. Pollution has destroyed plants and animals in our streams and has left them as ideal breeding areas for mosquitoes. Wholesale destruction of plant life has reduced bird population for lack of cover and breeding grounds. As a result, insect pests swarm into our gardens and destroy the crops we need for food.

Ewing Galloway, N.Y.

A Worn-Out Field. This field would have produced a better crop of cotton if the soil had been fertilized adequately.

The grasses of our plains and prairies have been plowed under for cultivation of more land for crops or have been destroyed through overgrazing. These grasses no longer supply the fertility to the soil which made these lands the bread basket of the nation.

These are only a few of the influences of civilization upon the balance of nature. Other examples are on every hand.

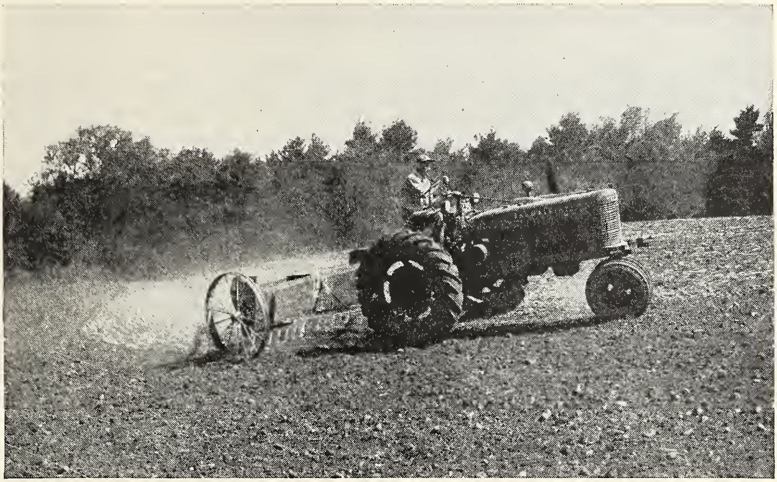
Conservation, our hope of restoring the balance. Naturally, we cannot restore America to the condition in which our pioneer ancestors found it. We value our civilization too highly for that. It is possible to build cities, grow crops, use lumber, and carry on all of the other activities civilization demands and still not upset the balance of nature. Our present condition has resulted from ignorance, not from necessity.

Biologists now face a tremendous task in correcting, within a short time, conditions brought about by generations of misuse of nature. Biology has shown us the intricate relationship between all living things. We now understand the cycles in nature and realize the extent to which we have upset these cycles.

The task is now one of conservation. Federal, state and local agencies are at work replacing destroyed plant life, restoring necessary animal life, and rebuilding the worn-out soils of the nation. We will deal with conservation many more times in our study of biology — it is one of the most important reasons for studying life.

Summary

Life depends upon life. No living thing is entirely self-sufficient. The interdependence of plants and animals is shown in the food and energy cycles of life. Green plants serve as the food factory of the living world, but rely upon



LIMING A FIELD. Why is it necessary to restore essential minerals to the soil?

other forms of life for the materials with which to form foods. Soil, the source of minerals to plants, must be conditioned by many plants and animals. Through this interdependence every plant and animal fits into the world of life — dependent upon other organisms for certain needs and contributing in some manner to other living things.

The most serious threat to this necessary balance is man himself. The inroads of civilization have been so costly to nature that we have endangered our own future. Conservation, through understanding of the interdependence of living things, is our hope of re-establishing the balance in the world of life.

Using Your Knowledge

1. Under what conditions is an organism termed independent?

2. Starting with the sun, trace energy to your own body.

3. Explain the principles of a balanced aquarium.

4. How is soil fertility maintained through natural means in the woods? How does this illustrate interdependence?

5. In what ways do birds depend upon plants? How do the plants, in turn, depend upon birds?

6. Explain the relationship between certain molds and higher plants such as trees.

7. Discuss the role of natural enemies in maintaining the balance of nature.

8. Mention some of the ways in which civilization has upset the balance of nature.

9. Discuss the role of conservation in restoring the balance.

Expressing Your Knowledge

constructive process
destructive process
independent
dependent
interdependence
balance
energy cycle
food cycle
nitrogen cycle
parasite
natural enemy
predatory
cultivate
pollution
conservation

Applying Your Knowledge

1. Prepare a balanced aquarium, cover it with a glass plate, and see how long the plants and animals live in the aquarium without your attention.

2. Construct a diagram of a food cycle showing how the substances composing it originate from the soil, pass through several organisms, and return to the soil.

3. Make a list of some of the predatory animals of your region and list the animals which each helps to hold in check.

4. Prepare a report on the effects of civilization on the balance of nature in your community. Even if you live in a city, certain effects can be seen. Study vacant lots and railroad right of ways.

Chapter 7

Classification of Plants and Animals

Over 340,000 kinds of plants and over 800,000 kinds of animals are, today, known to science. The task of naming and grouping all these life forms has been enormous and has been accomplished only through the combined effort of biologists throughout the world.

Classification, as this naming or grouping is called, represents one of the specialized fields of biology. Specialists in the field are called *taxonomists* [*tax-on'o mists*]. Their work is carried on according to an international system of classification which has been in use for nearly two hundred years.

If you happen to be a stamp collector, you are probably familiar with the principles of scientific classification, for postage stamps are classified in much the same manner as plants and animals. The collector divides his stamps first into countries, then into issues, denominations, and varieties. By tracing an unknown stamp through these various groups and subgroups, the experienced collector may separate it from all other stamps and find its allotted space in his collection.

This chapter will explain the scientific principles of classification. You will learn the methods by which biologists have named and sorted into orderly groups over one million different kinds of living things.

Common names of organisms. Long before science devised a system of grouping and naming the living organisms of the earth, man found it necessary to give names to the plants and animals with which he lived. These *common* names were usually based upon certain characteristics, habits, or uses of a plant or animal. Such names as sunflower, buffalo grass, blue grass, cattail, redwood, rattlesnake, and ground hog, familiar to all of us, probably were given to these organisms by the early pioneers who broke the North American wilderness and found these plants and animals. As civilization spread and new organisms were encountered, the long list of common names was expanded.

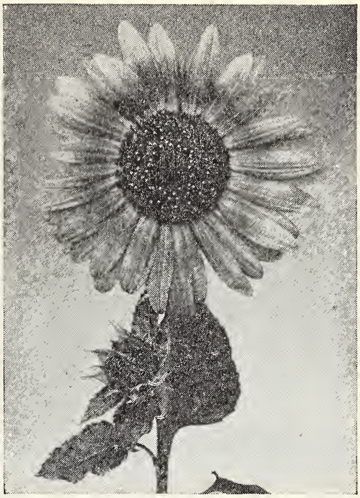
The majority of people use common names in referring to plants and animals. These names are most familiar and are frequently used even by biologists. As long as a common name means a particular plant or animal to you, it is advisable to use it. Yet there are several reasons why common names cannot be used in the scientific study of plants and animals.

If a plant or animal had but one common name, it would be quite usable by a scientist. But such is usually not the case. Frequently an organism is called by different names in the various regions in which it is found. A North American woodpecker, for example, is called flicker in certain localities while in others it is called yellow hammer, high-hole, and golden-winged woodpecker. Fortunately, the woodpecker, being unaware of any of its names, is spared the confusion which we have created in trying to refer to it.

These conflicting common names become even more confusing when plants and animals are distributed across our international boundaries. Each language spoken in foreign localities adds another list of names for the same organism. A scientist attempting to describe a plant or animal could not possibly use all of its common names.

Another manner in which common names have been duplicated is in the reference to several organisms by the same name. When you speak of a buttercup, just what do you mean? Probably you refer to a small, yellow flower with yellow, waxy petals. Yet there are many such flowers and they are all called buttercups. Bluebell, daisy, blackbird and bluebird are other common names which refer to several different organisms. Common names are not specific and are not, therefore, scientific.

Still another objection to common names is the lack of scientific basis for their selection. Fish, to a scientist, means a type of animal with a backbone, scales,

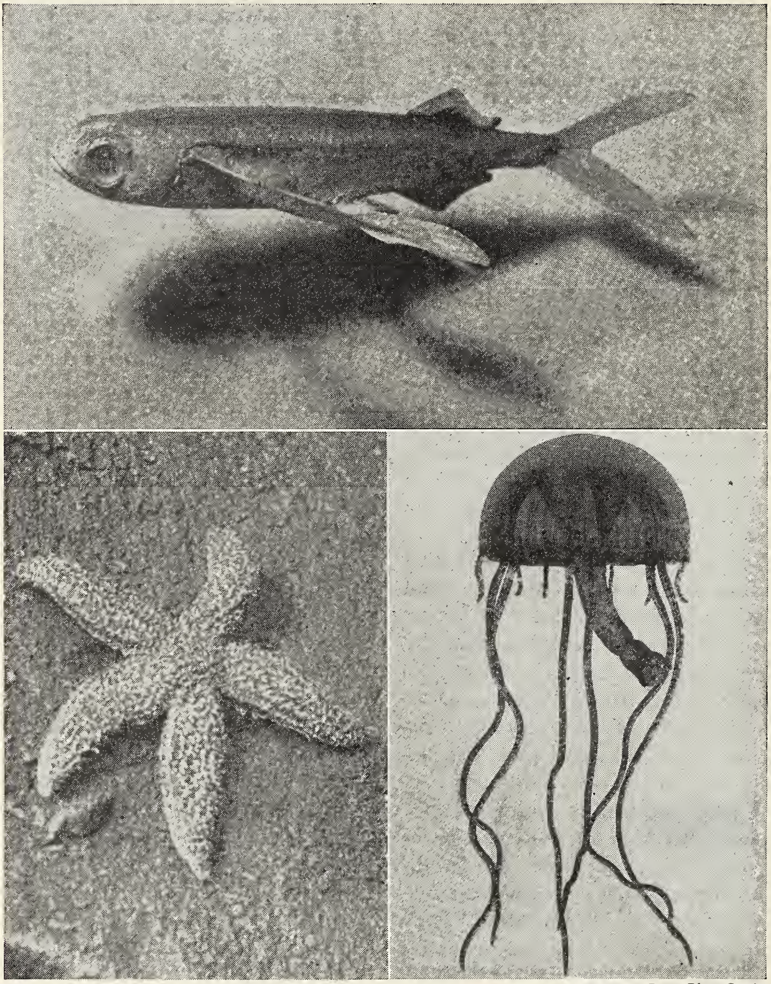


A Sunflower. Not everyone calls this flower by this name. Some people call it the "yellow daisy." Others know it as the "canary seed flower."

fins, and gills for breathing. Yet, in the realm of common names, an insect is called a silverfish, clams and oysters are called shellfish, and other animals in no way resembling fish are called crayfish, jellyfish, and starfish.

These are only some of the reasons why biologists cannot use the common names of organisms. Science is international. Biologists the world over must co-operate in the study of organisms. They must "speak the same language" in referring to plants and animals.

The beginning of scientific naming and classification. For nearly two hundred years a scientific system of grouping and naming plants and animals has been used. This system began in 1735 when a Swedish botanist, Carolus Linnaeus, began the systematic naming of plants. His work was published in a book called *Systema Naturae* in which each plant was given a Latin name consisting of at least two parts. These names



Monkmeyer Press Photo Service

DIFFERENT KINDS OF "FISHES." Top: a flying fish; lower left: a starfish; lower right: a jellyfish. All animals whose common names end with "fish" are not structurally alike, nor are they necessarily closely related organisms.

referred to some characteristics of the plant or, in some cases, to the discoverer. Zoologists soon adopted Linnaeus' plan and began to name animals. Today, every known plant and animal has a scientific name which is universally used.

Latin was selected as the basis for scientific classification for several reasons. It is the basis of many languages and is understood by the learned people of most nations. Furthermore, Latin is unchanged. Its words no longer come into use and disuse. Another advantage is its descriptive qualities, which are ideal for the selection of appropriate scientific names.

The basis of scientific classification. Plants and animals could be classified according to several plans. For instance, size might be used. But size shows no definite relationship of one organism to another. A mouse and an insect may be about the same size, but the mouse is much more like an elephant than like an insect. Again, organisms might be grouped according to their habitats or surroundings. But other problems arise, for a seal is much more like a cat than like the fish with which it lives.

We can readily understand why the cat, lion, leopard, cougar, and tiger are grouped together — they look somewhat alike. By this system, science groups the cow, buffalo, deer, and caribou, together because of similarity in body structure. Scientific classification is based upon *structural similarity*. Such a system provides the only real basis for logical grouping of related plants and animals.

How scientific names are written. Linnaeus' system of giving each organism a scientific name of at least two parts is called *binomial nomenclature*. The first name is called the *genus* [*jee'nus*] (pl. *genera* [*jen'era*]) and begins with a capital letter. The *species* follows, and begins with a small letter. The genus name is usually a noun and the species name an adjective; the genus name precedes the species name as in regular Latin order. We follow this order in our lists of names in all formal records, when John J. Smith would appear as Smith, John J. Scientifically written, his name would appear Smith, John J.

Scientific names become more significant when they are used. For example, *Pinus strobus* is the scientific name for

CARIBOU. In what ways does this animal resemble a cow?

the white pine. It is a species or kind of pine. Wherever it grows it is called *Pinus strobus*. Furthermore, no other plant has this name. *Pinus resinosa* is the red or Norway pine; *Pinus rigida*, the pitch pine; *Pinus pungens*, the mountain pine; and *Pinus ponderosa*, the western yellow pine. You will note that each kind of pine has a different species name. Yet, all pines have the genus name *Pinus*. The pine trees of Sweden, Russia, or Germany likewise have the genus name, *Pinus*. Two principles of classification are now evident. A *species* is a particular kind of plant or animal. It is different from all others and is, therefore, given a name. A *genus* is composed of closely related species. This relationship is clearly shown in the use of scientific names.

While scientific names may seem somewhat strange and complicated, you can readily understand their importance to science for they:

1. are absolutely definite
2. are used by people of all languages
3. are usually descriptive
4. show relationship of species

DIFFERENT SPECIES OF PINE. Top: *Pinus ponderosa;* middle: *Pinus pungens;* bottom: *Pinus rigida.* Although cones and needles differ slightly, all resemble pines.

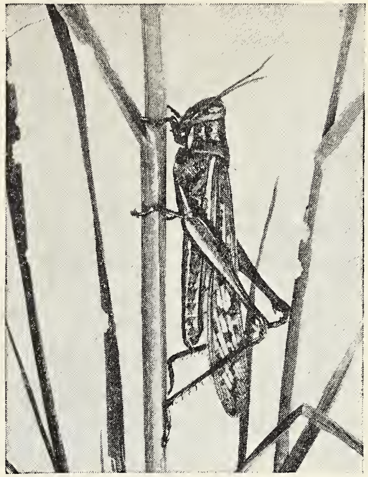
Scientific classification. As knowledge increased as a result of the work of Linnaeus, biologists began to apply the principles he used in naming plants and animals, for the purpose of classifying all living things.

Everyone had long recognized the two broad divisions of organisms: the plant *kingdom* and the animal *kingdom.* Great subdivisions of each kingdom called *phyla* [*fi′la*] (sing. *phylum* [*fi′lum*]) were also recognized, though to this day complete agreement has never been reached as to what phyla should be accepted by the scientific world. Scientists did agree, however, to subdivide the phyla into groups called *classes,* and the classes into *orders.* Orders, in turn, were divided into *families* and families into *genera.* Each genus included *species,* which in certain cases, were divided into *varieties.*

Classifying an animal. To show how an animal is classified, let us take for an example a common grasshopper.

Kingdom: Animal
Phylum: Arthropoda (jointed-foot animals)
Class: Insecta (body "cut into" three regions)
Order: Orthoptera (straight-winged)
Family: Acrididae (locust family)
Genus: Schistocerca (cleft-tail)
Species: americana (American)

As we follow this grasshopper through its classification, each group we place it into becomes smaller and the individuals making up the group, more closely related. The kingdom includes all animals. The phylum (Arthropoda) includes only such animals as insects, spiders, and crayfish which have certain similar body structures. The class (Insecta) rules out all animals which are not insects. The order (Orthoptera) includes only a certain group of insects with the peculiar "straight wings" which are found on crickets, roaches, grasshoppers, and mantids. The family (Acrididae) separates the grasshoppers from the other "straight winged" insects. The genus (*Schistocerca*) includes only a small group of closely related grasshoppers, while the species name (*americana*) is given to one specific kind of grasshopper. We use only these last two names in the scientific name. Hence, the insect whose common name is the cleft-tail, American, grasshopper is called scientifically, *Schistocerca americana*. And if you really want to know your grasshoppers, isn't it easier to say, "*Schistocerca americana*," than, "There's the cleft-tail, American grasshopper"?



A GRASSHOPPER. Biologists call this by its scientific name, *Schistocerca americana*.

Scientific classification may be compared to the system used in addressing mail. You will note, however, that the address on a letter would be read from bottom to top — the reverse of the order used in making a scientific classification.

Grasshopper	Letter
Kingdom: Animal	Nation: United States of America
Phylum: Arthropoda	State: Illinois
Class: Insecta	City: Chicago
Order: Orthoptera	Street: Madison
Family: Acrididae	Number: 3561
Genus: Schistocerca	Surname: Smith
Species: americana	First name: John J.

Use of scientific classification. Classification of a plant or animal requires careful study of its body structures. The experienced biologist can place an unknown organism into its proper scientific groups by comparing it with other organisms which are structurally similar.

As you become familiar with plants and animals in your study of biology, these similarities and differences will become more evident. Then, such groupings as phyla, classes, and orders will have more meaning.

You will find in the appendix a partial classification of the plant and animal kingdoms. The four plant phyla and the eleven most important animal phyla are included. In addition, classes and orders of the more familiar organisms are given. Careful study of this classification will give a general view of both plant and animal kingdoms and will show the relationship of various organisms to one another.

Summary

By a scientific system devised by Linnaeus over two hundred years ago, scientific names have been given to all known plants and animals. Each name is composed of two Latin words, the first representing a genus and the second, a species.

The system used in naming organisms was later applied to the complete classification or grouping of all living things. Based upon similarities in structure, kingdoms are divided into phyla, phyla into classes, classes into orders, orders into families, families into genera, genera into species and, in some cases, species into varieties.

Scientific classification serves to arrange all living things into systematic groups and to show relationship in structure of organisms to one another.

Using Your Knowledge

1. Develop a table of comparisons with different divisions in classification, other than the example of the letter address used in the text.

2. Explain why it was necessary for science to adopt a system of scientific classification.

3. State some of the reasons why Latin was selected as the basis for scientific classification.

4. Scientists do not all agree on the exact meaning of a " species." What do you think a species should represent?

5. Of what use may scientific classification be to the nonscientist?

Expressing Your Knowledge

classification	taxonomy	family
popular name	kingdom	genus
scientific name	phylum	species
Linnaeus	class	variety
binomial nomenclature	order	

Applying Your Knowledge

1. Make a list of six common plants and six common animals of your area and look them up in books or manuals to see how many other common names are listed for the same organisms.

2. Prepare a report on the work of Carolus Linnaeus in classifying plants.

3. Classify man as an organism, including all of the groups into which he is placed from the kingdom to species.

4. Make a collection of native plants. Identify each with its scientific name. Your teacher will show you how to make permanent mounts of these.

Chapter 8

Animals and Plants at Home

Have you ever heard of Walden Pond? It is famous in America, not because of anything unusual about the place itself, but because of the inspiration it brought to Henry David Thoreau [*Tho ro'*], the noted American author and philosopher.

Thoreau loved nature and wrote many inspiring books about his observations in the out-of-doors. One of his best books, *Walden,* or *Life in the Woods* was written about this famous pond near Concord, Mass., and the woodland around it. Seeking solitude and inspiration such as only nature can give, Thoreau built a hut in the woods near the pond, where he lived a hermit's life for over two years. It was during this period, over a century ago, that he made his famous study of Walden Pond which is preserved forever in the literature of America.

Thoreau was not a biologist, but he was a keen observer of nature. He watched with great interest the daily events in the life of the pond. He became thoroughly acquainted with the grasses and sedges, pond lilies, frogs, tadpoles, salamanders, and other living members of the Walden society. He watched these plants and animals struggle with environment and with each other, as they performed their activities of life. While not a trained taxonomist, he knew the names of the forms of life, both plant and animal, which flourished in the pond and in the woods near by. These living things he observed at all seasons of the year. He knew when the frogs laid their eggs in the spring and when the tadpoles grew their legs and absorbed their tails to emerge on land as another generation of frogs. He knew when swamp plants formed their flowers through the spring and summer and early autumn. Thoreau stated that he could tell the time of year, almost to the week, merely by observing conditions in Walden Pond.

Such was the effect of nature upon one man. Millions of others have received equal inspiration, though they may not have possessed Thoreau's literary genius to record their inspiration in writings about the out-of-doors.

Field biology. If, in your study of biology, you become interested in life to the extent that you enjoy trips into the field, you will have attained one of the greatest goals of the course you are taking. You can learn much about life from specimens brought into the laboratory. But these specimens lose much of their true significance when taken from their natural surroundings. In the laboratory, they become isolated organisms, no longer a part of the living world. Only in nature can an organism be observed in its normal surroundings, responding to the natural forces of environment and to the other living things about it.

Field study is essential, also, in getting acquainted with a variety of living organisms. The study of biology is much more valuable to the pupil who is familiar with the plants and animals about him. This knowledge may be acquired,

A Biology Class on a Field Trip

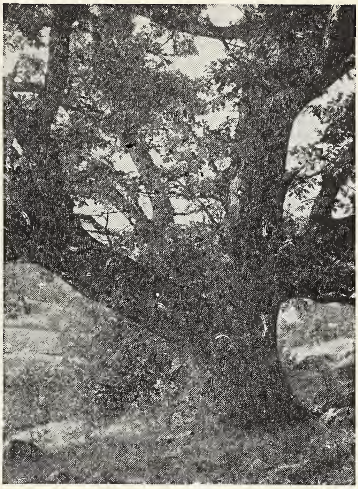
to some extent, from reading and from the study of pictures of plant and animal life. But one can hardly become thoroughly acquainted with organisms until he has observed them firsthand in their native haunts.

Field phases of the biology course. Many schools are situated near ideal surroundings for field study of biology. A near-by woods, or field, or pond may be visited by an entire class during the school day. If such opportunities are at hand, your teacher will be able to give you skilled direction in observing in nature.

Frequently, however, the school is far removed from natural surroundings. Field study is thereby limited to trips to neighboring parks or to the school grounds itself. In many instances, thickly populated districts of large cities do not provide even these limited facilities. This does not mean that the urban pupil cannot appreciate nature, even though his environment may be entirely artificial. It means, merely, that he must provide his own opportunities through week-end hikes, vacations, or trips to parks, conservation areas, or zoological gardens. The interested pupil, whether rural or urban, will make some opportunity to study living plants and animals.

Field observation. Much of the training of the scientist is directed toward accurate observation. Field observation is frequently more difficult to develop than observation in the laboratory. Facts are demonstrated, in the laboratory, by carefully arranged experiments, but in nature these facts are hidden in an array of activity. The observer in nature must learn just what to look for.

To become a skilled observer in the field, the biologist must develop "eyes that see" in nature. The average untrained observer walking through a woods notices the trees, a few shrubs, and possibly a toad jumping across his path. The woods are not especially in-



Philip D. Gendreau, N.Y.

A Black Walnut Tree and an Oak Tree

teresting to him because his eyes "do not see." A trained observer, however, walking through the same woods, finds a friendly place, full of the wonders of life. The soft black earth, the ferns and mosses, fungi growing from decaying stumps, birds darting ahead from tree to tree — even the tiny tree frogs, half hidden on the tree trunks — all come under his close observation. Biology has taught him what to look for — he has developed "eyes that see."

Field identification. An important part of the study of biology, and especially of field study, is getting acquainted with plants and animals. You have already learned the principles by which living things are grouped and classified according to scientific rules. You are familiar, too, with the system used in naming all of the different kinds of plants and animals. You need not attempt to add a long list of Latin names of organisms to your vocabulary in order to broaden your acquaintance with the life around you. Common names are much to be preferred for the beginner. The principles of scientific classification will become much more apparent to you, however, as you learn to recognize greater numbers of living things.

We learn to recognize our friends by seeing them often. Certain characteristics distinguish them from all of the other people we see in the course of a day. Plants and animals are distinguished from each other in much the same way. All living things have "personalities." They have distinct characteristics of their kind. To a trained observer, an oak tree and a walnut tree are similar in that both are trees, but differ in many distinct ways. Bark, branching habit, leaf arrangement, leaf structure, the type of flower, the fruit, bud characteristics, and even the conditions preferred for growth, may be used to distinguish oaks and walnuts from each other. A closer look will reveal, further, that not all oaks are alike, nor

A Stand of Forest Trees. Note the tall, straight trunks of these trees.

are all walnuts alike. Again, leaf shape, bark and twig structure distinguish the species of oaks and the species of walnuts. Identification is a matter of close observation and practice. After you have learned the name of a particular organism, continue looking for it. The "personality" of this plant or animal will soon become fixed in your mind. You will learn to recognize it as readily as you do your friends.

As you develop ability to distinguish different kinds of plants and animals, you will probably be amazed at the variety of living things in your community. To learn all of the plants and animals of any region is a tremendous undertaking, but to learn the more common forms about you is not difficult. Future chapters dealing with plants and animals will broaden your acquaintance with life considerably. For further assistance, a broad selection of books dealing with identification and classification is available in book stores and libraries. Such books covering trees, shrubs, wild flowers, fungi, birds, mammals, fishes, and other plant and animal groups are available in many styles, from paper-backed pocket editions to beautifully bound volumes. With the ability to observe closely and a few supplementary guides to study, field identification will become one of the most fascinating phases of the biology of the out-of-doors.

Field study of environment. Field identification and classification lead, quite naturally, to another important phase of the biology of the out-of-doors — the study of environment. The biologist is interested not only in the kinds of plants and animals to be found in nature, but in the type of surroundings in which he may expect to find them.

We discussed previously environment and the factors, both physical and biological, which compose it. Field biology affords an opportunity to see these forces of nature in action. Light, soil conditions, moisture, air currents, and other dynamic factors of the environment become much clearer when one

Philip D. Gendreau, N.Y.

AMERICAN TOAD SINGING. This animal blends perfectly into the color of its surroundings.

enters the surroundings in which they are exerting their influence upon life.

While observing life in the forest and becoming acquainted with the plants and animals which thrive there, notice carefully the conditions of a forest environment. How do light intensity, moisture, soil characteristics, and air currents compare with those of an open field? What kinds of plants and animals prefer these surroundings and how do they react to the forest environment? Notice the tall, straight trunks of the forest trees and their spreading crowns which form the canopy overhead. What factor of environment has caused this pattern of growth, so characteristic of the forest, and so different from the branching habit of trees of the open field? What kinds of trees are able to endure the deep shade of the lower levels and to occupy those spaces in the forest which are left by old trees as they die and fall from their places? The answer to this question will determine the content of the forest in the future.

As you make trips into other types of environment, you will find totally different kinds of plants and animals from those of the forest. Careful analysis of the environment will reveal the reasons for this. Compare the light intensity, soil conditions, moisture, and wind exposure of the open field with those of the forest. Notice the way in which plants of the field are adapted to these conditions. Compare the animal populations of the two environments. They, too, show adaptations which suit them for their particular natural surroundings.

Field biology should take you into numerous habitats of nature. You will learn what kinds of plants and animals to expect in each type of surroundings you visit. Learn to identify as many of these life forms as you can and analyze, as far as possible, the environmental surroundings in which each organism lives.

Adaptations for protection. To survive in the struggle for existence, organisms must be provided with some means

Monkmeyer Press Photo Service

An Opossum and Her Young. When captured, this animal plays dead and can be carried by the tail.

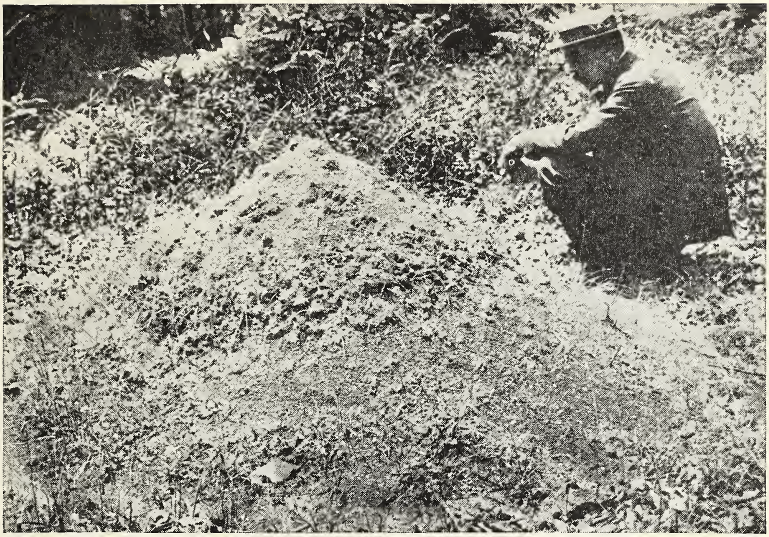
of protection. These marvels of life are best studied in nature where the struggle to live can be witnessed firsthand.

Many animals are colored like the plants upon which they live. The gray tree frog or "rain toad" called *Hyla versicolor,* when on a tree trunk in the woods, will escape observation from nineteen out of twenty people. The common toad, crouched close to the ground, blends so perfectly with the surroundings that it is unnoticed except by the most careful observer. Examples of *protective coloration* in which the organism blends into the color of its surroundings, and *protective resemblance,* or resemblance to shape in part of the environment are exceedingly common in nature and are most important to organisms which lack any other means of self-protection.

Rapid movement serves as the best defense of many animals. Until one sees it, the speed with which a red squirrel can whisk up a tree, or a black snake slip through the grass can hardly be appreciated. As you hike through a field or a woods, living things, aware of your presence, move continually ahead of you. Watch closely and you can observe a great variety of ways in which living things preserve themselves by movement.

Adaptations for self-defense include many special devices which are especially intriguing. We are all aware of the special adaptation of the skunk. Offensive as this device may seem, it is most satisfactory from the standpoint of the skunk. The opposum, slow and cumbersome as he is, plays dead when captured. You may pick him up by the tail and carry him about, while he remains stiff and motionless. Lay him down and retreat a distance, and he scampers off to the nearest tree.

Teeth and claws provide the fox, ground hog, badger, wolf, and bobcat



Ewing Galloway, N.Y.

An Ant Hill

with very obvious means of self-preservation. To this positive type of adaptation for defense belong, also, the stinger of the bee or wasp, the pincer jaws of beetles, the claws of the crayfish, and the poison fangs of certain snakes. One task of the biologist in making field studies is to learn the plants and animals which may be handled safely and those which should be admired from a distance.

Field study of behavior of organisms. Why do animals behave as they do? Is it native instinct or is it intelligence? We frequently credit animals with much more intelligence than they actually possess. Yet, regardless of reason, animals perform marvelous activities which are of constant interest to the field biologist.

The distinction between instinct and intelligence is difficult to make. Birds do not learn to make nests. A young bird leaves its nest without any knowledge of how its parents constructed this marvelous home. Yet, those same birds will seek similar surroundings and construct the same kind of nest the following year, as adults. Nest building is a good example of instinct. However, we who possess such remarkable powers of learning could not build a nest nearly as fine as the robin, or wren, or oriole.

To study instinctive behavior in the field, locate an ant hill and sit down prepared to observe closely for at least an hour. Watch the endless columns of these tiny creatures moving through a jungle of grass, carrying on their routine tasks. One who has never seen the soldiers of two different species of ants lock jaws in deadly combat has missed one of the greatest thrills to be found in nature. To account for all of the activities in and around the ant hill would require an explanation of the origin of instinct. Yet these activities are no less wonderful to observe.

Many animals show definite evidence of intelligence and learning in their behavior. To say that all bird behavior is instinctive would certainly bring forth arguments from hunters. Anyone who has hunted will agree that crows seem to know when you are carrying a gun. The unarmed observer does not seem to alarm the crow nearly as much as the hunter with a gun across his arm. If this fact could be proved biologically, it would certainly illustrate intelligence.

Chipmunks, squirrels, rabbits, deer, and many other higher animals show definite intelligence in their activities. How much activity is instinctive and how much is the result of learning is again difficult to determine. The answer to this question can be found only through very accurate observation in the field.

These are but a few of the phases of field biology. They are intended only as a guide to study in the out-of-doors. The trained observer will find many other subjects of great interest in nature. He will learn to recognize animals by their sounds and by their footprints. He will become familiar with the migratory routes of birds. He will study the feeding habits of various animals. He will watch the distribution of seeds by various devices and the coloration of leaves with the approach of autumn. The possibilities of study in field biology are almost unlimited.

Summary

Field biology offers an ideal opportunity to combine outdoor study with pure recreation. Nature has provided the perfect laboratory for the illustration of all of the principles of life. One who has failed to walk along a stream bank or to penetrate a marsh with its redwings and marsh wrens, or to smell the woodland odors has missed much of life.

We all have a natural desire to get out-of-doors and walk through nature. If, through your course in biology, you become sufficiently acquainted with plants and animals to lead you into the field, you will have been well repaid for your effort.

Using Your Knowledge

1. What distinct advantage does field biology have that is lacking in study in the laboratory?
2. Explain " eyes that see " in nature.
3. Define protective coloration and protective resemblance and give an example of each.
4. Explain the special adaptation of each of the following animals for defense: fox, bobcat, wasp, beetle, rattlesnake.
5. Distinguish between instinct and intelligence, as demonstrated in animal behavior.
6. What suggestions can you make toward nature projects to be undertaken by your biology class?

Expressing Your Knowledge

Thoreau
Walden Pond
adaptation
protective coloration
protective resemblance
behavior
instinct
intelligence

Applying Your Knowledge

1. Observe carefully the activity of a bird in nature, preferably while building a nest or caring for young. Which actions seem to be governed by instinct and which ones by intelligence?

2. Locate an ant colony or hill and observe carefully the behavior of the ants as they go about their numerous activities.

3. Take a hike through a woods or along a stream and make notes of all the different forms of plant and animal life you observe.

4. Select two trees of different species. List all of the characteristics you can find in which they differ.

5. Make a list of the fields, vacant lots, woods, streams, ponds, or seashore regions near your school which might serve for class field trips. Can you state the advantages of each area for study?

Increasing Your Knowledge of This Unit

Andrews, Roy Chapman. *This Amazing Planet*. G. P. Putnam's Sons, New York. 1940

Beebe, Charles William. *Half a Mile Down*. Harcourt, Brace and Co., New York. 1934.

Chapman, Frank. *My Life in an Air Castle*. D. Appleton-Century Co., New York. 1938

Clark, James Lippitt. *Trails of the Hunted*. Little, Brown and Co., Boston. 1928

Comstock, Anna. *Handbook of Nature Study*. Comstock Publishing Co., Ithaca, New York. 1911

Corbett, James Edward. *Man Eaters of Kumaon*. Oxford University Press, New York. 1946

Fairchild, David. *The World Was My Garden*. Charles Scribner's Sons, New York. 1938

Foreman, Grant. *A Pathfinder in the Southwest*. University of Oklahoma Press, Norman, Oklahoma. 1941

Hill, Joe, Jr. and Hill, Ola Davis. *In Little America with Byrd*. Ginn and Co., New York. 1937

Howes, Paul Griswold. *Backyard Exploration*. Doubleday, Page and Co., Garden City, New York. 1927

King, Eleanor and Pessels, Wellmer. *Working With Nature*. Harper and Brothers, New York. 1939

Mann, Paul B. and Hastings, George. *Out of Doors*. Henry Holt and Co., New York. 1937

Morgan, Ann Haven. *Field Book of Ponds and Streams*. G. P. Putnam's Sons, New York. 1930

Pickwell, Gale Benjamin. *Deserts*. Whittlesey House, New York. 1939

Thoreau, Henry David. *Walden*. Modern Library, New York. 1937

Twain, Mark. *Huckleberry Finn*. Harper and Brothers, New York. 1935

Williamson, John. *Twenty Years Under the Sea*. Hale, Cushman & Flint, Boston. 1936

Williamson, Thames Ross. *Opening Davy Jones's Locker*. Houghton Mifflin Co., New York. 1930

Unit 3 —

The Biology of Plant Life

WHICH appeared first upon the earth, plant life or animal life? Your study of the relationship of living things has provided a definite answer to this question. Animal life exists only because of the vital link between the inorganic world and the living world through the green plant.

It is natural then that our study of a specific kind of organism should begin with the plant. In this unit, you will learn about four great groups of plants which compose the plant kingdom. One of these groups, the seed plants, you will study in detail. You will learn about highly developed organs which form the body of these, the most complex plants. You will trace a drop of water from the soil through the root system and upward through the stem to the leaves, where it serves as a raw material in the most wonderful of all chemical reactions. You will visit the chemical laboratory of nature where things occur which have never been duplicated even by our most brilliant scientists.

Chapter 9

The Vegetation of the Earth

Over 340,000 different kinds of plants are known to biology. Ranging over all the earth, from pole to pole and from mountain peak to ocean depths, there is plant life of some sort.

All of these plants compose the *vegetation* of the earth. A most interesting feature of the plant world is the almost infinite variation of its numbers. The smallest plants, the bacteria, measure less than 1/50,000 of an inch. Compare them with the giant redwoods reaching to heights of over 350 feet and weights of several thousand tons. Such is the range in size of the members of the plant kingdom.

But size is not the only variation in the plants of the earth. They differ, likewise, in structure, methods of reproduction, nutritional processes, habitat or environment required, and in many other ways.

The four great groups of plants. On the basis of structural and reproductive differences, biologists have classified all plants into four great groups or *phyla* [*fy'la* (sing. *phylum*)] as follows:

Algae and fungi — Thallophytes [*Thal'o fites*]

Mosses and their relatives — Bryophytes [*Bry'o fites*]

Ferns and their relatives — Pteridophytes [*Ter'rid o fites*]

Seed plants — Spermatophytes [*Spur'-mat o fites*]

These phyla, in addition to showing structural relationships, illustrate a development from simple to complex. Biologists believe, further, that plants appeared on the earth in the order of their complexity. There probably was an age during which Thallophyte plants were the only members of the earth's vegetation, followed later by an age of Bryophytes. The age of Pteridophytes, while millions of years ago, is quite definitely known to have existed, as we shall see from later discussion of these plants. Today, we live in the age of Spermatophytes. Seed plants compose the most conspicuous part of our present vegetation. They form our forests and meadows; our flower and vegetable gardens. Yet all divisions of the plant kingdom are represented in the vegetation around us.

Algae and fungi — Thallophyte plants. From the standpoint of structure, Thallophytes are the simplest of all plants, and include the smallest members of the plant kingdom. But the fact that they are small does not mean that they are unimportant. Quite to the contrary, some of the plants which affect our lives most closely are members of this lowly division.

Algae [*al' jee*] (sing. *alga* [*al' gah*]) are for the most part, water plants growing abundantly in lakes, streams, and oceans. The salt water or marine forms of algae may be seen clinging to rocks along the sea coast or floating onto the beach with the tide. Certain sections of the ocean contain particularly abundant growths of these curious brown or red-colored algae or " sea weeds " as they are frequently called. One such section, the Sargasso Sea, occupies an area of about

FUCUS, A BROWN ALGA. This seaweed is very common on the Atlantic Coast.

a quarter of a million square miles in extent, lying off the southeast coast of the United States. The Red Sea derives its name from an alga which occasionally grows in its waters in such abundance as to color the water red.

To those who have not seen the oceans, the familiar fresh water algae or "pond scums" serve as common examples. These algae are known to everyone as floating masses of scum-like green growth, or slender green threads attached to rocks in a rapids, or as a slippery, green coating on objects in the water.

While some algae may appear brown or red in color, they all contain the green substance found in the leaves of higher plants. Like leaves, they manufacture food within their cells and, thus, shift for themselves as far as nutrition is concerned. They constitute the simplest group of independent plants, and we shall study them in more detail in a later unit.

The tremendous significance of Thallophytes is due not to the algae, but to their relatives, the *fungi* [*fun'jye*] (sing. *fungus* [*fun'gus*]). Fungi lack the green substance which most plants contain and therefore are unable to make their own food. They live entirely upon other plants or animals, or upon food and other organic matter which is produced by living things. Strangely enough, fungi may be either beneficial or harmful, depending upon the nature of their activities. Disease, food spoilage, and decay rank high among the destructive processes of fungi. On the other hand, the activities of certain members of this group in food processing, in industry, and in relation to soil fertility are exceedingly useful.

Bacteria, yeasts, molds, mushrooms, rusts, smuts, and mildews are fungus plants which are known to everyone. We shall study these plants in later chapters. For the present we are concerned only with their place in the vegetation of the earth.

Mosses and their relatives — Bryophytes. Science tells us that life originated in water and that millions of years probably passed before plants became adapted to life on the land. This idea is

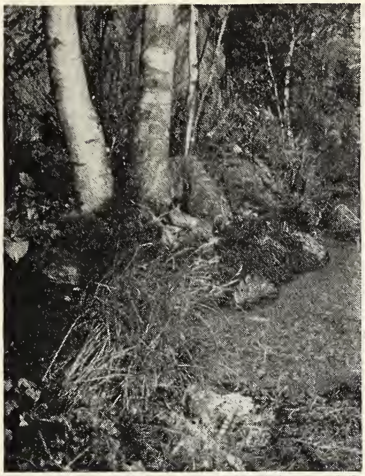
INKY CAP MUSHROOMS. These fungi lack the green substance which most plants contain.

well illustrated when we compare the Thallophytes which require a water environment and the Bryophytes which are the simplest known land plants.

We have all seen mosses growing in the cracks of shaded sidewalks, on moist ground under trees, or in luxuriant clumps in the woods. What frequently appears as a dense tuft or carpet of green is, actually, a compact mass of tiny moss plants, each with a diminutive stem with numerous pointed leaves circling about it. If you pulled one of these tiny plants from the soil, you would find a cluster of tiny root-like growths called *rhizoids* [*ry'zoids*] growing from the base of the stem. These rhizoids differ from the roots of higher plants because they lack the specialized tissues of a true root. But roots or rhizoids, these finger-like projections absorb water and minerals from the soil and anchor the tiny plant.

Anyone who has watched a growing clump of moss through the spring and early summer, has witnessed a most interesting occurrence. Out of the tip of certain leafy shoots, there appears a tiny hair-like structure, lacking any leaves, and bearing on the end a tiny cylindrical or pear-shaped container called the *capsule*. This minute stalk and capsule is, really, a second moss plant, or second generation, essential to its reproduction. A moss in such a condition is, thus, a plant growing upon a plant — a moss upon a moss! The capsule is covered by a hood or *calyptra* [*ka lip'tra*] which falls off as the capsule ripens and turns yellow brown. Then a lid at the top of the ripened capsule opens and allows a fine yellow powder to sift out through the open end. Under the microscope this fine yellow powder will be found to consist of large numbers of minute, round or oval bodies called *spores,* each one capable of germinating to form a new moss plant. Each spore accomplishes the purpose of the seed of a higher plant. We may, then, use the term *spore plant* to distinguish plants like the moss from the more complex *seed plants.*

The detailed study of the structure and reproduction of mosses is most complicated and should be reserved for the study of botany or more advanced phases of biology. The economic importance of mosses is of much more concern to the pupil beginning biology.



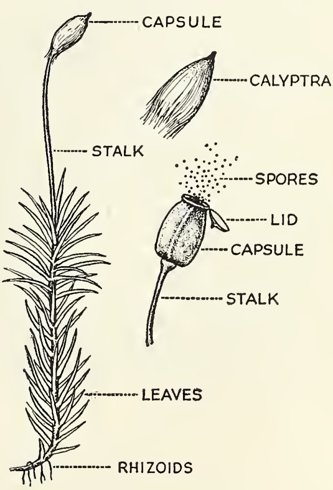
Ewing Galloway, N.Y.

Clumps of Mosses. These plants grow in woodland soil.

Most important among the mosses are the Sphagnum [*Sfag'num*] or peat mosses which form dense mats in lakes and bogs. Each season, a generation of mosses dies on the surface of the mat and is replaced the following season by a new generation. Hence, the mat becomes thicker and thicker, until it may finally reach the bottom of the lake or bog in which it is growing. Extensive mats of Sphagnum mosses may be found around the shores of lakes or bogs or floating in the open water. As new moss plants increase the thickness of the mat in some places, others reach out around the edges and cover more and more space. In time, such mats may entirely cover and completely fill a lake or bog. Upon such large mats, larger plants like the pitcher plant, rushes, grasses, shrubs, and even trees may grow. In walking on such a mat, one is somewhat alarmed at the spongy underfooting and much more so at the fact that each step jars all of the vegetation around him.

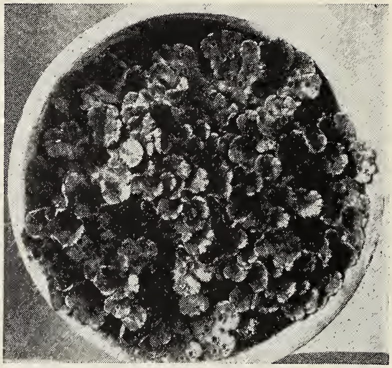
The deposits of peat to be found in old lakes and bogs where Sphagnums have been active may be removed to supply a valuable article of commerce. The brown, spongy remains of peat mosses have tremendous water absorbing qualities. Nurserymen pack wet peat moss around the roots of trees and shrubs to prevent their drying out during shipment. This same quality of peat makes it very valuable to the gardener. Placed on the surface or worked into the soil around plants, it keeps heavy soils from packing too tightly and aids greatly in holding moisture in the soil. The gardener refers to this use of peat and other substances as *mulching*.

In certain sections of the world, peat serves still another important use. As peat deposits rest in the bottom of lakes or bogs they undergo slow decay and compression, characteristic of early stages of coal formation. Such deposits may be removed, dried, and pressed into small lumps suitable for burning. In regions where peat is plentiful and coal is



Structure of the Moss Plant

Sphagnum Bog



Liverwort Plants

scarce or costly, peat serves as an important source of fuel.

While Sphagnum mosses are the most important commercially, other mosses render valuable services to man of other sorts. Because of their small size, mosses are able to grow in places lacking sufficient soil to support larger plants. Apparently bare surfaces of cliffs and rocky ledges often support luxuriant growths of moss plants anchored in tiny cracks and crevices. As mosses grow in such situations they gradually enlarge these cracks by crumbling the rock particles with their rhizoids and filling them with the remains of their vegetative parts. These moss parts decay and form soil, capable of anchoring larger plants in succeeding years. This activity of mosses in forming soil is responsible for many of the plant-covered rocks and ledges to be seen in hilly regions.

We can hardly complete our discussion of the mosses without mentioning the beauty which they provide in nature. Who has not stopped to admire a dense carpet of green moss in the woods or to gaze upon a shady hillside or ravine covered with thriving clumps? If the mosses were of no practical importance whatever, their contribution to the beauty of the landscape would be sufficient to hold them in high esteem.

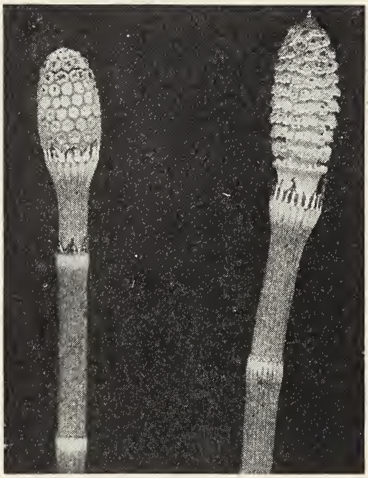
Much less familiar than mosses, are their relatives, the liverworts. These curious plants grow in moist, shady places, often along the banks of streams or on rocky ledges. A liverwort plant looks like a flat, leathery green leaf laid flat against the ground. Under ideal conditions, they may form clumps of considerable size. Once you have learned to recognize a liverwort, you will probably have no difficulty in distinguishing it from other plants.

Ferns and their relatives — Pteridophytes. As we progress through our survey of vegetation from simple plants to complex plants, we come to the ferns and their allies, as members of the third division of the plant kingdom. Ferns are more like seed plants than are any of the plants previously mentioned.

To have appreciated the Pteridophytes fully, one should have lived a few million years ago during the age in which they were in their glory. Then

Vegetation of the Carboniferous Period

The Underside of a Fern Leaf. Notice the fruit dots (sori).



Horsetails

they were not limited to a few places in the woods, or swamp, or hillside, or flower pot. They formed extensive forests which covered the wet, marshy land which, science tells us, was characteristic of that day. Ferns much like our ferns of today flourished during this past age, and in addition, tree ferns which grew to a height of 30 to 40 feet.

But no man ever saw these great forests of ferns, although today we are reaping the benefits of their existence. During this age, referred to as the Carboniferous period, great layers of fern remains accumulated in the swampy areas where they grew. Later, the movements of the earth compressed these layers into layers of coal. When one considers what coal has meant to industry, he might almost conclude that the high civilization of modern America has sprung from the Pteridophyte vegetation of millions of years ago.

Most of us are familiar with ferns as clumps of graceful, deeply cut leaves. In all but the few remaining tree ferns of the tropics, the stems are underground, creeping horizontally just below the surface. These underground stems, called *rhizomes* [*ry'zomes*] bear clusters of true roots which spread profusely through the ground in anchoring the plant and in absorbing water and minerals. The leaves of most ferns perform a double function. In addition to food manufacture, they bear little dots, called *sori* [*sor'eye*] (sing. *sorus*) on their underside. These sori are essential in reproduction and should not be laboriously picked off the leaves, as some people have tried to do. Each *sorus* contains a cluster of small helmet-shaped *sporangia* [*spor ran'jee ah*], which contain numerous spores. Fern spores, like the spores of mosses, grow into new fern plants, thus performing a function similar to that of seeds. Also, like the mosses, the reproductive cycle of the ferns is complex and is, therefore, reserved for more advanced study.

The modern fern is of relatively little importance to man except as a thing of beauty. Ferns are widely cultivated for decorative purposes in the home and in floral displays. Native ferns abound in certain places, though they lack any wide distribution except in the tropics. Certain species inhabit marshes; others thrive in the woods, in ravines, or in the case of the bracken fern of the northern United States, in dry open fields. When ferns meet the competition of seed plants for a place in which to grow, they are usually no match for these highly developed, more perfect organisms. So, we find them only rarely.

Closely related to the ferns are two groups of plants, fairly common in some localities. The *horsetails* or *scouring rushes* are frequently seen in wet places or around the margins of lakes. They appear as slender, dark green, rod-like stems bearing light colored cones at their

CLUB MOSSES. Too many of these mosses are used at Christmas time. They are rapidly becoming extinct and should be conserved.

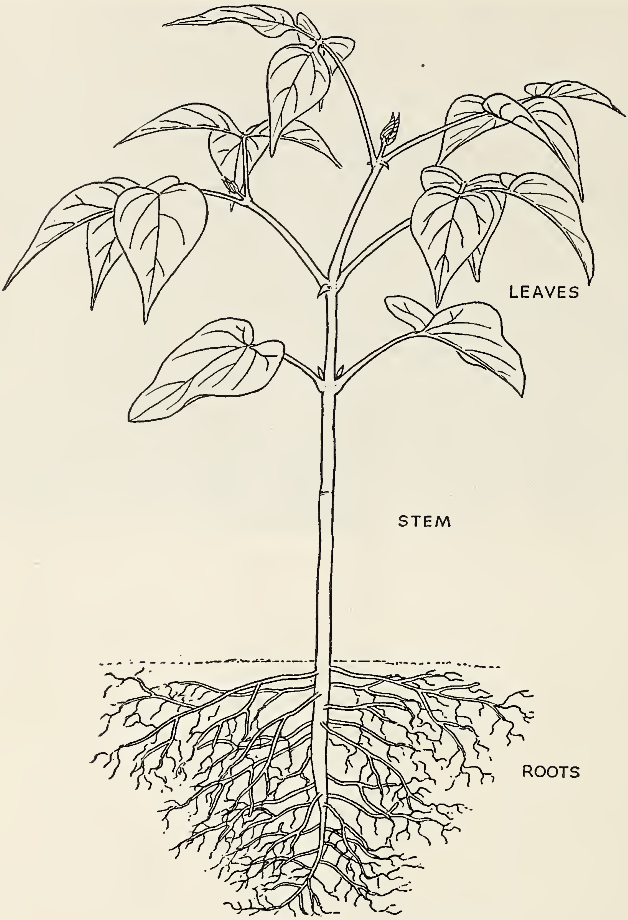
tips. The leaves are reduced to small scale-like structures growing in circles around the stem at regularly spaced intervals. The name scouring rush came from the pioneers, who found them valuable for scouring kettles due to the limy texture of their stems.

Club mosses, resembling mosses only in general appearance, constitute another group of relatives of the ferns. These plants, some of which are the ground pine, which is used frequently in Christmas wreaths, bear curious club-shaped reproductive structures at the tops of certain of their branches. They are found in rich, damp woods, or creeping along the rocky slopes of mountains. Like the ferns, both scouring rushes and club mosses are now merely remnants of the once flourishing age of Pteridophytes. At that time they were the size of trees. Some of their remains may be seen in the form of leaf or stem imprints in coal.

The seed plants — Spermatophytes. To this group belong all our plants which produce *seeds* instead of spores. They dominate our vegetation today to the extent that we may truly say this is the age of Spermatophytes.

Earth changes after the age of Pteridophytes resulted in the formation of many environments unsuited to ferns and mosses. Land masses gradually became drier, mountains arose, dry plains were formed, and deserts appeared. In occupying all of these different environments, new plants became more adaptable than the mosses and ferns. The seed plant with its complex structure and greater efficiency in this way replaced its more primitive ancestors and became the dominant type of vegetation.

The plant body. Seed plants are composed, usually, of three sets of complicated organs: roots, stems, and leaves. Each organ contains complex tissues,



Young Bean Plant. This is a typical seed plant.

specialized in performing certain activities with the greatest efficiency.

Roots serve as organs of *support* or *anchorage,* capable of holding a stem as large as a tree firmly in the ground. By extensive branching and rebranching, they reach far into the soil and *absorb* the required water and minerals. Many plants like the carrot and radish send quantities of food into the root for *storage,* safely hidden from passing animals.

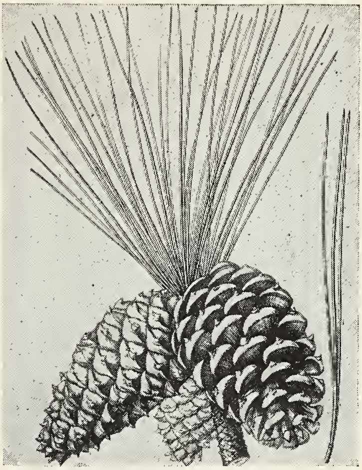
The stem serves as the connecting organ between the roots and the leaves. It *conducts* water and dissolved minerals upward from roots to leaves, and manufactured food downward from leaves to roots. In addition to this two-way conduction, stems bear the leaves and, in most plants, raise them into the air and light. Like the root, the stem contains many kinds of tissues, each specialized in carrying on specific activities.

The leaf serves as the *food factory* of a plant. Frequently, stems contain the green tissues necessary for food manufacture, but in most plants this activity is centered in the leaves. Leaves likewise contain pores which permit the *exchange of gases* between plant and atmosphere. These pores serve, also, in giving off water which rises through the stem from the roots. As we shall learn when we study the leaf in detail, it is indeed a marvelous organ of plant activity.

Reproduction is accomplished by special organs which appear at certain seasons. These special structures may be *cones,* as in the case of the pine, fir, or spruce, or *flowers,* in the case of all flowering plants. Cones give rise to seeds which contain young plants, capable of sprouting from the seed in new areas where the seeds may fall. In the case of flowers, petals and other parts fall away as the *fruit* develops. Within the fruit, *seeds* mature and give rise to future generations of plants.

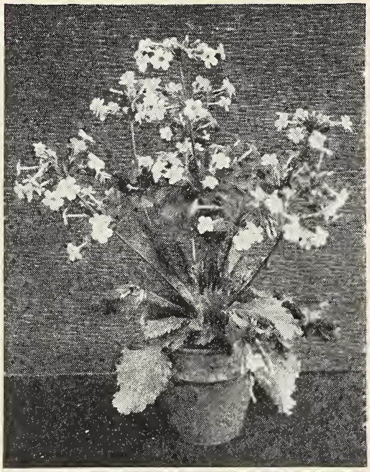
Classification of seed plants. While seed plants all are similar in general structure, certain differences in the manner in which the seeds are produced divide them in two distinct groups. *Gymnosperms* [*Jim'no spurmz*] include those plants which bear seeds openly on the surface of the scales in their cones. Such cones are familiar on the spruce, hemlock, cedar, larch, redwood and cypress. *Angiosperms* [*An'jee o spurmz*] bear flowers of various sorts and produce seeds enclosed in a protective structure called an *ovary.* The ovary ripens into a fruit which, in the peach, becomes a fleshy, edible part, or in the bean, develops into a pod.

Angiosperms, or flowering plants, are further divided into two groups, the *monocotyledons* [*mon o kot ee le'dunz*] or monocots and the *dicotyledons* [*di-kot ee le'dunz*] or dicots. Distinctions between these groups are made in the structure of the flowers, leaves, and stems. We shall discover these differences in the study of these organs of the seed plant.



PINE CONES AND LEAVES

The duration of seed plants. The life span of seed plants varies from a single season to several centuries. The shortest lived seed plants are called *annuals.* These plants sprout from seeds and go through a period of a few weeks or months of rapid growth. With the full development of roots, stem, and leaves, the energies of the plant go into reproduction. Flowers appear, followed quickly by the fruit and seeds. So much energy is used up during this reproductive period that little is left for future activity of the plant. Consequently, with the ripening of seeds, the roots, stem, and leaves die. Many of our most beautiful garden flowers, including the zinnia, marigold, and larkspur live only one season, but climax the brief growing period with an array of flowers and an abundance of seeds.



PRIMROSE. Note the rosette type of leaves at the base of this biennial plant.

Somewhat less common than annuals, the *biennials* live two seasons. The first season is spent in vegetative growth, that is, the growth of the roots, stem, and leaves. During this first season, biennials accumulate food reserves, usually in the root, as in the carrot, the beet, and the radish. In the second season, reproduction occurs. Flowers appear followed by seeds. As in the case of annuals, reproduction exhausts the reserves, resulting in the death of the plant following seed production. Some familiar biennials are the Canterbury bells, foxglove, primrose, and sweet William.

Perennial plants vary in life span from several years to several thousand years. To this group belong the oldest living things, as represented by many of our largest trees. After sprouting from a seed, the perennial plant usually carries on purely vegetative growth for one or more seasons. During this period, all energies of the plant go into the production of roots, stem, and leaves and the accumulation of reserve food supplies. When maturity is reached, flowers appear, followed by fruits and seeds. In the case of perennials, however, the plant continues growth after reproduction and rebuilds lost energies for another season of flowering.

Summary

Vegetation includes all plants which live upon the earth. Our vegetation, today, consists of four great groups of plants known as Thallophytes, Bryophytes, Pteridophytes and Spermatophytes.

Of these four groups, Spermatophytes, the seed plants, are the most complex. Largely through competition with seed plants, Bryophytes and Pteridophytes have been reduced to secondary importance today.

Using Your Knowledge

1. In what respect is the plant body of an alga or a fungus more simple than that of a seed plant, such as a tree?

2. Thallophyte plants are divided into two great groups; the algae and the fungi. Upon what basis is the distinction made?

3. Under what conditions does a moss plant become a plant upon a plant?

4. Describe the formation, dispersal, and germination of spores of the moss plant.

5. Name several economic uses of Sphagnum moss.

6. Discuss the relation of ferns to coal deposits.

7. Describe the manner in which the fern plant produces its spores.

8. Name the specialized organs of a seed plant.

9. Compare the plant body of an alga, a moss, a fern, and a seed plant. How does

such a comparison illustrate development of organs in the plant kingdom?

10. Discuss the relation between specialization of plant organs and the extent of distribution of various kinds of plants.

11. Into what two large groups are the seed plants divided, and what is the basis for the distinction?

12. Upon what basis do you distinguish annuals, biennials, and perennials?

Expressing Your Knowledge

vegetation	moss capsule	sorus
phylum	calyptra	scouring rush
Thallophyte	spore	seed plant
Bryophyte	fern	gymnosperm
Pteridophyte	rhizoid	angiosperm
Spermatophyte	leafy shoot	monocotyledon
pond scum	Sphagnum moss	dicotyledon
alga	sporangium	annual
fungus	Carboniferous period	biennial
moss	rhizome	perennial

Applying Your Knowledge

1. Collect as many different kinds of mosses as you can find, with stalk and capsule present if possible, and arrange them in a moist woodland terrarium.

2. Obtain some living Sphagnum moss from a bog or from a supply company and establish it in a wet terrarium. You will find that it will thrive and will be most interesting to watch.

3. Obtain some fern leaves (fronds) with fruit dots on the lower sides. Examine the fruit dots with a hand lens. Scatter some of the contents of the fruit dots on a microscope slide and examine with the microscope. What do you find?

4. Prepare a report on the forests of the Carboniferous period and the formation of coal.

5. Make a table of the organs of a seed plant and the uses of each to the plant.

Chapter 10

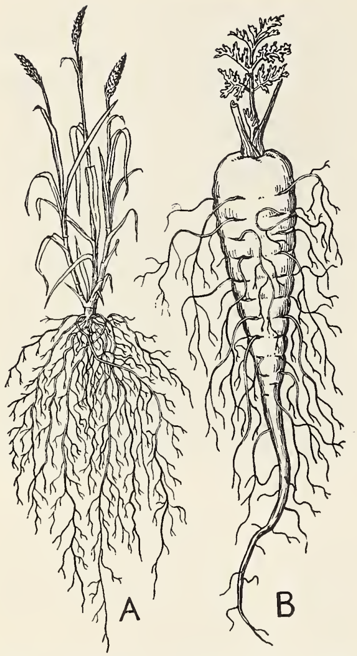
Roots and Root Systems

How much of a plant lies buried in the ground? What activities, essential to the plant, are carried on by its roots? Do plants add to their root systems as rapidly as they grow new branches and leaves? These are questions which our study of roots will answer.

Root systems of plants are frequently ignored except as necessary parts which must be removed from the soil when we move a plant from one location to another. But to the plant, its parts below the ground are just as essential as its spreading, leafy branches.

The lesson of buried roots is that it is not always necessary to be conspicuous in order to accomplish important results in the world.

Why do plants have roots? The root *anchors* the plant in the soil and holds



Root Systems. A. Fibrous root system. B. Taproot system.

it firmly in position. Equally important, if not more so, it is the main organ of the plant in *absorbing* water and dissolved mineral substances from the soil.

By processes of *conduction*, water and minerals pass upward through the root to the stem and leaves. Downward conduction brings food substances into the root. Some roots are bulky enough to serve as efficient organs for *storage* of the food supplies of the plant. This makes it possible for such plants to die to the ground at the end of the season and sprout again the following season by using the food reserves in the root. Certain roots possess buds near the point where they join the stem, and these buds serve as organs of *reproduction* by sprouting new shoots. Dahlia roots may be divided and multiplied by planting roots separately the following season. Each root becomes a new plant.

While these are the more common functions of roots, special roots perform still other functions.

Forms of root systems. All of the roots compose the *root system* of a plant. While plants vary in the size of the root system in comparison with the branches, one may assume that, in the average plant, the parts below the ground are of about the same extent as the parts above the ground. This general rule will give you some idea as to the enormous area covered by the roots of a large tree.

If you pull a number of plants from the ground, you will observe two general forms of root systems. In one form, a large central root composes most of the system. This large *primary* or *taproot* bears numerous smaller *secondary* or *branch roots* which grow horizontally. Such root arrangement is called a *taproot* system and is familiar in the carrot, the beet, and the dandelion.

Many plants like the grass and the corn lack a single, large root and, instead, have numerous *fibrous* roots, the main ones of which are about the same size. A system of this type is termed *diffuse*.

Taproots and diffuse roots — advantages of each. The fact that plants grow in such varied types of surroundings is due, in part, to the form of their root systems. In regions where rainfall is scant and deep supplies of water are lacking, as in the prairie, plains, and desert regions, diffuse roots close to the surface enable plants to absorb water over large areas after rains. On the other hand, deep taproot systems aid plants in reaching supplies of water deep in the earth and thus in flourishing during periods when the surface soil is dry.

Ewing Galloway, N.Y.

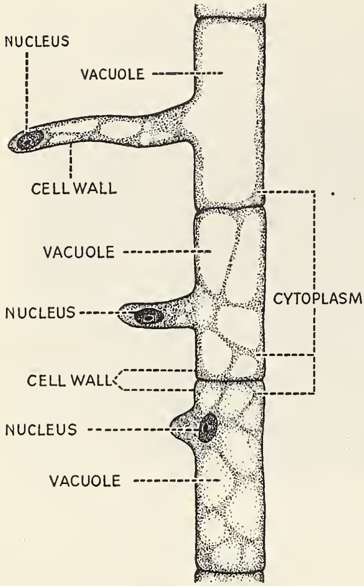
BLUEGRASS ROOTS. Note how these fibrous roots hold the soil.

Obviously, taproots anchor the plant much more firmly than do diffuse roots. Deep-rooted hickory, walnut, and oak trees survive many severe wind storms which uproot the more shallowly rooted elms, willows, and cottonwoods. On the other hand, the widely diffuse roots of the sod and bunch grasses intertwine in the top soil of the grasslands and prevent erosion by winds. This important role of soil binder could not be performed by plants with taproot systems.

The origin of the root system. The root system originates with the germination of the seed, when the first or *primary* root pushes into the soil. After a brief period of growth, this primary root gives rise to numerous branch or *secondary* roots, first near its top, then continuing farther down. Secondary roots later form still other branch roots, thus spreading the root system over a large area.

In some plants, the primary root continues growth throughout the life of the plant and remains the principal root of the system. Obviously, such a manner of growth results in a taproot system. Diffuse systems are formed when the primary root lives only a short time and is replaced by numerous secondary roots.

Young roots and root hairs. Roots of seedlings show another important characteristic of young roots. A short distance back of the tip, strange white fuzzy growths may be seen extending from the surface of the root. These tiny *root hairs* are important in absorption, as we shall learn later. Root hairs are delicate projections of the outer covering or *epidermis* of the root. They should not be confused with secondary roots which form a considerable distance back of the root hair zone. Root hairs are produced in a zone about one to two inches in length. As the root moves downward, new root hairs form close to the tip and older ones wither away near the top of the region. Thus, they are constantly extending into new areas of soil as the young root pushes on.



Development of Root Hairs

Seeds germinated in covered dishes will form young roots and root hairs usually within a week. Under such conditions you may observe them quite easily. Be careful to avoid touching them or exposing them to dry air or they will shrivel away.

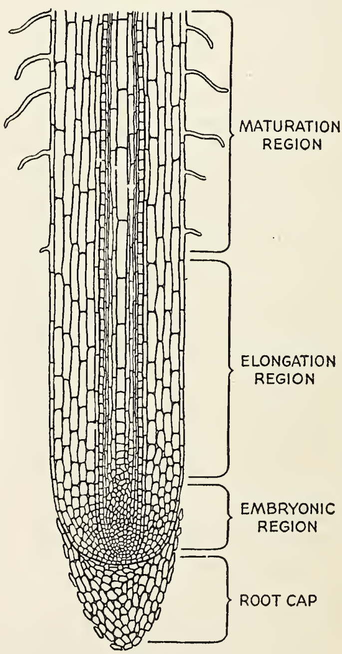
Detailed structure of a root tip. If a root is cut off half an inch or so back of the tip, sectioned lengthwise and examined with the microscope, the cells composing it and several important regions, are clearly visible.

These regions are:

1. The root cap
2. The embryonic region
3. The elongation region
4. The maturation region

Regions of the young root. At the very tip is the *cap* which protects the delicate end of the root. As the cap is pushed through the soil by the growing root behind it, the outer surface is torn away. The addition of new cells to the inner surface, however, keeps it in constant repair.

One might wonder at the fact that the delicate root tip can force its way through soil without damage. An interesting phenomenon explains some of this remarkable occurrence. The root tip partly pushes its way and partly *dissolves* its way through soil. The gas, carbon dioxide, combines in water to form a weak acid called *carbonic acid*. Carbonic acid is familiar to all as soda or "fizz" water used at the soda fountain. Root caps give off carbon dioxide into the soil water and so form carbonic acid which, in turn, aids the progress of the young root by dissolving minerals in its path. As roots grow over smooth rocks, their pattern is often etched into the surface by the carbonic acid they form.



Longitudinal Section of a Root Tip

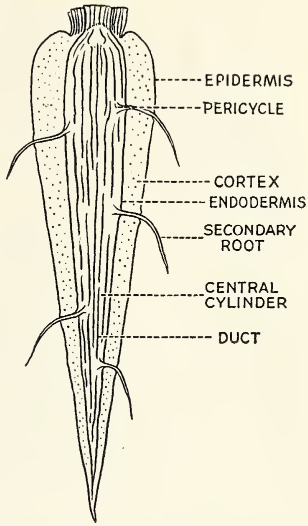
Immediately behind the cap, at the tip of the root proper, is the *embryonic* region or growing point of the root. Cells of the embryonic region are small, nearly square, and contain large nuclei. They are in a constant state of cell division, thus giving rise to new root cells.

Back of the embryonic region, cells gradually lengthen until they reach full length a considerable distance from the tip of the root. This lengthening of cells marks the *elongation* region, which causes the forward movement in the growth of the root tip.

At any point either in the embryonic region or elongation region the cells appear all alike. However, after they have grown to full length, they change further. Cells on the surface give rise to root hairs, while those inside of the root change somewhat as they become special tissues of the mature root. Modification of cells to form these special tissues marks the *maturation* region of the root.

Regions and tissues of a mature root. Any large root, such as a carrot, may be sectioned lengthwise to show characteristic regions of a mature root. The outer edge or *epidermis* appears as a thin outer skin. Within the epidermis is a thick, spongy area called the *cortex*. The center of the root is a well defined area called the *central cylinder* or *stele*.

Under the microscope, these same root regions are visible and, in addition, groups of specialized cells or tissues which form them. The *epidermis* appears as a single layer of brick-shaped cells. Beneath the epidermis is a thicker layer of thin-walled, loosely packed, roundish cells, the *cortex* which serves as the principal storage area of the root and which passes water from the epidermis to the inner tissues. Distributed through the cortex there may be various spaces between the cells. These are *air*

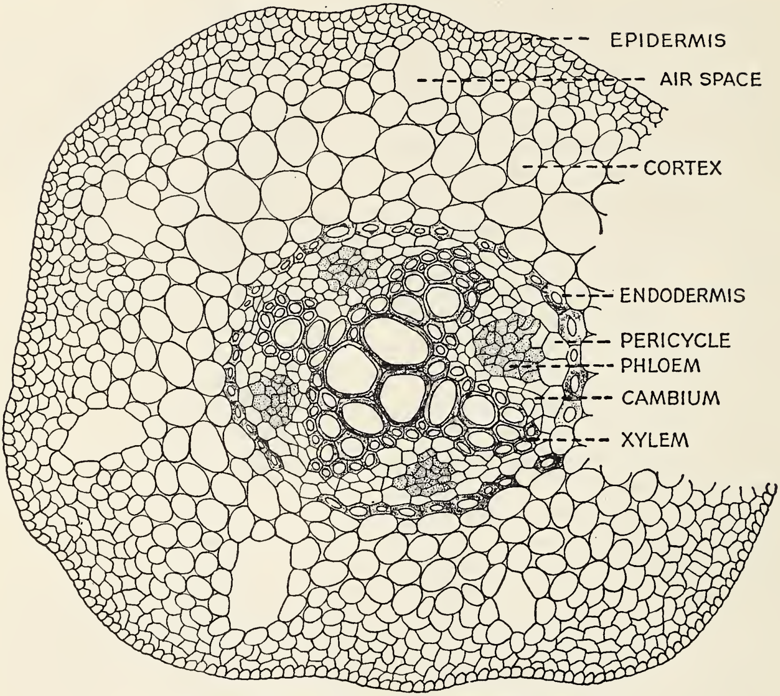


LONGITUDINAL SECTION OF A CARROT ROOT

spaces. The inner edge of the cortex is a special layer of cells, frequently possessing thickened walls, called the *endodermis* or *boundary layer* which separates the cortex from the central cylinder within.

The outer rim of the central cylinder consists of a special ring of cells, the *pericycle*. This tissue is important as the region from which secondary or side roots are formed, in pushing their way through the cortex out into the soil. Within the central cylinder are three other important tissues. They are: (1) xylem or woody tissue (2) phloem (3) cambium.

Xylem is composed mainly of *wood fibers:* thick-walled cells giving support to the root, and *ducts* or *vessels:* long, hollow tubes used principally for transferring water upward, hence called *water-conducting tubes*. Phloem consists of tough *bast cells,* and long, perforated cells — the *sieve tubes* — which carry food downward, hence are called *food-*



Cross Section of a Root Showing the Tissues

conducting tubes. The *cambium* is the most remarkable tissue in the plant. It consists of thin-walled, very active cells, which are full of living protoplasm and which are capable of rapid growth. In fact, all growth of the plant occurs here, and if the cambium is destroyed, the plant will die. Since these tissues extend into the stem, and we shall hear of them again when we study stem structure, it is important that we should remember their function in the root.

The xylem or woody tissue is generally grouped in four areas joined near the center, and alternating with them, though outside, is found the phloem. The cambium forms a more or less complete ring between the two. The cambium provides new growth in width.

Summary of Root Tissues and Their Special Functions

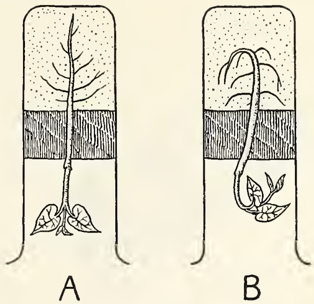
Tissue	*Function*
epidermis	absorption
root hairs	outgrowths of epidermis which increase the absorbing area
cortex	storage of food and water
endodermis (boundary layer)	no special function
pericycle	origin of secondary roots
phloem	conduction of food
cambium	increase in diameter of root
xylem	conduction of water and dissolved minerals

Responses of roots to their surroundings. The various parts of plants respond, usually in a rather slow manner, to certain factors of the environment. These responses are called *tropisms.* Several such responses are especially noticeable and may be observed in the study of an active, growing root.

Geotropism. Because roots usually grow where they can best absorb food materials, they show a tendency to grow downward, i.e., toward the earth. This might at first thought be credited to mere weight, but it is evident that stems, though equally heavy, cannot be made to grow down, and that roots, though lighter than the soil, still force their way through it, and cannot be made to grow upward, even though repeatedly started in that direction.

This turning of roots and stems is caused by the attraction of the earth, called *gravitation,* and this response that plants make to gravitation is called *geotropism* — positive in the case of roots, and negative in the case of stems. Positive geotropism plays an essential part in absorption by causing the roots to penetrate the soil rather than to grow in any chance direction. Roots always grow down, not because they seek water but because gravity pulls them.

To prove that roots turn toward the earth. If well-started seedlings be inserted in a split cork which is then put into a test tube of water and inverted, it will be found that the upward-pointing root will soon turn *downward* at the tip, as will all of its branches. This should be repeated with another kind of seedling. It would not do to infer a general rule from one case. Another form of experiment is to place seedlings on a circular disk. At regular intervals the disk is rotated and the positions of the roots and stems noted. Why is it necessary to rotate the plants? Can you devise other experiments to prove that gravitation affects plants?



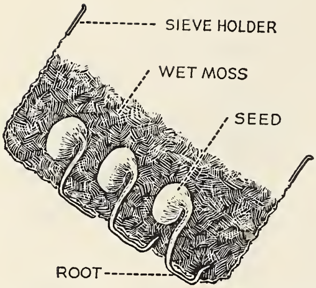
Experiment Illustrating Geotropism. A. The roots point upward and the stem downward. B. The roots start to bend down and the stem turns upward.

If a germinating box with well-grown seedlings is turned on its side, the roots will turn down, no matter how often the experiment is changed, thus proving the same thing in another way. Our experience with planting seeds in the garden also is a good experiment on the same line; the root turns down, no matter how the seed is placed.

The same experiments prove that stems turn *away* from gravitation's pull. This is called negative geotropism, and applies to most plant parts except roots.

It might be thought that light had something to do with this change of direction in plant parts. How could it be decided by experiment?

Hydrotropism. Roots respond similarly to the presence of water, turning toward moisture even at long distances. This tendency, called *hydrotropism,* is very useful, especially if soil water is scant. Vast numbers of fine roots are often found projecting into springs and streams, forcing their way into water pipes, or piercing deep into the soil, led by this force that turns them toward the needed moisture.



Experiment Illustrating Hydrotropism. The seeds are planted in an inclined sieve filled with wet moss.

The roots of poplar trees so frequently penetrate into drain pipes that in many cities the planting of poplar trees on the streets is forbidden.

To prove that roots turn toward moisture. If seeds are planted on the bottom of a coarse sieve which is then filled with wet moss and tilted at an angle of about forty-five degrees, the direction taken by the roots will be different from what might have been expected from the above experiment. The roots will start downward at first, directed by gravitation, but when they have penetrated the sieve, they will turn toward it again and re-enter the moss in order to find moisture.

This response of roots to moisture (hydrotropism) will cause roots to turn toward a water supply if the surroundings are dry, even though they turn partly away from the direct downward line.

Classification of roots. The usual place from which roots develop is the lower end of the stem. Such roots are called *normal roots.* If they grow from other places on the stem, as in the corn plant, or from leaves, as in English ivy, they are called *adventitious roots.*

Normal Roots

Soil roots. Of all forms of normal roots, the commonest are the soil roots. These are of many kinds, depending upon what functions they must perform and the character of the soil, moisture, and climate that surround them. They may be divided into three general classes.

Fibrous roots are made up of many fine slender rootlets, giving large extent of surface for absorption. The roots of the grasses, for instance, are so numerous that they hold the soil together, forming a compact layer called turf.

Taproots are greatly lengthened primary roots which enable the plant to go deep after water supply and hold firmly in the ground. The thistle, dandelion, burdock, and many more of our worst weeds are thus adapted to making a living under adverse circumstances.

Fleshy roots are adapted for storage of foods and have the main part thickened, as in the carrot, turnip, and beet. They are generally found in plants which require two seasons to mature their seed and so need stored food to carry them over the winter. In some cases, including the dahlia and sweet potato, the fleshy root is used to reproduce the plant.

Aerial roots. Some tropical orchids which live attached to trees and never reach the soil develop aerial roots. They have a spongy cortex, which absorbs water from the moist air of the forests.

Aquatic roots. In a few floating plants such as the duckweed and water hyacinth the root system consists of aquatic roots. These roots are usually small, few in number, and lacking in root hairs. They do not need extra surface for absorption because they are surrounded by an abundant water supply.

Adventitious Roots

Brace roots. From the stems of corn and many other grasses develop brace roots, which help to support the slender stems or to raise them again if they are bent down.

Roots for propagation. In certain plants if the stem lies in contact with the soil for a sufficient length of time, roots will spring from the joints and produce new plants. The stems of various berry bushes can thus be fastened to the earth — "staked down" — and will take root in this way. The new root systems when sufficiently developed can be separated from the parent plant and will produce a new berry bush.

Slips or cuttings from certain plants develop adventitious roots from the stem or leaves and start new plants by this means. Many plants, like the strawberry, send out horizontal stems called "runners" from which adventitious roots develop and produce other individuals.

Climbing roots. The stems of poison ivy, English ivy, and some other vines grow climbing roots which act chiefly as a means of support. These plants have ordinary soil roots also, for the purpose of absorption.

Parasitic roots. In a few plants, such as the dodder and mistletoe, parasitic roots develop from the stem, penetrate into the tissue of some other plant, and absorb food from their victim, often causing its death or serious injury. The dodder is parasitic upon clover, goldenrod, and other plants; the mistletoe usually grows upon oak, hackberry, and elm trees.

Roots as crops. Many plants develop large fleshy taproots as reservoirs of food, stored for future activities of the plant. Such plants are commonly grown as crops, the roots serving as a valuable article of food.

Among the more important root crops are the carrot, radish, beet, turnip, parsnip, and sweet potato. The white potato is not a root, but a stem.

Observing roots. Roots are easily examined when plants for any reason are taken from the ground. Excavating usually exposes root systems, and even weeding the garden — an occupation not generally welcomed — may add to our knowledge if the weeds pulled up are examined. To trace a poplar tree root for more than thirty feet gives one a new appreciation of the spread of some root systems in their search for water. Pull up a clump of grass and wash off all the soil. Are you a good enough mathematician to count the tiny roots? It will bring a realization of the enormous numbers of competing roots which branch through the soil wherever plants are growing. Many plants do not pull up so easily as grass. After you have tugged at a burdock or dandelion you may begin to appreciate how deep roots can grow down into the soil.

The roots of a large tree usually extend horizontally under the soil for about as much distance as the branches extend from the trunk.

Brace Roots of the Corn Plant

Summary

Roots, those organs which grow under the ground and are not seen, are essential to all the other activities of the plant. As well as anchoring the plant, they spread through the ground reaching water and minerals which they conduct upward to the stem and leaves.

Many plants store large quantities of food in specially enlarged fleshy roots. These plants are widely grown as root crops.

New cells continually develop at the tip of the root where growth in length occurs. Later, these cells mature into tissues, specialized in performing definite activities. The root is, therefore, a highly developed organ capable of performing with great efficiency functions necessary to the life of the plant.

Using Your Knowledge

1. Describe the general form of a tap root system; a fibrous root system.

2. Explain why plants with diffuse roots act as soil-binders.

3. From the standpoint of origin, distinguish between primary and secondary roots.

4. Root hairs are sometimes incorrectly called branch roots. From the standpoint of structure, why is it biologically incorrect to speak of a root hair as a branch or secondary root?

5. What four distinct regions may be readily distinguished near the tip of a young root?

6. If a large root, such as a carrot, is sectioned, what three regions are clearly visible?

7. Branch roots develop from the pericycle at the outer edge of the central cylinder. Explain why a branch root must connect with the central cylinder and could not grow merely from the surface of the root.

8. What force exerts an influence upon root growth during geotropism? Is the root response positive or negative?

9. Explain the importance of hydrotropism to the life of a plant.

10. Distinguish between adventitious roots and normal roots.

11. Name four special purposes served by adventitious roots.

Expressing Your Knowledge

anchorage	elongation region	stimulus
conduction	maturation region	response
support	carbonic acid	adventitious root
storage	epidermis	fibrous root
root system	cortex	fleshy root
primary	endodermis	brace root
secondary	pericycle	propagation
taproot system	central cylinder	parasitic
diffuse root system	cambium	geotropism
root hair	xylem	hydrotropism
root cap	phloem	root crop

Applying Your Knowledge

1. Remove five common plants from the soil and examine the root system of each. Classify the root system of each.

2. Germinate some seeds (corn, pea, bean, or radish) in covered dishes. Watch carefully the development of root hairs.

3. Section any large root (carrot or parsnip) and see how many regions you can distinguish.

4. Devise an experiment of your own to prove that roots turn downward.

5. Examine carefully the plants around your home and see if you can find any examples of adventitious roots.

6. Make a list of crop plants which are grown for their roots.

Chapter 11

The Root as an Organ of Absorption

The preceding chapter has presented the structure of roots and the variation in the form of roots and root systems which, to a great extent, enable plants to inhabit extremely different kinds of surroundings.

We found that a root is composed of many kinds of specialized tissues, each suited to a particular function performed by the root. Roots are specialists in absorption, anchorage, and storage, and, in addition, serve as organs of conduction in delivering water and minerals removed from the soil and in receiving food materials for storage.

We could hardly compare the values of these processes to the plant, but we could say that among these processes the most apparent and most amazing role of the root is as an organ of absorption.

During absorption, water and minerals leave the soil and enter the root system. This is common knowledge. Were we unscientific, we would be satisfied with this wholly inadequate explanation for this very important root process.

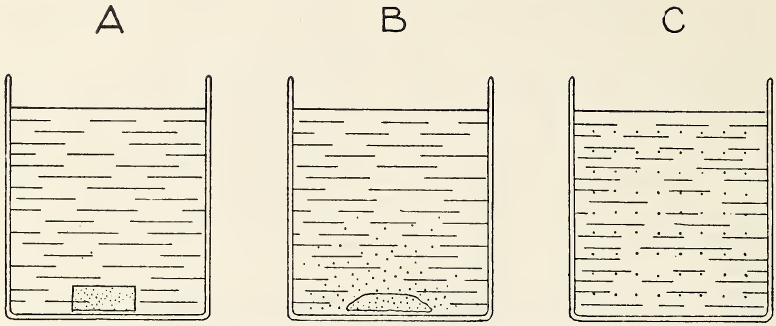
But as students of science, we are interested in causes. Science cannot give all of the answers to this amazing occurrence, but certain basic principles presented in this chapter will explain much about absorption and how it works.

Why must living cells absorb? You learned, in the study of cells, that a cell is a unit mass of protoplasm *enclosed* in a living membrane. Since membranes surrounding cells are living, they must, likewise, be made of protoplasm. While living membranes are thought to contain great numbers of extremely minute pores, they certainly do not contain any special openings through which water may stream in, for such openings would, likewise, allow the living content of the cell to stream out.

Through the membranes of cells, materials of various sorts are constantly passing. In this manner, cells get food, water, and oxygen, and discharge waste products and cell secretions. The only way in which substances may enter cells is by *absorption*.

We know that water enters epidermal cells through the absorbing projections or root hairs temporarily formed on the young root. Water and minerals pass into these root hairs from the soil through living membranes. But why? Are they sucked in? Certainly not! To answer this question, we turn to some physical principles — principles which are in no sense limited to living cells.

Diffusion. According to the natural laws of *diffusion,* substances tend to equalize through space. If, in one area,



Diffusion. A. Lump of sugar is placed in water. B. As it starts to dissolve, the particles spread out in the water. C. After it has completely dissolved, its particles are found scattered throughout the water.

a substance is more abundant, or is more *concentrated* than in another, its particles tend to spread into the area of less abundance, or less concentration. Diffusion equalizes the substance.

To illustrate diffusion, let us imagine that you open a can of ether in the corner of a room. Particles of ether come out of the can and mingle with the air particles, giving an odor of ether. As this process continues, the odor becomes stronger. More and more ether has become distributed throughout the room. Finally, after the ether has stopped flowing out of the can, a point is reached at which the ether fumes have penetrated into all parts of the room and all areas of the room smell equally of ether. According to diffusion, *two* things have caused this condition. Ether particles diffused among the air particles, and air particles diffused among the ether particles. Or, we could say that ether particles diffused from an area of greater concentration (the container) into an area of lesser concentration (the room) until the concentration of both ether and air was equal in both areas. This phenomenon is repeated daily in hospitals where ether particles diffuse from the operating room through all parts of the air, and greet you even at the front door.

Other familiar examples of diffusion. Solids and liquids, or liquids and other liquids may diffuse just as readily as gases *if they normally mix* and do not repel each other. A lump of sugar placed in a glass of water will gradually dissolve and completely disappear, even without stirring. According to the principles of diffusion, sugar particles which are concentrated in the lump, pass to the area of less sugar concentration, the water, and distribute themselves equally. During this movement of sugar, water particles distribute themselves through the sugar, according to the same principle.

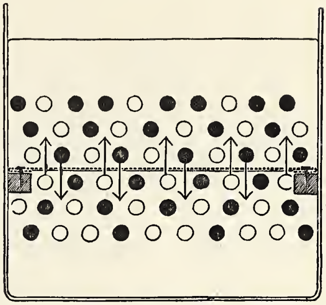
A layer of alcohol or glycerin and a layer of water in a container, diffuse in the same manner to form a solution containing equal amounts of each substance in all parts.

Diffusion through membranes. The study of diffusion becomes more complicated and more interesting when a membrane is involved. *Membranes* are thin materials such as cellophane, a portion of an animal bladder, a piece of parchment, or a section of muslin, which will permit substances to pass through.

If a certain substance passes through a given membrane, it is said to be *permeable* to that substance.

Diffusion through a permeable membrane can easily be illustrated. Stretch and securely fasten a square of muslin over a frame which securely fits the inside of a rectangular jar. Lower the frame into place so that it divides the jar into equal parts, top and bottom. Now pour water into the jar and watch it pass through the muslin and fill the lower half of the jar. Then fill the top half with molasses. Within a few minutes, the brown molasses will appear on the lower or water side of the cloth and will penetrate the water area. At the same time, water will enter the top or molasses portion. Finally, a solution containing equal amounts of water and molasses will occupy both areas of the jar. Therefore, we conclude that muslin is permeable both to molasses and to water particles.

Now, if we change the muslin to parchment or a piece of animal bladder and repeat the experiment, we find that the results are quite different. These membranes permit water to pass through quite readily, but they greatly retard the passage of molasses particles. Water particles penetrate the membrane and pass back and forth quite freely, tending to flow more rapidly toward the area of lesser concentration within the molasses area. The same forces move molasses particles toward the water area, but the membrane interferes with their progress and very few reach the water area. Consequently, the water and molasses can never equalize. The membrane used in this experiment is *differentially permeable:* that is, permeable to different substances to different degrees. It is freely permeable to water but not to molasses.

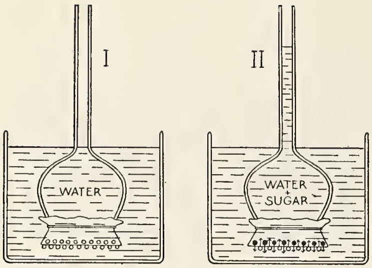


Diffusion of Water and Molasses. The white circles represent water particles; the black dots represent molasses particles.

Osmosis, a special type of diffusion. When a differentially permeable membrane involves diffusion of water, we term the diffusion *osmosis.* Diffusion through this type of membrane frequently involves substances other than water, though they may not move as readily as water.

The diffusion of any substance through a differentially permeable membrane is a type of diffusion, but in defining osmosis, we are even more limiting. To distinguish the movement of water from that of other substances during this type of diffusion, we limit osmosis to the diffusion of water. It may, then, be defined as the *movement of water through a differentially permeable membrane from a region of greater concentration of water* (where the particles of water are closer together) *to a region of lesser concentration of water* (where the particles of water are farther apart, due to the presence of other substances such as salts and sugars). We will learn later that this movement depends upon definite conditions which regulate the flow.

Laboratory demonstration of osmosis. Osmosis may be illustrated easily by a simple experiment. Plug the stem of a



OSMOSIS. I. Why is there no rise of water in the thistle tube? II. Why, in this case, does the water in the thistle tube rise?

thistle tube. Then fill the bowl with molasses, allowing the molasses to penetrate the stem several inches below the bowl. Gently lay across the bowl a previously moistened square of sheep intestine, cellophane, or goldbeater's skin. Stretch tightly and secure by rubber bands. Now thoroughly wash the exterior of the thistle tube. Using strips of cork on the inside of the jaws of the clamp of an iron stand, securely support the thistle tube inverted in a battery jar partly filled with water. Remove the cork from the stem and make additions to, or subtractions from, the water in the jar, so that the apparatus may be set up with the molasses in the thistle tube at the same level as the surrounding water. Mark this level on the outside of the jar with a colored paster. Cover the jar with a circle of cardboard slit to the middle, to prevent evaporation of water. Slip a piece of rubber tubing over the end of the thistle tube stem and thus attach a section of glass tubing above it, properly supported.

Within a few minutes, the level of liquid in the stem of the thistle tube will have risen noticeably. Within an hour's time the column should be several inches higher. It may go up several feet in twenty-four hours and will probably reach its greatest height within forty-eight hours.

Interpretation of the experiment. Since this experiment is typical we may well study it carefully to interpret the osmotic reactions. Since no water has been added to the thistle tube after the apparatus was set up, the only possible explanation of the increased amount of water is that water penetrated the bowl of the thistle tube through the membrane. We do not yet know whether molasses passed out.

It is clear that there is an evident movement of water through the membrane into the molasses, which is a thick solution made from brown sugar and a little water. Water, then, is diffusing through the membrane from a region where there is relatively much water, into the molasses, a region of relatively little water.

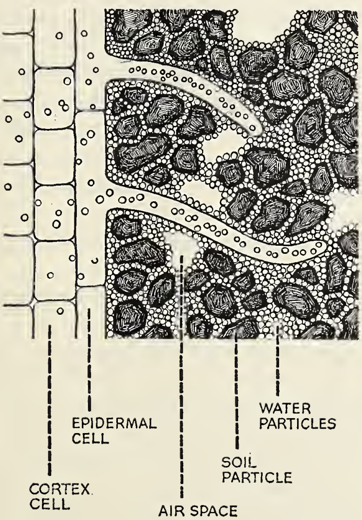
However, the law of diffusion indicates that there should also be a tendency of molasses particles to leave the area of greater concentration, through the membrane into the water. This actually takes place. But since the membrane is much more permeable to water than it is to molasses, the flow of the molasses through the membrane into the water is naturally much slower.

The more rapid movement of one liquid, in this case water, piles up this liquid on the inside of the membrane, causing pressure enough to raise the level of the liquid.

The root hair and the soil — an osmotic system. Keeping in mind the experiment just described and interpreted, let us now substitute for the thistle tube, a root hair; for the molasses, the content of the cell; and for the jar of water, the water in the soil. Within the cell there are solutions of various substances dissolved in water. Protoplasm is such a solution, containing as you have already learned, about seventy per cent water. Within the cell protoplasm are cavities called vacuoles which contain solutions of mineral salts, food materials, and other dissolved substances. Water in the soil likewise contains dissolved mineral matter but *normally* not as much as the cell contents. In other words, the concentration of water outside of the cell is greater than inside. Water in the soil is separated from the contents of the cell only by a thin, porous cell wall and by the membrane surrounding the protoplast. Hence, an osmotic system is set up; two solutions containing water in different concentrations are separated by a differentially permeable membrane. The result is a movement of water from the soil into the cell by osmosis.

Why must cells have water? Water is essential to all living cells for several important reasons which include:

1. *Growth.* Since water is the basis of protoplasm, a plant or animal cannot



Successive Osmosis in Root Hairs

Turgor. Turgid cells enable a plant to push through cracks in cement sidewalks such as this.

grow without having sufficient water in its cells.

2. *Food manufacture.* Water is a raw material necessary for the formation of food materials in the green plant.

3. *Transportation of essential substances.* Foods, oxygen, and other materials are carried to the cells in solution in water, or in a transporting substance of which water is the base. Sap in the plant and the blood in animals are such transporting substances.

4. *Waste removal.* Waste products are removed from living cells and from the bodies of plants and animals dissolved in water.

5. *Maintenance of rigidity necessary to living plant cells.* Water plays an important part in giving rigidity or stiffness to the plant, especially to its softer parts. This value will be discussed in detail in the following paragraphs.

Turgor. A strong, vigorous plant usually stands erect and comes back to position if bent. This is due to the fact that normally each cell in the plant is full of water. The water gives each cell firmness, much as a blown-up paper bag seems hard. In turn all of these expanded cells taken together give rigidity to the whole plant. We can realize this better if we consider a plant that has been deprived of water until it has begun to wilt. The cells of such a plant not receiving a full supply of water tend to collapse like half-empty balloons, thus causing the leaves and stems of the plant to droop. If water is supplied before the protoplasm dies, the plant will soon resume its rigid position.

This stiffness of plants due to the presence of water in their cells is called *turgor* and is very important in supporting the smaller plants, whose stems are not stiffened with wood fibers. Nearly all leaves depend to a considerable degree on turgor for their expansion. The water which supplies these essential needs comes from the soil.

A simple experiment may serve to clarify this matter still further. Cut several slices from a raw potato. Place some of the slices in water and leave others exposed to the air for an hour or two. When taken from the water, the former will be as rigid or even more so than when first cut, while those exposed to air will have become soft because some of the water in the cells will have evaporated. If you drop one of these flabby pieces into water it will again become firm and regain its turgor, because the cells swell as they absorb water.

Water is normally taken in by living plants to such an extent that when the plant is fully turgid the pressure within its cells usually rises to an amount varying between 60 and 150 pounds per square inch. In a few plants it may reach 1,500 pounds per square inch! Pollen grains and some fruits and vegetables may occasionally burst open under conditions of extreme moisture because of this internal pressure from absorbed water.

Sometimes groups of cells where growth is taking place become so hard and turgid that plants, apparently delicate, accomplish seemingly impossible feats in penetrating hard-surfaced ground. Mushrooms and seedlings frequently emerge through layers of solid earth; there are even cases where concrete has been known to burst with the push of young ferns, and where rocks have been split by growing trees.

The rate and quantity of water absorption varies with the kind of plant, with variations in temperature and light, and with the kinds of dissolved substances surrounding the cells. It also depends largely on whether the cells are alive. Dead cells, instead of absorbing water, at first tend to lose their watery contents. For instance, much of the red coloring matter of beets can be extracted easily after killing the cells by boiling, whereas even when grated, fresh beet cells retain their color. For commercial uses plant tissues are killed by immersing them for a time in liquid air, after which their watery juices are easily extracted by pressure.

Critical conditions for osmosis. The normal entry of water into a cell depends upon certain critical conditions both within and outside of the cell. Remember that osmosis is a purely physical process over which the cell has no control whatever. While many factors influence osmosis, two critical conditions determine whether water will enter a cell or whether the cell will lose its water supply to its surroundings. These critical conditions are:

1. Concentration of water within the cell.

2. Concentration of water outside of the cell.

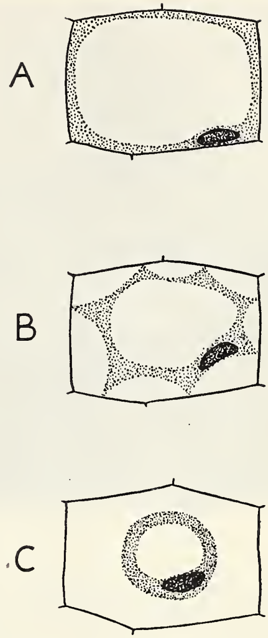
If water enters a cell, it is because the water concentration is less inside of the cell than outside. Concentration of water within is related directly to the amount of minerals and soluble food materials contained in solution in the vacuole. The greater the quantity of these dissolved substances, the less the concentration of water and, logically, the greater the water attracting power of the cell solutions.

Osmosis is regulated, also, by the concentration of water outside of the cell. If the soil contains large amounts of soluble matter, solutions may form outside of cells with less water concentration than cell content, in which case a most damaging condition results.

Osmosis " in reverse " — loss of turgor in cells. We have learned that, during osmosis, water normally enters a cell causing an internal pressure resulting in turgor. But if the greater water attracting solution happens to be outside of the cell, water is lost by osmosis and turgor likewise is lost, accompanied by a resulting reduction of internal pressure.

To demonstrate the loss of turgor, slice two pieces of potato and place one into strong salt water and the other into fresh water. The slice in salt water soon becomes limp or *flaccid,* while the slice in fresh water, serving as a control in the the experiment, remains stiff and turgid. The control demonstrates that slicing alone was not the cause of limpness.

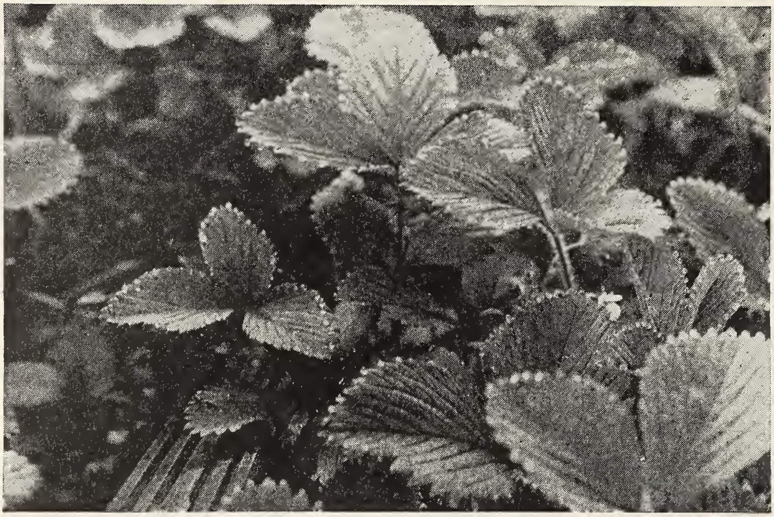
The microscope will greatly assist us in observing what actually happens in such a case. With a razor prepare two thin sections of fresh potato. Mount one in a concentrated (containing a large amount of the dissolved substance) salt or sugar solution, and the other in pure water to be used as a control. As you watch both slides, you will soon see the protoplasm in the cells surrounded by the salt or sugar solution move away from the walls and shrink to a mass in the center of the cell because the water is leaving the protoplasm and vacuole and entering the solution outside of the cell. On the control slide, the cells remain as before, with the protoplasm pressed firmly against the wall in a normal, turgid condition. Glycerin, alcohol, and any other substance which will dissolve in water in considerable quantities may be substituted for salt or sugar. Similar results will be obtained.



Plasmolysis. A. Turgid cell of a potato. B. Partially plasmolyzed cell. C. Completely plasmolyzed cell.

The collapse of cell protoplasm due to the loss of water is called *plasmolysis* [*plas moll'ih sis*]. Temporary plasmolysis may be corrected by an intake of water but if this condition continues very long, the cell will die.

Now you can understand why salt kills grass. You can understand too, why shipwrecked men die from drinking salt water, for the cells of our mouths, throats, and stomachs are just as subject to plasmolysis as are the cells of roots or leaves. Plasmolysis explains also why a too heavy application of fertilizers to the



GUTTATION IN STRAWBERRY LEAVES

soil may result in strong solutions which are capable of killing the roots they contact. Fertilizers contain large quantities of various chemical salts.

Successive osmosis. Our discussion of osmosis has concerned so far, only the entry of water into a cell from the outside. Absorption of water by the epidermis of a root would be of no avail to the plant if there were no means of delivering this water to all of its tissues.

Successive osmosis is osmosis from cell to cell. By means of it, water passes from the epidermis through the thick layer of the cortex to the central cylinder. There it begins its long journey through the special conducting vessels to the stem, leaves, and flowers.

When the outer layer of cells has taken in soil water, the contents of these cells are diluted; that is, there is relatively more water in them than before. Their contents are now more watery than the contents of the adjacent cells. As the osmotic current is always toward the place where there is less concentration of any liquid, the water contents of the root hair cells (outer layer of cells) tends to pass from these cells containing much water toward the cells lying directly inside of them. By the same process repeated in adjacent cells, water moves toward the center of the root. Thus the newly absorbed soil water moves inward from the epidermal cells, leaving them denser again, ready to absorb more soil water from without.

Root pressure, a factor in water conduction. The absorption of water by the root and passage of water through its tissues toward the central cylinder results in a pressure within the cells known as *root pressure*. This pressure is maintained or even increased from outside to inside. Thus, when water reaches the ducts in the water-conducting region of the central cylinder it enters the pores in their thick walls with considerable force.

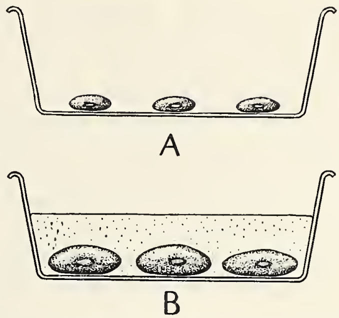
Rise of water through the root and

stem due to root pressure may be demonstrated by cutting a plant off near the ground. Water may be seen to run out of the severed vessels. In some plants such as the grass and the tomato, root pressure may be great enough to force water through the stem and out through the ends of the veins of the leaves, where it appears as drops. This forcing of water through the leaves is referred to as *guttation,* while the loss of water through a cut stem is called *bleeding.*

Root pressure alone, however, cannot account for all of the force necessary to raise water through the stem. Especially in longer stems such as trees, forces other than root pressure are necessary to accomplish conduction. In later chapters you will learn about these other factors which, together with the push of root pressure, exert a pull necessary to conduction.

Absorption through the forces of imbibition. Many substances such as starch, gelatin, wood, and the coats of seeds absorb large quantities of water, thereby increasing enormously in size. This absorption of water by a solid, which results in swelling is termed *imbibition* [*im bih bish'shun*]. Imbibition differs from osmosis in that water enters the substance which absorbs it rather than entering a vacuole within the living cell. When wood imbibes water, it swells due to the entry of water into the wood substance itself.

Primitive people made use of the forces of imbibition by driving wooden wedges into crevices in rocks and then wetting the wedges. The swelling wood exerted a force sufficient to split large stones in this manner. The fact that a leaky boat ceases to leak after being put into the water is due to closing of the cracks as the boards swell due to imbibition. Still another example is the swelling of dry beans put to soak for several hours before baking. You have probably observed how greatly such beans increase in size as they imbibe water through their seed coats.



IMBIBITION. A. Dry beans. B. Beans which have been soaked in water for twenty-four hours.

In much the same manner, the walls and protoplasts of cells imbibe water. While imbibition is not thoroughly understood by scientists, its forces, together with osmosis, account for the entry of water into a plant cell.

Absorption of minerals. Absorption by the root concerns not only the intake of water, but the entry of mineral substances as well. These minerals pass through the membranes of root hairs in solution with water. Together with water, they move through the cortex to the inner tissues of the central cylinder where they are conducted to other parts of the plant.

The relation of dissolved minerals to water in the soil solution is very close. One might assume that they enter the root with water during osmosis and imbibition. Biologists have found evidence that mineral absorption may be independent of water intake. This phenomenon of mineral intake has been called *selective absorption.* It takes into account the variation of mineral content found in different plants even when they are grown under very similar conditions of soil environment.

Broccoli has a high calcium content. But another vegetable, peas, growing under the same conditions in the same soil will not have the same high calcium content because selective absorption is not as active in peas as in broccoli.

The soil environment of the root. Before closing our discussion of absorption by plant roots, we should include a brief consideration of the soil environment in which roots carry on this activity.

Basically, soil is a mass of rock particles of various sizes, formed through weathering, freezing and thawing, rainfall, and other natural activities. Soil in many regions is the result of vast deposits left by the glaciers of former eras.

Through the ages, plants have enriched this mineral matter with the organic remains of their roots, stems, and leaves which have become part of the soil by the processes of decay. Associated with the mineral and organic portions of the soil are large numbers of bacteria, molds, and other microscopic organisms which are essential to its fertility.

The texture of soil refers to its physical composition, that is, the size of its particles and the amount of space between these particles. The average loam soil is estimated to contain spaces amounting to from one third to one half of its total volume. Spaces between soil particles are exceedingly important to the root, since they fill with water after rains and allow the water to penetrate to areas in which roots are carrying on absorption.

Soil must supply water, mineral compounds, and oxygen to the living root. It must be loose enough to permit water to enter from the surface after rains and to permit oxygen to filter through it and become dissolved in the soil water. Seepage of water through the soil spaces results in the dissolving of necessary soil minerals.

The water-holding capacity of soils depends directly upon their texture and content. If the particles are extremely small, as in clay, the soil becomes packed tightly and lacks the spaces into which water may penetrate. Sand and gravel, on the other hand, consist of large particles and have large spaces between the particles, but cannot hold water because the spaces are too large. Loam soil is ideal for most plants because of the relation between particles and spaces.

Organic matter in soil holds water by imbibition and, in swelling, tends to keep the soil loose. This accounts for the constant wetness of rich woods earth. However, in soil such as peat, the organic matter may imbibe so much water that roots are unable to absorb from soil which is so wet that water may be squeezed from it. Again, loam soils seem to have the ideal balance between organic matter and mineral particles. We must remember, however, that plants are adapted to live in all types of soil. To say that plants prefer sand, loam, clay, or peat soil would be to disregard the special requirements of plants.

Summary

While roots perform various functions, including anchorage, absorption, and storage of food, perhaps their most vital role is the supply of water and soil minerals to the plant.

Absorption results from several purely physical processes involving the soil and the root. Both water and minerals enter the root as a result of forces of diffusion. Since living root cells possess differentially permeable membranes, diffusion is altered to the extent that different substances diffuse in different amounts and at different rates.

Diffusion of water through the cell membrane is termed osmosis. The flow of water is always from the region of greater water concentration to the region of lesser concentration regardless of the effect upon the cell. Another type of diffusion, imbibition, is responsible to some extent for entry of water into root cells. By the process of successive osmosis, water passes from the outer tissues to the central cylinder of the root. Root pressure, due to turgor in the root tissues is responsible, in part, for the rise of water through the water conducting vessels in the central cylinder.

Minerals enter the root in solution in the soil water, but as the result of forces independent of the osmosis of water.

Using Your Knowledge

1. Explain why absorption must be involved in the entry of food and water into the protoplast of a cell.
2. Explain how particles of a substance are distributed equally through space according to the laws of diffusion.
3. What is meant by the permeability of a membrane?
4. In what important respect does osmosis differ from other types of diffusion through membranes?
5. Why does water normally enter rather than leave a root hair growing in the soil?
6. List five important uses of water to a cell.
7. What characteristic denotes that a plant tissue is turgid? What causes this condition?
8. What two critical conditions, both concerned with concentration of water, determine the direction of the greatest flow of water during osmosis?
9. Explain how loss of turgor may occur and leave cells limp or flaccid.
10. Explain successive osmosis in the movement of water from the outer tissues to the inner tissues of a root.
11. What is the importance of root pressure in forcing water upward through the root and stem?
12. Explain how imbibition differs from osmosis, even though both forces are concerned with the entry of water into a cell.

Expressing Your Knowledge

absorption	osmosis	root pressure
diffusion	osmotic system	guttation
concentration	turgid	bleeding
membrane	flaccid	imbibition
permeable	plasmolysis	selective absorption
differentially permeable	successive osmosis	water-holding capacity

Applying Your Knowledge

1. List several examples of diffusion which you observe during the day.
2. Plan an experiment to show osmosis. Do not use examples in the text.
3. Place some slices of potato or cucumber into a dish containing strong salt solution for several minutes. Examine and explain the change in texture.
4. Get samples of sand, loam, and clay. Fill funnels with the same amount of each. Place a container under each. Pour equal amounts of water in the funnels. Saturate the soils and allow some to run through. Measure the amount of water passing through each soil and explain the results.

Chapter 12

The Stems of Plants

You have learned about the root and its vital activities so essential to the life of the plant, but without the stem as a connecting link between the root and the leaves, the soil water and minerals absorbed by the root system would be entirely useless to the plant.

Stems are familiar to all of us. We admire them as stately trees and spreading shrubs. We watch with interest the stems of the morning glory, sweet pea, and bean as they twine up a string or pole in our gardens, and the creeping stem of the strawberry as it inches its way along the ground, spreading new plants in an ever-increasing patch.

Plants vary widely in the kinds of stems they produce. We find them modified for all sorts of purposes, creeping, climbing, standing upright, and even hidden in the ground as they render their useful services to the plant.

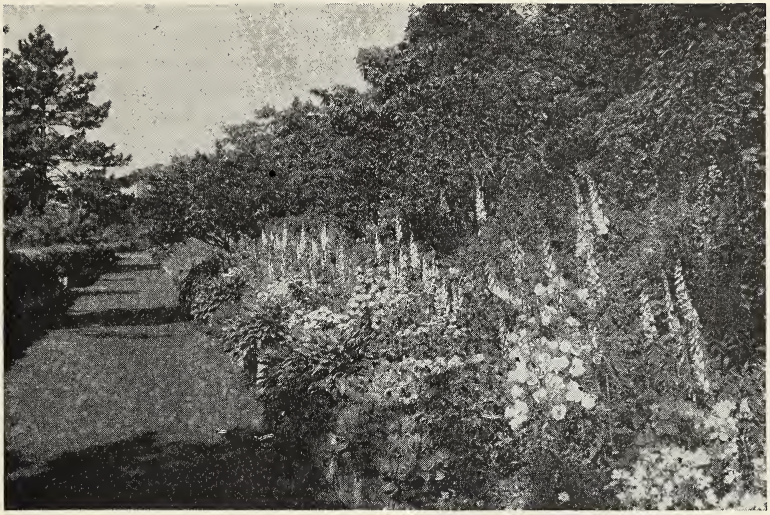
The work of the stem. The most apparent function of the stem is the *production* and *display* of leaves and flowers. Food-making processes carried on in the leaves require light. In most plants, the stem bears leaves arranged on branches which provide them with sufficient light to meet their particular requirements. Flowers, too, usually require display in order to accomplish pollination, essential to the production of fruit. Wind and insects commonly serve as agents of distribution of pollen from flower to flower — both requiring display of the flowers on stems.

As the connecting link between the roots and leaves, stems serve another important role in *conduction*. Water and minerals, entering roots from the soil, pass upward through the stem to the leaves. Similarly, the stem serves as the avenue of downward flow of water and dissolved food materials from the leaves to the living tissues of the stem and roots. You will learn, later, how the stem performs this vital role of conduction.

Some stems are modified to afford excellent places for *storage* of water and reserve food supplies for the plant. The cactus, for example, may hold sufficient water in its thick, fleshy stem to last through long periods of drought which are characteristic of desert regions. While all stems contain some stored food, specialized stems such as potatoes or the thick rootstocks of iris serve especially as organs of food storage.

Even *food manufacture,* usually associated with leaves, is in many plants an activity of the stem. Green tissues in the outer area of many stems greatly increase the food-producing regions of the plant.

Certain plants may even *reproduce* by means of their stems. This type of reproduction is termed *vegetative* to distinguish it from reproduction involving flowers, fruits, and seeds. By means of stem cuttings willows, roses, and many other plants may be multiplied quite easily. Strawberries form new plants by means of horizontal runners which give rise to roots and new shoots at regular intervals, where the stem contacts the ground. Other examples of plants which



Plants with Herbaceous Stems. Most of our common garden plants are of this type.

carry on vegetative reproduction by means of their stems are the blackberry and raspberry, the sugar cane, and numerous greenhouse plants.

The variety of activities carried on by stems results from numerous adaptations in their form and structure. While a complete classification of stems would be a tremendous undertaking, we can learn much by examining a few familiar plants and the manner in which their stems perform their activities.

Aerial and underground stems. Most plants bear their stems above the ground, where they may either stand erect, cling to objects of some sort, or trail along the ground. These *aerial* stems are the familiar type which we are accustomed to see. However, many plants produce stems which lie hidden in the ground. These *underground* stems frequently serve special purposes to the plant and are so different from aerial stems that we shall discuss them in a special section of stem classification.

Herbaceous and woody stems. If you were asked to define an *herb,* you would probably think immediately of a plant from which a special drug is extracted for making medicine or which is used as an ingredient in an herb tonic. In medical terms, you would be entirely correct. But to the botanist, the term herb is used much more widely to refer to any plant which is not *woody.* Tomatoes, violets, beans, peas, grasses, lilies — in fact, all plants with soft, green stems — are classified as herbs. In referring to plants of this sort, we commonly use the term *herbaceous,* to distinguish them from woody plants.

Herbaceous stems lack the woody fibers which give strength to trees and shrubs. Deprived of water, they frequently wilt and become limp. As a rule, herbaceous stems grow little in diameter and last only one season. In this respect, we classify the herbaceous stem as annual, though the plant as a whole may be perennial, forming a new stem

STRAWBERRY PLANTS WITH RUNNERS. A. Parent plant. B. Runner. C. New plant.

each season from a more or less permanent root system. Such familiar garden plants as delphinium, poppy, and daisy produce annual stems from perennial roots. In cases where both roots and stem die after one season, as in the nasturtium, marigold, and pansy, the entire plant is called an annual and the stem is of course herbaceous.

Woody stems are nearly always perennial — that is, they live for several years. These stems grow season after season, adding to their length, forming branches, and increasing in diameter. The formation of woody tissues in seasonal layers gives them great strength and causes them to remain standing even after they have ceased to live.

Seasonal growth of trees, both in height and diameter, accounts for the tremendous size they attain during their lifetime. A single growing season completely matures the herbaceous stem of a potato or goldenrod, but centuries are required for the oak, cypress, or redwood to reach its greatest size.

The form of aerial stems. The terms herbaceous and woody refer to the structure of a stem. We classify them further according to the form which they assume and the manner in which they grow. Form and growth habit illustrate the wide variation in stems resulting from adaptation to the surroundings. In general, aerial stems may be grouped as:

1. Shortened
2. Creeping
3. Climbing
4. Erect

Shortened stems. While shortened stems are aerial in that they are formed above the ground, actually they are so reduced in size that they frequently appear to be lacking entirely. For this reason, the dandelion, primrose, and carrot are often called *stemless,* although anyone referring to them as such has failed to notice the short, disk-shaped stem growing just above the root. Leaves develop from the shortened stems of these plants in a circular arrangement called a *rosette.*

While shortened stems, because of their reduced size, cannot elevate their leaves in competing for light with taller plants, their nearness to the ground results in certain distinct advantages in the open fields where they usually thrive. Among the advantages of shortened stems to plants are:

1. Escape from grazing animals.
2. Less danger of crushing from being stepped on.
3. Crowding away of neighbors by the wide, close leaves.
4. Retention of water near the root

due to shading by the leaves which lie close to the ground.

Creeping stems. The *creeping stem,* like the shortened stem, remains close to the ground but its leaves spread much more widely as a result of its length. Plants with creeping stems often form patches or communities of plants all connected by *runners,* as their stems are frequently called. The creeping stem is weak and slender. Lacking woody tissues for support, it must grow along the surface of the ground. Like plants with shortened stems, creeping plants require open places where they are not forced to compete for light with taller growing plants.

Climbing stems. Among the most interesting modifications of stems are the climbers — not just because they climb but also because of the manner in which they use objects or other plants for support. Climbing stems are, as a rule, slender and very long. Like creepers, they lack sufficient woody tissue to stand erect and so are curiously modified in raising their leaves to light by clinging to supports.

In some cases, the stem alone accomplishes the climbing, while in others, roots or even leaves may serve as special grasping organs to fasten the stem to a support.

The pole bean and morning glory lift themselves into the air by *twining* around an object with encircling growth of the stem. On the other hand, the grape and wild cucumber produce *tendrils,* which are really the mere skeletons of leaf veins, as a means of grasping a support and holding the stem securely. The coiling of tendrils or twining of stems is a curious process, for it frequently seems as though a plant or tendril had started straight for a certain support and deliberately coiled about it.

Melon Plant with Tendrils

This is not the case, though the real process is scarcely less wonderful. The tip of the twining stem or tendril grows unequally on different sides, causing it to swing through the air in circles, as it grows. Thus it may reach anything within the radius of its swing, which is often several inches.

Having reached a support, the tip of the tendril no longer swings but coils about the support as it grows. Coils between the support and the stem serve as springs which allow swaying of the vines in the wind without tearing the tendrils loose from the support.

The climbing rose and honeysuckle climb upon objects by merely falling upon them and growing over them. Leaning plants with long, slender stems are exceedingly common in the jungles, where vines form a large part of the tangled mass of tropical vegetation.

Erect stems. A stem which stands above the ground with no attachment to an object is termed *erect.* Such stems may range from a few inches to several hundred feet in height. They may be herbaceous or woody. *Trees* and *shrubs* are familiar examples of erect woody stems. Though usually quite different in appearance, the exact distinction between a tree and a shrub is frequently difficult to make. Size alone is no distinction, though trees are generally larger than shrubs. The *tree* possesses a single woody stem which rises some distance above the ground before it branches. A *shrub,* on the other hand, branches close to the ground, forming several stems of approximately equal size. Some plants, like the rose of Sharon, willow, and the sumac may be tree-like or shrub-like, depending upon the conditions under which they grow.

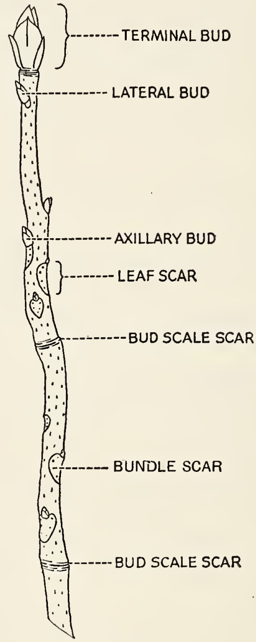
The External Structure of a Woody Stem

The twig of a tree or shrub is an ideal subject for study of the external structure of a stem. In regions where trees shed their leaves during autumn, a dormant winter twig is especially suitable.

Buds are perhaps the most noticeable structures on the dormant stem. Each bud contains a growing point of the stem — a place from which a new stem, leaves, and flowers may develop. In cold climates, *winter buds* are protected by overlapping *bud scales* which completely enclose the tender growing point. These bud scales serve in protecting the tender tissues within from drying out during the resting period. Contrary to common opinion, they do not prevent freezing of these tissues in cold climates.

Buds are classified, further, according to their position on the twig. The *terminal bud,* not present on all twigs, is located at the tip and contains the terminal growing point of the stem. Along the sides are *lateral* buds, from which branches may develop. Lateral buds are usually smaller than terminal buds and, as a rule, are somewhat different in shape.

At intervals along the twig, circular, oval, or shield-shaped *leaf scars* mark the point of attachment of leaf stalks from previous seasons. Within the leaf scars, minute dots called *bundle scars* show the location of the conducting vessels which carried water and minerals into the leaf from the stem. These bundle scars are of a definite number and arrangement, depending upon the kind of stem.



A Woody Twig

You will note, in examining the lateral buds, that they are usually located just above a leaf scar. When the leaf was attached to the twig, these buds were situated in an angle between the leaf stalk and the twig, an angle referred to as the *axil.* Lateral buds produced in the leaf axils are given the special name, *axillary buds.*

The points at which leaves or branches are produced from a stem are referred to as *nodes.* The space between two nodes is termed an *internode.* You will find in examining several twigs that a node may develop a single leaf, two leaves or three or more leaves. If a winter twig shows one leaf scar at each node it is called an *alternate;* if two are present, *opposite;* and, in the case of three or more, *whorled.*

Along the internodes, especially on young twigs, tiny raised pores or *lenticels* open through the bark. These pores permit air to enter and water to escape from the twig, especially while it is young and active. They later become covered with bark and cease to function.

Other interesting structures are found on certain twigs. When terminal buds swell and drop their scales at the beginning of the growing season, a series of rings encircling the twig marks the place where the bud scales were fastened. These *bud-scale scars,* at intervals along a twig, reveal the exact location of the terminal bud during previous seasons. Thus, by starting at the present terminal bud and counting the sets of bud-scale scars along the twig, the exact age of a twig may be determined.

Some twigs bear characteristic thorns which make them very easy to identify. These thorns may be short and broad, long-pointed or branching. In some cases, thorns are outgrowths of the epidermis. They may also be modified branches. The thorns of hawthorne trees and the branching thorns of the honey locust are examples of stems modified into protective thorns.

Identification of trees by means of their twigs. To a casual observer, twigs

HAWTHORN STEM WITH THORNS

are twigs, regardless of kind. They all have buds and, in general, appear similar. But now that you have heard of leaf scars, bundle scars, bud scales, terminal buds, and the other characteristic twig structures, a twig begins to develop a definite personality.

By using tree guides, based upon these twig characters, accurate identification is just as possible in winter as in the summer when leaves are present. The forester usually works during the winter and relies purely upon these twig characteristics for identification of forest trees.

Branching due to bud arrangement. Many trees may be recognized from a considerable distance, especially in winter, because their branches form definite and distinct patterns. Environment may alter the manner of branching to some extent. Trees growing in a forest usually form long, slender trunks and smaller crowns of branches than the same tree would develop in an open

Evergreen Trees in Heavy Snow

place. But aside from environment, the arrangement and manner of growth of buds on the twig influences, to a great extent, the branching form of a tree.

If a young tree possesses a strong terminal bud and terminal buds of succeeding years escape injury, the main stem will continue upward forming a central shaft. Branches will grow from this as a result of the development of lateral buds. Such trees, characterized by forming branches from a central shaft, are classed as the *excurrent* type.

Excurrent branching is illustrated in such species as pine, fir, spruce, redwood, and cypress. These trees, unless injured or diseased have a perfect cone-shaped outline. A strong, central shaft rises to a point at the tip of the tree. Branches grow horizontally at regular intervals along the stem, decreasing in length from botton to top. The difference in length of the branches is due to a difference in age, the oldest branches being located at the base, while the youngest are at the top. By counting the number of circles or whorls of branches along the trunk one may determine fairly accurately the age of the tree.

The excurrent form of branching and the cone-shaped pattern of the pines, spruces, firs, hemlocks and other evergreens have suited these species ideally to the severe winters of northern areas and high mountain regions, though the trees are by no means limited to cold climates. Among the advantages we may include:

1. Small resistance to storms due to slender tops.

2. Branches which may bend downward and shed snow easily.

3. Pyramid shape allowing light to reach all branches to the base of the tree.

Quite a different form of branching is illustrated in the willow, cottonwood, and elm. These trees produce a single trunk which divides, usually rather low, to form several large branches. The effect of such branching is a spreading

Monkmeyer Press Photo Service

ELM TREE. This tree illustrates the deliquescent type of branching.

pattern of growth called the *deliquescent* form. Deliquescent growth results when twigs lack a terminal bud or when lateral buds form branches which equal or exceed growth from the terminal bud. In trees like the buckeye, horse chestnut, and magnolia, terminal buds develop flower clusters, while lateral buds form branches, resulting in a spreading, deliquescent pattern.

Branching form and timber value of trees. Quite obviously, trees forming large, central shafts far exceed the spreading type in timber value. This growth characteristic of pine makes it ideal for lumber, while spruce and fir cannot be excelled for telephone poles.

In the case of the oak, walnut, hickory, maple, and other forest trees, long trunks develop under forest conditions while the same trees may branch more freely in open places. Foresters have found that the best timber trees of these types grow in dense stands.

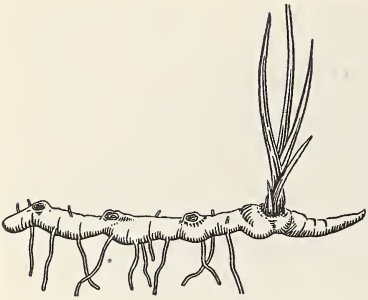
Specialized Stems

The most common specialized stems are those which grow beneath the ground and serve purposes quite different from aerial stems. While underground stems resemble roots in their place of growth, they possess all of the structures of a stem, such as nodes and internodes, buds and even leaves.

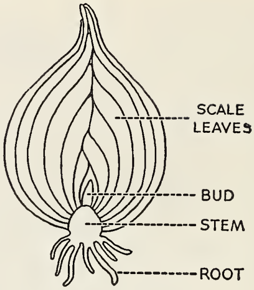
Among the most common forms of underground stems are:

1. Rhizomes
2. Tubers
3. Bulbs
4. Corms

Rhizomes and tubers. One cannot dig a clump of iris or lily-of-the-valley without noticing the thick, fleshy underground parts from which the leaves and flowers develop. These root-like parts are *rhizomes* which grow horizontally,



Rhizome of Iris



Bulb of Onion

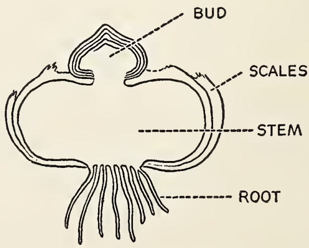
just beneath the soil. Careful examination of a rhizome will reveal nodes at which buds and leaves develop and spaces or internodes between nodes. On the lower side, nodes give rise to clusters of roots. Rhizomes may be thick and fleshy and filled with food, or slender, as in many grasses. As rhizomes grow from year to year, they increase in length and serve as efficient organs of reproduction by forming new plants at regular intervals.

Tubers are enlarged tips of rhizomes which are swollen with stored food. The potato is an example. A tuber, like other stems, has nodes at which buds or "eyes" develop. Internodes separate the "eyes." Each bud may form an aerial shoot and thus reproduce the plant. In nature, the whole plant except for the tubers usually dies when winter comes. Tubers lie dormant until spring, when they sprout and form new plants. Eyes of the potato are conserved in planting, however, by cutting tubers into pieces called "seed pieces," each containing one or more eyes.

Bulbs and corms. These underground stems are commonly seen, though usually confused with each other. A *bulb* is really a large, underground bud as illustrated in the onion. An onion which is sectioned lengthwise will show a small disk-shaped stem at its base from which roots develop. Attached to the upper surface of the disk are thick leaves filled with food and arranged in compact layers. Tucked away in the center of the leaves, or what would be the tip of a compressed stem, is a flower cluster which will eventually grow through the leaves at the top of an aerial stem. A bulb consists largely of thick leaves with the stem area reduced to a small disk.

A *corm* differs from a bulb in that its bulk is stem with one or more shoots at the top. Leaves are mere scales which cover the corm. The gladiolus and crocus are examples of corms.

Gardeners frequently use the term "bulb" quite incorrectly in referring to underground stems from which plants may be grown. Lilies and daffodils produce true bulbs, but tulips, crocuses, and elephant ears form corms, not bulbs.



Corm of Crocus

Summary

A plant stem is a highly specialized organ functioning chiefly in displaying leaves and flowers, conducting materials between the roots and leaves and storing water and food substances.

While all stems are similar in the activities they perform, their structure and form vary widely. Aerial stems develop above the ground, where they may stand erect, creep along the surface, or climb upon supports. Shortened stems are so reduced in size that the plants which produce them are frequently regarded as stemless.

Herbaceous stems are soft and green and last only one season. Woody stems, on the other hand, develop strong fibers enabling them to stand erect, sometimes reaching heights of several hundred feet. The woody stem in cold climates forms buds protected by scales to protect its growing points from drying out through the winter. The arrangement and manner of growth of buds accounts for the form of branching assumed by different woody plants. Trees, especially, tend to follow either the excurrent or deliquescent form of branching.

Underground stems show various modifications, especially in storing food. Rhizomes, tubers, bulbs, and corms are the chief types of underground stems.

Using Your Knowledge

1. Name five uses which stems may serve to plants.

2. Distinguish between woody and herbaceous stems. Give examples of each.

3. Enumerate both advantages and disadvantages of shortened stems.

4. Explain how creeping stems frequently serve to multiply the plant.

5. List three ways in which certain stems accomplish climbing.

6. What is the best method of distinguishing a tree from a shrub?

7. Explain how the branching pattern of a tree is determined by the arrangement of buds.

8. Explain how branching patterns of trees are related directly to timber value.

9. Name four types of underground stems with an example of a plant producing each type.

10. What special function is usually associated with an underground stem?

Expressing Your Knowledge

conduction	rosette	internode
storage	tendril	lenticel
vegetative	twine	alternate
aerial	winter bud	opposite
underground	bud scale	whorled
herbaceous	terminal	bud-scale scar
woody	lateral	excurrent
shortened	leaf scar	deliquescent
creeping	bundle scar	rhizome
erect	axil	tuber
climbing	axillary	bulb
stemless	node	corm

Applying Your Knowledge

1. Plant some seeds of either morning glory or climbing bean and observe carefully the manner of growth of the stem as it twines around a support.

2. Collect twigs from two different species of trees. Locate the structures and characteristic markings on each and determine the differences in structure of the two twigs.

3. Make a collection of twenty different kinds of twigs from the trees in your vicinity, during the dormant season if possible. Obtain a tree book giving twig characteristics and and see how many you can identify. Your collection may be displayed by mounting the twigs on cardboard.

4. Collect some dormant twigs from several different species of trees in the early spring. Place them in water in the laboratory and observe carefully the swelling of the buds, the falling of the bud scales and the appearance of the new shoot with leaves.

5. Make a collection of armed twigs of trees and shrubs of your vicinity. How do the thorns differ in structure, in location on the twig, and in size?

6. Obtain a potato and see if you can locate the nodes, internodes, and buds or " eyes." Section the potato to see how much internal tissue is used for the storage of food.

Chapter 13

Structure and Activities of Stems

Did you every try to carry an open umbrella in a wind storm? If so, you can appreciate the tremendous strength necessary to support the heavy crown of leaves of a large tree in the wind. It is almost incredible that cell walls can be so strong. But after you have studied the internal structure of a woody stem, you will understand how a tree trunk is able to withstand the tremendous force of wind against its branches. You will discover, also, how the plant conducts materials upward, downward, and across its stem, all at the same time. You will see the channels through which these materials pass and will learn about certain forces which raise water through the stem, in some trees hundreds of feet above the ground.

The activities of the stem cannot be understood without a knowledge of its structure. As we learn about the specialized tissues which form the stem, we shall discuss the work of each in performing the processes carried on by this important organ of the plant.

How do stems grow? Our study of the structure of stems may well begin with the manner in which they grow, since growth results in the formation of the original tissues composing the stem and may cause it to increase both in length and in diameter for a period of many years.

To illustrate the manner in which stems grow, assume that a mature tree is thirty feet high, one foot in diameter, and that the first branch is exactly six feet from the ground. After ten years, we return to the tree and find that the trunk is now sixteen inches in diameter, and that it is now forty feet in height. After this period of growth, how far is the first limb from the ground? The answer is: still six feet. Growth in length has occurred at the tips of all of the branches, but the stem regions below the tips have not lengthened at all.

Stem growth is quite different from the growth of our bodies. Our arms and legs and trunk grow uniformly — that is, they increase in length and in diameter in all regions. But plants grow only in certain places which are called *growing regions.* Only in these special places may new tissues form as a result of cell division. Furthermore, the growing regions of the stem are of two distinct types — one causing increase in length; the other, increase in diameter.

Stems grow in length by forming new tissues at their tips, or, in some cases, at the nodes. Such growing points were found, also, at the tips of roots. The growing area or *embryonic region* of the stem is much like the root, except that it is longer and is not protected by a cap. The embryonic region of a stem is frequently several inches in length, while the corresponding region of the root is but a fraction of an inch long. As new tissues are produced at the stem tip, they continue to grow until they reach maximum size. Once they have matured they can never lengthen again. Growth in length is limited to the actively dividing cells of the growing point.

LONGITUDINAL SECTION OF A BUD. Note the enclosed terminal growing point.

Growth in diameter results from the activity of an entirely different region, located deep in the tissues of the stem. To discover this region, we must study in detail the regions and tissues which compose the stem.

Regions of a woody stem. We found in Chapter 12 that stems may be classified into two distinct types — woody and herbaceous. The structure of these two stem types is so different that, in order to understand them thoroughly, they must be studied separately.

The Internal Structure of Woody Stems

If a branch or trunk of a tree is cut, three distinct regions may be seen. The outer region, or *bark* is quite distinct from the large area of *wood* within. Usually, a core of *pith* occupies the center of the stem, although the pith of a large tree is often difficult to find because it is so very small in comparison to the large amount of wood. A fourth region, the *cambium,* lies between the bark and the wood and consists of a thin, slimy layer of delicate tissue. This is so small that it cannot be seen without the aid of the microscope.

The wood in a stem frequently appears to be of two types. The outer area is usually light in color and is composed of active tissue called *sapwood.* Within

Cross Section of a Woody Stem. The dark portion in the center is the heartwood. The lighter region is the sapwood. The bark is seen as a thin layer on the outer portion of the stem.

the sapwood, a cylinder of darker wood called *heartwood* occupies the center of the stem. The tissues composing the heartwood are dead and are often filled with gums or resins which give it the characteristic dark color. Heartwood is of no use to the tree except for support. Sapwood is necessary to the life of the tree, but the heartwood may decay totally and yet cause no harm other than to reduce its strength. Undecayed heartwood makes beautiful furniture.

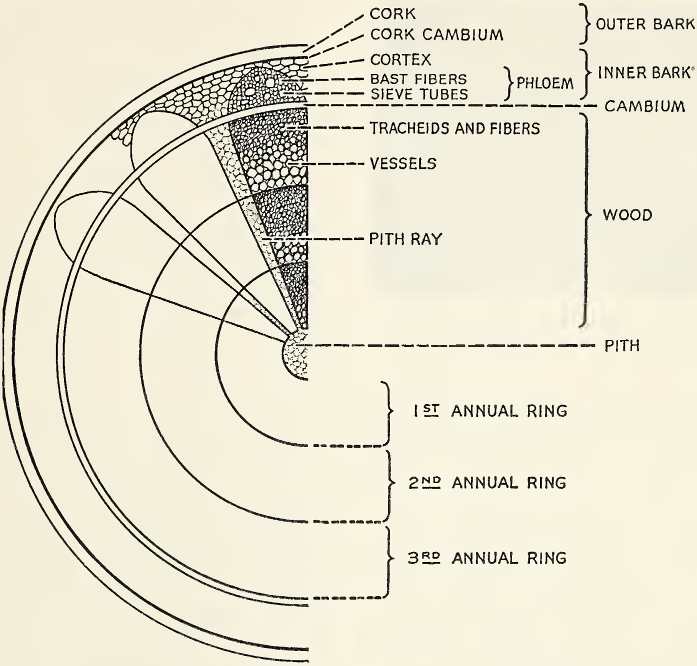
Additional markings may be seen in examining a cross section of a woody stem as, for example, the end of a log. The *pith rays* appear as lines radiating from the center to the outside of the wood like the spokes of a wheel. Some types of wood, such as oak, show especially prominent rays. *Annual rings* form circles through the wood, one outside of the other, and mark each season's growth of wood. By counting the annual rings, the age of a stem may be determined. The rays and rings will be explained more fully in the discussion of wood to follow.

Bark — its structure and activity. The term *bark* includes much more than the outer covering of a tree. It is a region of the stem, composed of several kinds of tissue.

A young twig is covered, for a time, by a thin *epidermis* which protects the young stem from injury and disease. Soon, however, the epidermis is replaced by a tissue called *cork,* which forms the outer covering we see on a branch or tree trunk. Cork is composed of dead cells arranged in layers and containing special substances which give it a characteristic waterproofing. The corky layer on a woody stem *protects* the stem from mechanical injury, from the entrance of disease, and from loss of water.

As stems grow in diameter, the outer corky layer splits continually due to internal expansion. Consequently, it must be constantly renewed. New cork is produced by a special layer of cells at the base of the cork, called the *cork cambium.* The cells which compose the cork cambium divide frequently and add new cork on the inside as it is destroyed by weathering on the outside. The structure of the cork cells and the continual splitting the cork layer due to growth of the stem results in the characteristic appearance of tree trunks — scaly, peeling, grooved, fissured or, in some cases, smooth. The cork tissue of a tree is often called the *outer bark* to distinguish it from other bark tissues within.

Inside of the cork and cork cambium lie two other important bark tissues composing the *inner bark.* The outer one of these, the *cortex,* is composed of large, thin-walled cells, rounded or brick shaped and arranged like stones in a wall. In young stems, the cortex cells contain green chloroplasts and carry on *food manufacture.* As the stem matures and cork begins to form, this function



Diagrammatic Cross Section of a Three Year Old Woody Stem

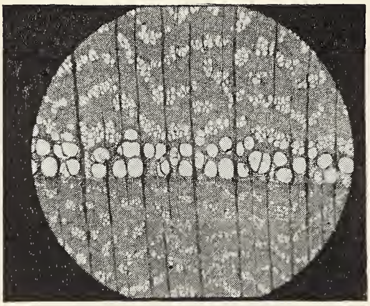
ceases and the cortex becomes an area of *food storage.*

Within the cortex lies the innermost layer of the bark, called the *phloem* [*flow'em*]. The phloem consists principally of large, thin-walled *sieve tubes* which conduct *food materials* dissolved in water. Since food materials usually come from the leaves, the phloem carries them downward toward the roots. In plants like wheat and rye, however, foods are conducted upward through the phloem to the heads of grain at the tip of the stem. Tough, thick-walled fibers, called *bast fibers* may frequently be seen associated with the phloem tubes. These fibers give toughness to the bark.

Activities of the cambium. As stated, the cambium lies between the bark and the wood. Its activity cannot be too greatly emphasized, for this small ring of active tissue is responsible for all increase in thickness of the stem.

During the growing season of spring and summer, the cambium is active in producing new cells by division. It forms new phloem tissues on its outer surface and new wood tissues on its inner surface. Growth of these newly formed tissues thus causes the stem to increase in diameter. During one season of cambium activity, many more wood cells than phloem cells are formed. Consequently, the wood area of a tree is always much greater than its bark thickness.

The tissues composing wood. *Wood* or *xylem* tissues extend from the cambium to the pith in the center of the



Spring and Summer Wood. Can you distinguish between the two kinds?

stem. Wood is a complex tissue, composed of several different kinds of cells. The largest of these are the *vessels* which appear in the stem as large, thick-walled tubes. Viewed from the ends in a cross section of wood, they are nearly round. If the stem is cut lengthwise, the vessels appear as long tubes arranged end to end which form continuous channels through the stem. Other wood cells called *tracheids* [*trake'ee ids*] are frequently grouped among the vessels. Tracheids are smaller than vessels and are more angular. They are elongated and have pointed ends. The smallest wood cells are the *fibers,* which have extremely thick walls and very little cell cavity. Many stems, especially those composed of heavy wood like the maple and oak, contain large numbers of fibers scattered among the vessels and tracheids.

Cells of the *pith rays* are quite different from the vessels, tracheids, and fibers. They are thin-walled, and form rows of two or three cells in width, and contain protoplasm and a large nucleus.

Each type of cell composing wood is specialized in carrying on definite activities. Vessels serve as channels of *conduction,* carrying water and minerals upward from the roots to the leaves. Tracheids, likewise, serve for *conduction* and in many stems serve as the principal channels of water movement. They serve, also, as *supporting* tissues because of their thick walls. Fibers do not conduct materials but give great strength to the wood. Much of the toughness of many kinds of lumber is due to the large number of fibers the wood contains. Pith rays serve as channels for *conduction* across the stem and make possible the transfer of materials between the bark and wood. Ray cells are frequently filled with food materials and also function as places of *storage.*

As woody stems increase in thickness, year after year, the wood formed by the cambium is arranged in layers. Frequently, the cambium produces two kinds of wood during the season — *spring wood,* containing many large vessels mingled with tracheids and fibers, and *summer wood,* containing few vessels and large numbers of fibers. This difference in texture between spring and summer wood results in layers which appear as annual rings. In cases where spring and summer wood differ considerably in texture, the rings are prominent and may be counted easily to determine the age of the stem.

Many trees produce wood of uniform texture throughout the growing season but form a small layer of tiny cells at the close of the growth period. These cells appear as dark rings at the outer edge of a season's layer of wood.

Wood texture determines lumber uses. The cellular make-up — the amount of vessels, tracheids, and fibers which compose the wood — determines its texture. Texture, in turn, determines the uses which the wood may serve as lumber. Maple, for example, is extremely heavy due to the quantity of

SUMMARY OF THE TISSUE OF A WOODY STEM

Region	Tissue	Function
bark	epidermis (only on young stems)	protection
	cork	protection
	cork cambium	production of cork
	cortex	storage and food manufacture
	phloem tubes	conduction of food usually downward
	bast fibers	strengthen bark
cambium	cambium cells only	formation of phloem, xylem (wood) and rays
wood	vessels	conduction of water and minerals upward
	tracheids	conduction and strengthening of wood
	fibers	supporting tissues
	rays	conduction laterally
pith	pith	storage

fibers composing it. This makes it ideal for furniture and for high grade flooring. Oak, on the other hand, produces numerous vessels in the spring wood, while the summer wood is very dense and composed largely of fibers. Alternate layers of spring and summer wood, in addition to very prominent wood rays, form the grain and markings so desirable in furniture and woodwork. The tulip tree or "yellow poplar" produces wood of uniform texture. Lacking the heavy fibers of maple and oak, it is ideal for woodworking and cabinet making.

The wood produced by conifers such as the pine, spruce, and fir is composed entirely of tracheids, no vessels being present. The lack of fibers gives it a characteristic *soft* texture as compared with the oak, maple, ash, elm, and other *hardwoods*. White pine, especially, because of its soft, uniform texture is highly valued for wood working and pattern making. Western yellow pine and the southern long-leaved yellow pine supply great quantities of lumber for building.

The pith region of the stem. The central core of pith is often scarcely noticeable in an old woody stem. In the young stem, however, the pith occupies a proportionally large area and serves as an important place of storage. Since pith is not produced by the cambium, it never increases in size. Regardless of the size to which a tree may grow, its pith never increases beyond the amount present during the first year of its growth.

Why does girdling kill a tree? The complete removal of a section of bark around a woody stem is known as *girdling*. This may be done by mice, rabbits, beavers, porcupines, horses, or other animals which chew on the bark. It may also occur if a wire is placed around a tree and allowed to remain there until expansion during growth causes the wire to cut entirely through the bark. In some cases, trees are girdled deliberately to destroy them.

In any case, the result is the same. The tree will die because food can no longer pass through the phloem from the leaves to the roots. If the tree is girdled

Girdling a Tree. Why does this process kill the tree?

during the winter, its leaf buds may open in the spring because the foods which were stored in the root can still pass up through the xylem to the buds. But because root activity demands a supply of food, death will follow sometime during the season since the source of the food has been removed.

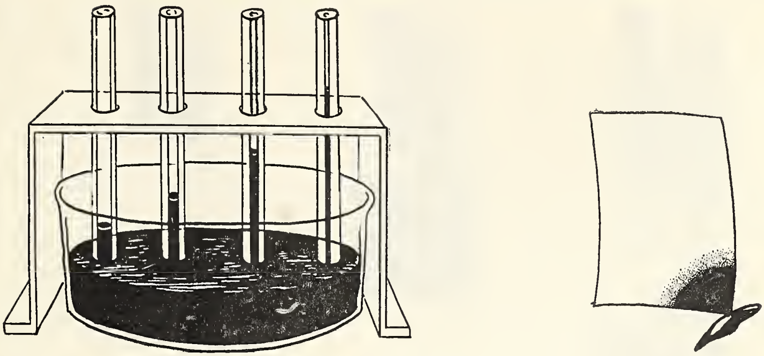
Movement of materials through the stem. We have discussed several stem tissues which conduct materials through the stem. We have not, however, accounted for the factors which make this conduction possible.

Blood circulates through our bodies due to the pressure maintained in the blood vessels because of the pumping action of the heart. Plants have no such pump, yet are able to carry water and minerals hundreds of feet high — a feat requiring considerable force. The flow of food materials through the phloem tubes of the bark is not difficult to understand, since the flow is downward. Likewise, the movement of materials across the stem through the ray cells is quite understandable since only short distances are involved. But the rise of water and minerals through the wood vessels and tracheids against the force of gravity certainly involves powerful forces.

Biologists have not agreed entirely as to what these forces are, but several factors may be explained which account, for the most part, for the phenomenon of upward conduction.

Root pressure, explained in an earlier chapter, forces water into the stem with considerable force and is one of the factors. A second factor called *capillarity* is another force. Capillarity may be illustrated by placing a small tube or soda straw into a glass of water and comparing the level of water in the glass with the level in the tube. The level in the tube will be higher than in the glass. Water is attracted by the walls of the tube and is lifted above the level in the glass. The smaller the tube, the higher the level that will be reached. Capillarity acts in the stem by drawing water upward along the walls of the vessels and tracheids.

In recent years, biologists have found that another force in the form of a pull occurs from above. Leaves are constantly losing water due to evaporation from their surfaces into the air. This loss of water from the leaf results in an *evaporation pull* which, in turn, lifts water through the plant. Water is held in continuous columns through the vessels of the leaves, stem, and roots. As it is removed from above by evaporation, the entire column is pulled up. This rise of water is further accounted for by the *cohesion* of water in the vessels. Water clings together throughout the vessels and may be lifted as an entire column, much as drawing on a soda straw lifts an entire column of liquid and causes



EXPERIMENTS SHOWING CAPILLARITY

more to enter at the lower end. Other factors may be involved, but root pressure, capillarity, evaporation pull, and cohesion undoubtedly account for most of the force necessary to carry water and minerals upward through a stem.

Plant propagation by means of stems. While conduction, support, and storage are the most outstanding functions of a stem, propagation or multiplication of plants by means of stems is another function. Propagation may occur either naturally or artificially.

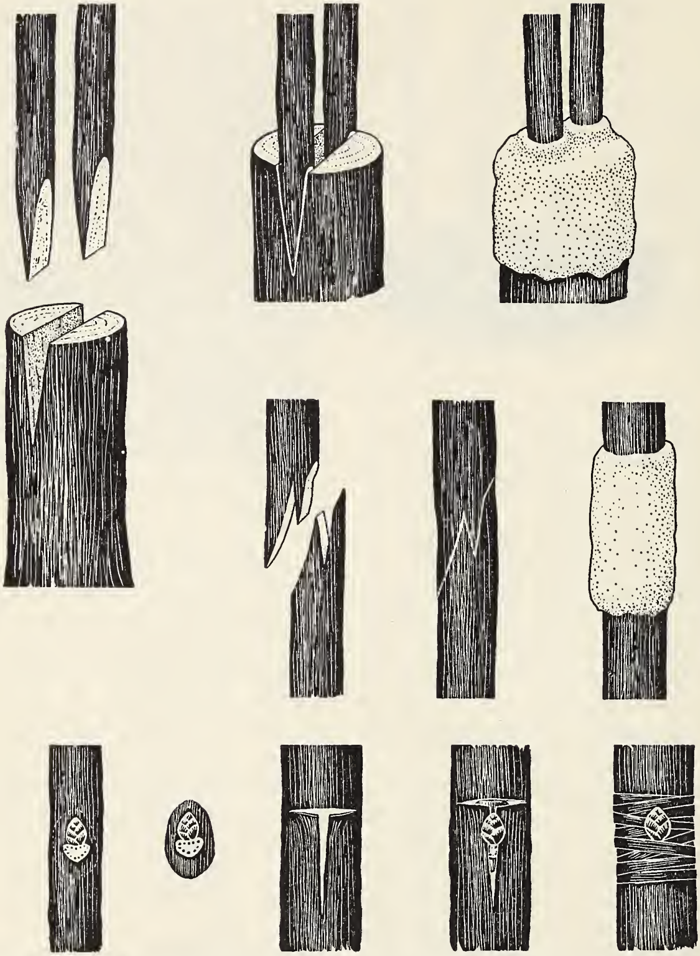
Budding and *grafting* are methods of propagating plants commonly used by gardeners and nurserymen. Both processes depend upon the ability of the cambium to produce new stem tissues.

Grafting consists of bringing into close contact the cambium layer of a live dormant twig and the cambium layer of the tree upon which it is to grow. This may be accomplished by tapering the end of the twig or *scion* to be used and inserting it into a slit prepared in the rooted branch or *stock* which is to receive the graft. Such a graft can be successful only *if the cambiums of scion and stock are brought into contact with each other*. Grafting is successful only when stems of the same species or closely related species are united. An apple twig could not unite with an oak tree, but several varieties of apple trees may be grafted on a single apple stock.

Budding is similar to grafting except that a bud rather than a twig is united with the stock. In budding, a vigorous bud is selected and removed with a heel of bark surrounding it. The bud is united with the stock by slipping the heel of bark under the bark of the stock which has been loosened by a "T" shaped cut. In this manner, the cambiums of bud and stock are united. In both budding and grafting, the wound resulting from the operation should be covered with wax to prevent the entrance of bacteria and various kinds of rotting fungi.

Pruning. Trees, shrubs, and vines often have surplus branches cut off. This is called *pruning* and is done for various reasons. In fruit trees the purpose may be to keep the tree in such shape that the fruit may more easily be picked, or to prevent the growth of unnecessary leaves and branches, so that more nourishment will go to make fruit.

Shade and ornamental trees are pruned to keep them in the desired shape and size. When trees are trans-



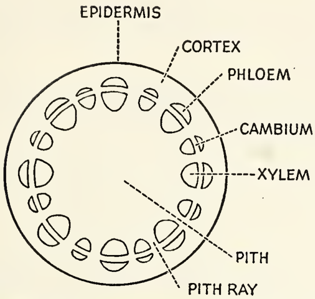
Different Methods of Grafting. Top row: cleft grafting. Middle row: whip grafting. Bottom row: budding.

planted, many of the branches are pruned, so that there will not be so much foliage to demand water from the roots until they have had time to get a start in their new places. If the full leafage were left on, the roots might not be able to supply sufficient water and the tree might die.

Vines have to be pruned to keep them within the bounds of their supports, and also to make them bear more fruit and fewer leaves. Hedges are sharply pruned to keep them in the desired shape.

As a rule, pruning should be done in winter or when the sap is not rising, so that the cut ends will not " bleed " and thus lose the food-bearing sap and weaken or kill the tree.

The Structure of Herbaceous Stems



Cross Section of an Herbaceous Dicot Stem

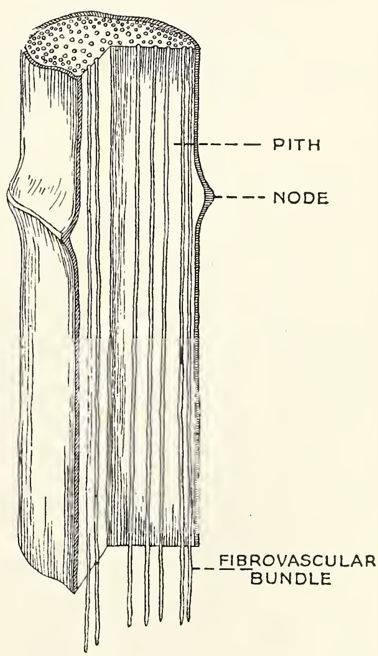
So far, all of our discussion has concerned the woody stem. With a knowledge of a woody stem, the herbaceous stem is not difficult to understand.

Herbaceous stems differ from woody stems principally in containing much less woody (xylem) and phloem tissue. These conduction and supporting tissues are found, in most herbaceous stems in the form of strands called *fibrovascular bundles* which run lengthwise through the stem.

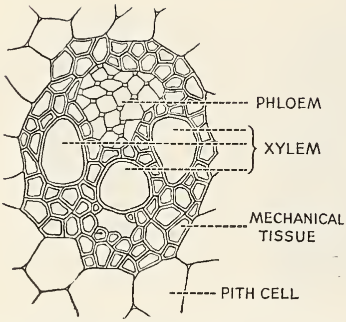
The stems of dicots and monocots. Herbaceous stems may be classified, according to structure, into two principal types. One type is produced by such *dicot* plants as the tomato, buttercup, bean, and pea. The other type is produced by the *monocot* plants, including orchids, lilies, and the grass family, of which corn is a familiar example.

The herbaceous dicot stem. If the stem of an herbaceous dicot plant is sectioned and examined with a microscope, several regions will be clearly visible. The outer covering of the stem is a thin *epidermis* which serves for protection. Within the epidermis is a layer of *cortex,* composed of loosely packed cells containing chloroplasts and serving as a food manufacturing tissue and as a place of storage. Within the cortex, the *fibrovascular bundles* occupy a ring or zone. These bundles contain conducting and supporting tissues. The bundles may form a continuous ring or may be separated by broad rays. Many herbaceous dicot stems develop a cambium in the form of a ring which runs through the bundle cylinder, dividing the phloem in the outer portion of the bundle from the xylem tissues within. Activity of the cambium results in increase in diameter of the stem just as we found in the woody stem, although such growth continues only for one season.

The structure of a monocot stem. The cornstalk is a good example of a monocot type of stem. If we cut a section across it, we find the tissues very differ-



Longitudinal Section of Corn Stem



One Fibrovascular Bundle of Corn Stem

ently arranged from those in the dicotyledonous stem, just discussed.

The outer covering of the stem is a *rind* composed of thick-walled, hard cells, whose function is support of the plant and protection of the other stem tissues. The bulk of the stem consists of thin-walled pith. *Scattered* through the pith are numerous fibrovascular bundles, containing xylem and phloem tissues. Monocot stems usually lack a cambium and, therefore, grow in diameter only until the cells have reached their maximum size. Consequently, the stems of monocot plants are usually long and slender.

Monocot stems cannot be used for the same purposes as dicot stems due to the fact that they lack hard, woody cells. The one exception is the bamboo. It has a very hard rind which makes it suitable for fishing poles and furniture.

But do not think that the monocotyledonous stem is weak because it has little woody tissue. The case is quite the opposite, as you may prove for yourself. Select a tall grass stem such as timothy, wheat or rye. Measure its height and its diameter. How many times its thickness is its height? Suppose it were a tree one foot in diameter; how tall would it then be? Compare this with the actual height of trees. Figure this out and you will have more respect for the strength of the grass stem, as well as for the " sturdy oaks."

Summary

Stems serve chiefly as organs of support and conduction. They may be woody or herbaceous, depending upon the tissues they contain.

Woody stems are composed of a region termed bark, a cambium which lies just inside the bark, a large area of wood, and a small core of pith in the center. Bark contains several kinds of tissues. The outer bark is a corky covering which protects the stem from injury. Cortex cells and the conducting cells of the phloem form the inner layers of the bark. Wood, likewise, is a complex tissue containing vessels, tracheids, fibers, and rays. It serves both as a conducting and supporting tissue. The pith of a woody stem functions while the stem is young as a place of storage.

Stems grow in length by forming new tissues in the growing regions of their tips. An increase in diameter occurs each season due to the production of bark and wood tissues by the activity of the cambium. The cambium is important also in the propagation of plants by means of grafting and budding.

Herbaceous stems have their conducting and supporting tissues in the form of strands called fibrovascular bundles. In the dicot stem, these bundles are arranged in a circular zone just within the cortex. The monocot stem is composed principally of pith with the fibrovascular bundles scattered through it. In stems of this type, as for example, the corn, a hard outer rind often serves as the chief strengthening tissue of the stem.

Using Your Knowledge

1. Compare the manner in which a stem grows in length, with the growth of your body.

2. The growing point at the tip of a stem is called the embryonic region. Where have you heard such a region discussed before?

3. What regions and markings are clearly visible on the end of a log?

4. Name the tissues of the outer bark of a tree; the inner bark.

5. List the different kinds of tissues which compose the woody region of a woody stem.

6. Account for the difference in texture of spring wood and summer wood.

7. Explain how the cambium causes increase in the diameter of the stem.

8. Name four independent forces which are concerned with the rise of water through a stem. Which force seems to be the most important in this respect?

9. What tissues must be united in a graft to join two stems together successfully?

10. Point out several differences in the structure of a monocot stem which distinguish it readily from a dicot stem.

Expressing Your Knowledge

growing region	cortex	hardwood
bark	phloem	root pressure
wood	bast fiber	capillarity
pith	cambium	evaporation pull
heartwood	vessel	cohesion
sapwood	tracheid	budding
ray	fiber	grafting
annual ring	xylem	scion
outer bark	conduction	stock
inner bark	support	pruning
epidermis	spring wood	fibrovascular
cork	summer wood	bundle zone
cork cambium	softwood	rind

Applying Your Knowledge

1. Mark off a young growing stem (using India ink) at one-eighth intervals for a distance of several inches. Observe growth daily. Note carefully from your marks the exact region in which the stem is lengthening.

2. See if you can find a freshly cut stump or a log. Saw a section and bring it into the laboratory. Study the regions, annual rings, rays, sapwood, and heartwood. Determine the age by counting the rings.

3. Make a collection of all of the kinds of wood you can obtain. Study differences in color, texture, and weight. They may be displayed upon a board.

4. Prepare models of several kinds of stem grafts and budding. These may be prepared from stem sections about one inch or less in diameter.

5. Place a stalk of celery with the base of the stem cut off into a container of water colored with red ink. Leave the stalk until the leaves turn color. Remove it and study the stem to determine what tissues carried the colored water upward.

6. Place a cut stem with leaves into a similar solution. After one day, cut the stem at intervals to see how far the colored water rose in the stem. What factor or factors caused the rise?

7. Obtain several corn stems and section them crosswise and lengthwise. Study the arrangement of tissues in this typical monocot stem.

Chapter 14

Leaves—Their Form and Structure

It is difficult to rank the organs of a plant in the order of their importance, for they all are essential to the life of the plant. But if such comparison could be made, the leaf would certainly head the list.

Most of the processes carried on by other organs of a plant concern the leaf directly. Roots anchor the stem which grows into the air and supports the leaves. Roots also absorb water and minerals, which are conducted through the stem and are used in the leaves. Food materials pass from the leaves to the stem and roots and nourish their tissues or are stored for future use. The leaf is the center of most of the plant's activity. It carries on more processes than any other organ.

During the study of the structure of a leaf, you will take a journey into the interior of this wonderful organ and will see the "machinery" which supplies your daily food needs. You will see the veins which bring a stream of raw materials to these "machines" and carry out the finished product in the form of manufactured food — food not only for the plant but for the entire living world as well.

Activities of leaves. *Food manufacture* is the process most commonly associated with leaves because of its significance to the biological world. But food manufacture depends upon other activities, equally important to the life of the plant. Through tiny openings in their surfaces, leaves admit oxygen for oxidation and discharge carbon dioxide, thus serving as organs of *respiration*. They also use carbon dioxide, contained in the air, during food manufacture. Leaf pores function, also, for the discharge of water from the leaf tissues during *transpiration*. As organs of *excretion*, they give off various waste products formed in the plant. Leaves possess, to some degree, the power of *motion* and adjust themselves to light. Even *reproduction* is accomplished by some leaves, capable of forming new plants on their margins. With all of these processes going on, the leaf is truly a scene of tremendous activity.

General Structure of Leaves

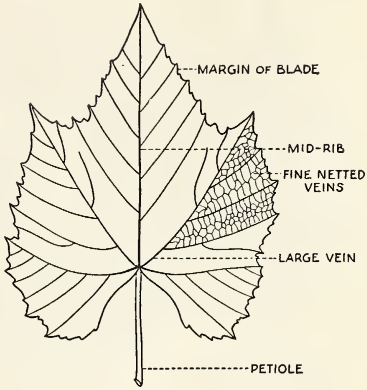
A typical leaf consists of a thin, green portion, the *blade*, strengthened by a framework of *veins*. Veins are really fibrovascular bundles which penetrate the tissues of the blade, much as blood vessels branch and rebranch in reaching all of the tissues of our bodies. In addition to strengthening the blade, they serve as channels of conduction by carrying water, minerals, and food materials in and out of the leaf.

Usually, the blade is attached to the stem and held out into the light by a stalk or *petiole*. At its base, the petiole joins the stem in a region called the *node*. Veins, in turn, connect with the petiole at its upper end. Some leaves have no petiole. Instead, the blade fastens directly to the stem by means of the veins. Leaves of this type are called *sessile* [*sess'ill*].

Venation. The arrangement of veins through the leaf blade is termed *venation*. In most leaves, the *principal veins* tend to follow one of three general patterns. The maple leaf illustrates an arrangement in which several large veins branch out from the tip of the petiole somewhat like fingers extend from the hand. This pattern is termed *palmate venation*. Other leaves, like the willow and elm, possess a single, large vein called a *midrib* which extends through the center of the blade from the petiole to the leaf tip. Smaller veins branch from the midrib and run to the margins. This type of venation, resembling the structure of a feather, is called *pinnate venation*. Palmate and pinnate venation are commonly found in leaves of dicotyledonous plants. Leaves of this large group of plants are further characteristic in the structure of the smaller veins, which branch very freely to form a *network* through the blade. The *netted* veins of a dicot leaf may be seen by holding the blade to the light and looking through it.

Many monocotyledonous plants including the grasses, lilies, and orchids have several large veins which run *parallel* from the base of the leaf to the tip. Smaller veins branch out from the large parallel veins, but usually do not form a network in the manner of a dicot leaf. Leaf venation alone will not always distinguish the monocot and dicot plants, but in a great many instances it serves as a definite point of difference, which is usually reliable.

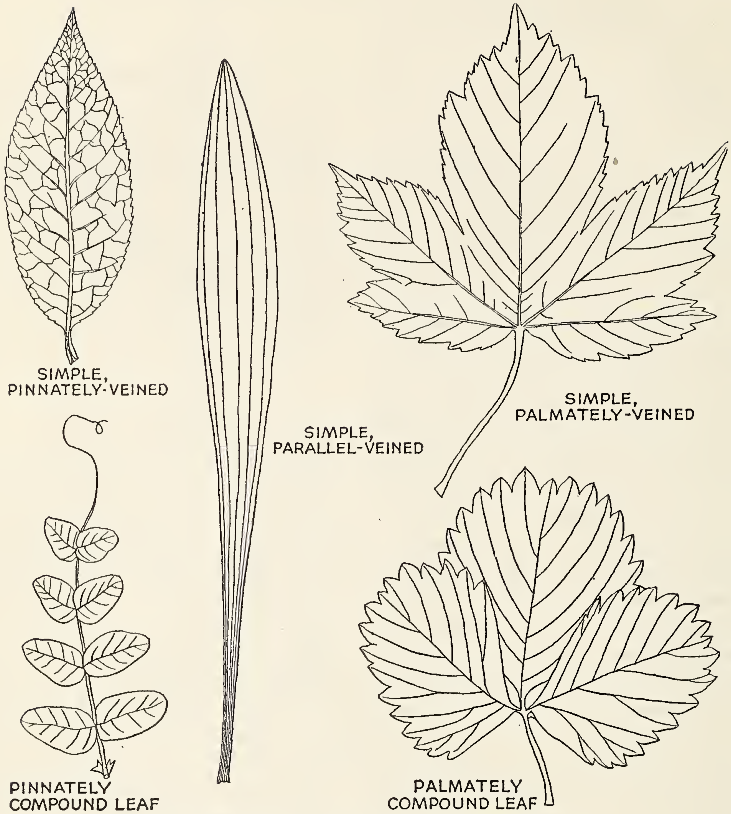
Leaf forms. The outline of a leaf depends somewhat upon the arrangement of its veins. If the veins are netted, the leaves are usually broad, notched, or



THE PARTS OF A LEAF

lobed. If the veins are parallel they are usually long and slender. The forms of the leaves are almost as various as the kinds of plants; some having regular or *entire* edges (lily), others notched (elm), lobed (maple), or finely divided (carrot).

Where the blade of the leaf, even though greatly indented, is in one piece, it is called a *simple* leaf. There are many leaves, however, where the blade is divided into three or more parts. In such a case the leaf is said to be *compound* and each separate part of the blade is called a *leaflet*. Where the leaflets radiate from a common point as in the clover and horse chestnut, the leaf is said to be *palmately compound*. When the leaflets are arranged opposite each other or alternate on the sides of a single midrib, as in the locust, the leaf is said to be *pinnately compound*. In the case of certain leaves, it may be difficult to tell whether the part is a leaflet of a compound leaf or the blade of a small simple leaf. If *stipules* (small leaflike parts) are found at the point of attachment it indicates that all the growth extending from that point is one leaf. Stipules are never found at the attachments of leaflets.



THE TYPES OF LEAF VENATION AND COMPOUNDING

Structure of Leaves

The chief function of the leaf is the manufacture of food materials. To understand this, a thorough study of its structure is necessary.

If the blade of a leaf is cut across and studied with a microscope, the following tissues may be observed. Mentioned in order from the upper surface they are:

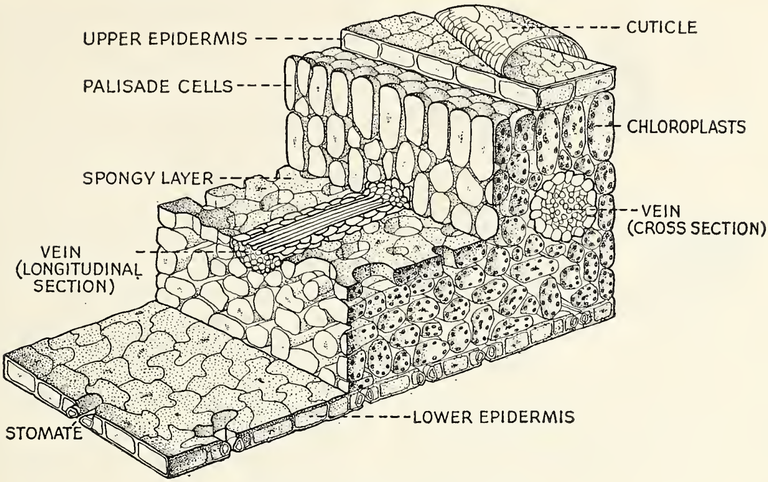
1. The upper epidermis

2. The palisade layer

3. The spongy layer (traversed by veins and including air spaces)

4. The lower epidermis (penetrated by stomates)

The upper epidermis. This usually consists of a single layer of cells, often very irregular as seen from above, but brick shaped when viewed in cross section. The function of the upper epidermis is to prevent loss of water. It is sometimes covered by a waxy layer called the *cuticle,* as in ivy, cabbage, and most leaves whose upper surfaces appear shiny or waxy. This layer usually makes the evaporation of water from in-



Internal Structure of a Leaf

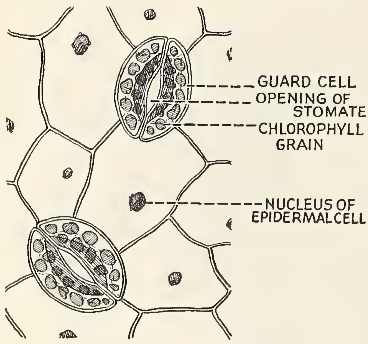
side the leaf difficult or impossible. It protects the tissues beneath.

The palisade layer. Just beneath the upper epidermis is the *palisade layer.* It consists of long narrow cells, arranged endwise, at right angles to the surface of the leaf. The palisade cells resemble slightly the upright stakes of a palisade fence, or the vertical formations of rock which are sometimes seen along river valleys, and which are referred to as palisades. From the standpoint of structure and arrangement in the leaf, these cells are well named.

Close examination of the palisade cells reveals numerous bodies, called *chloroplasts,* which are contained in the area of cytoplasm. Chloroplasts are composed of cytoplasm, and contain the important green pigment or coloring matter, *chlorophyll.* This remarkable green substance enables the plant to manufacture food. Consequently, the palisade cells with their abundant chloroplasts constitute an important part of the food-making " machinery " of the leaf.

Chlorophyll is extremely sensitive to light. Since light is essential to food formation, chloroplasts must be exposed to it; yet light also acts to destroy chlorophyll. The shape of the palisade cells meets this critical light situation by allowing the chloroplasts to receive intense light in the upper regions and to escape from light somewhat in the lower portion of the cells. During bright days, chloroplasts tend to concentrate in the lower portion of the palisade tissue, while on days when light is not so intense, they may be found abundantly near the top of the cells. This same condition applies to different times of the day, when leaves may receive full sunlight or shade, depending upon the position of the sun. It is interesting to note, also, that leaves normally exposed to intense light frequently contain several layers of palisade cells, arranged one above the other. Palisade cells are often entirely lacking in leaves which grow in deep shade.

The spongy layer. Beneath the palisade layer is a spongy layer, which consists of thin-walled cells and air spaces



Lower Epidermis of a Leaf with Stomates

and is penetrated in all directions by large and small veins. The spongy cells are rounded, irregular, loosely packed, thin-walled, and full of protoplasm. They also possess chlorophyll, but their chloroplasts are fewer and lighter in color than those of the palisade cells. This is the reason that the under surfaces of leaves appear a lighter green than the upper sides. In the cells of the spongy layer, as in the palisade layer, food making and other leaf functions are carried on. The passing off of water to the air spaces is part of their work.

The air spaces are usually large irregular cavities among the spongy cells. They open through the lower epidermis by way of the stomates, their function being to receive water vapor from the spongy cells and to pass it out through these openings. They also permit oxygen and carbon dioxide to pass to all the cells of the spongy layer. They are very important, since through them food making, respiration, and transpiration go on. They occupy about three-fourths of the bulk of the spongy layer. The thick-walled veins, scattered through the spongy layer, transport water and foodstuffs and support the blade of the leaf.

The lower epidermis. Like the upper, the lower epidermis usually has but one layer of cells. Through it open many *stomates* which regulate the passage of air and water vapor to and from the inside of the leaf.

The stomates. Stomates have been referred to as openings in the epidermis. They are minute slit-like holes, about one-twentieth as wide as the thickness of this paper. On each side of the slit is an oval *guard cell* which regulates the opening and closing of the stomate. Influenced by warmth and sunlight, the stomates open when there is an excess of water to be passed off, and close in a drought. The function of the stomates is threefold:

1. Regulating the transpiration of water vapor.

2. Admitting carbon dioxide used in making sugar and starch, and liberating oxygen, the left-over product of starch making.

3. Admitting oxygen for respiration, and liberating carbon dioxide formed by cellular respiration.

However, this elaborate mechanism would be of little use were it not for the extensive system of air spaces in the spongy tissue of the leaf into which the stomates open, and by means of which all parts may have access to air for starch making, respiration, and transpiration. The number of stomates may vary from 60,000 to 450,000 per square inch and is usually greatest on the lower surface. Floating leaves have all their stomates on the upper surface. In vertical leaves they are about evenly distributed.

Chlorophyll. The green coloring matter of plants is the most important part of the leaf. Practically the whole function of the other parts is in exposing the chlorophyll to light and in providing it with materials upon which to work. Chlorophyll is a complex substance composed of carbon, hydrogen, oxygen, nitrogen, and magnesium. Its action is aided by small amounts of iron compounds.

This is the substance which performs the essential function of the leaves in providing basic food for all animals. It is not too strong a statement to say that without the magic of chlorophyll, life as we know it could not exist. We shall devote the next chapter to the way in which it does this valuable work.

The Leaf and Its Environment

The growth and activity of a leaf depends directly upon the critical conditions of its surroundings. Light, moisture, and temperature affect all of the processes carried on in the leaf tissues. They also influence the form and size of the leaf, its internal structure, its position on the stem, and in many cases, even its color.

Leaves in relation to light. No factor of the physical environment has a more pronounced influence upon the leaf than light. As the source of energy necessary for food manufacture, light has a direct bearing upon the nutrition of the entire plant. The supply of food depends upon the extent to which a plant displays its leaves to light.

The critical relationship between a leaf and light is illustrated in the influence of light upon leaf area. In places of reduced light, as for example, the inside or lower branches of a tree, leaves tend to be much larger than those produced at the tips of branches or at the top of the tree where abundant light strikes the leaves. This increase in the area of shaded leaves would seem to compensate somewhat for the reduced light in which they grow.

Light influences leaf growth further in the make-up of the internal tissues. Leaves exposed to bright light usually develop one or more layers of elongated palisade cells on the upper or exposed side. Shade leaves of the same plant often lack palisade cells entirely and develop spongy tissue throughout the blade. This condition illustrates clearly the role of light in the development of the internal tissues of a leaf.

The arrangement of leaves in respect to light. Leaves are borne upon the stem in an arrangement which will expose each to light most advantageously. As pointed out in Chapter 12 in the discussion of winter twigs in relation to leaf scars, leaves may grow one at a node (*alternate*), two at a node (*opposite*), or three or more at a node (*whorled*). If you look down from the tip of a stem with alternate leaves, the leaves will appear to grow in a circle around the stem. This is because each leaf is produced at a different angle on the stem, or in a spiral arrangement from bottom to top. Thus, a leaf does not shade another growing from the node beneath it. If two leaves are produced at a node, they alternate in their arrangement. For example, two leaves growing north and south alternate with pairs above and below growing east and west. Plants with shortened stems lack long internodes in separating the leaves from each other. However, the *rosette*, or circular arrangement of the leaves of these plants provides each leaf with an exposure to light even though they are closely crowded.

Adjustment of leaves to light — phototropism. While the general arrangement of leaves upon the stem tends to place each leaf in the best position to obtain light, any rigid placing of leaves would be somewhat ineffective among plants which must compete with each other for

Seedlings Grown in Light (Left) and in Darkness (Right). When young plants cannot get light, their stems become thin and long.

light. Individual leaves adjust the position of their blades by turning the petiole. This phenomenon of response to light is called *phototropism* [*foto troe' pizm*]. It is another example of the sensitivity of protoplasm.

A plant grown on a window ledge will, within a few days or weeks, adjust its petioles so as to expose the leaf blades to light. The adjustment to light is aided by the stem, which bends toward the window, resulting in a lopsided pattern of growth. In bending toward the light, both the stem and the leaves illustrate a *positive* response. Roots, on the other hand, grow away from light as they carry on a negative *response* to light. The arrangement of leaves due to phototropism results in an intricate pattern of growth called a *leaf mosaic*.

An even more critical response to light is illustrated in some plants which react not only to light in general, but to the shifting rays of the sun. This response, called *heliotropism* [*heel'ee oh troe pizm*], is illustrated in the sunflower, which frequently bends its flowers toward the morning sun and follows its course across the sky, bending westward at sunset. Have you ever watched this?

Effects of moisture upon leaves. Like light, moisture affects the size and growth of leaves. Water passes from the leaf into the air through stomates in the epidermis. The rate at which this transpiration or water loss occurs depends, to a great extent, upon the amount of leaf area and the moisture content or humidity of the air. In regions of heavy rainfall and moist atmospheric conditions, leaves are usually large. As rainfall decreases and air becomes drier, leaves tend to become smaller. In extremely dry places, plants may have hardly any leaves at all, as in the cactus where leaves are reduced to mere spines.

Leaf coloration. Those who live in areas of broad-leaved forests which shed their leaves annually witness each season a glorious spectacle of nature — the autumn coloration of leaves. In these regions, forests of maple, oak, beech, red gum, and dogwood are transformed with the coming of the fall season into a brilliantly colored landscape of red, yellow, orange, and brown.

The phenomenon of leaf coloration is frequently attributed to the work of frost upon the leaves, but a more scientific explanation may be given in terms of light, moisture, and temperature. During the late spring and summer months, leaves are green because of the presence of chlorophyll in the chloroplasts of their tissues. During the growing season, chlorophyll is destroyed constantly by exposure to light, but is replaced as it is destroyed by the activity of the leaf cells. Light, moisture, and warm temperature are necessary for chlorophyll production.

In addition to green chlorophyll, chloroplasts often contain a yellow pigment, *xanthophyll* [*zan'tho fill*] and an orange pigment, *carotin* [*kar'o tin*]. Chlorophyll covers these other pigments during the growing season so we are hardly aware of their presence.

With the approach of fall, the temperature drops below the point necessary for chlorophyll formation. Light destroys the remaining chlorophyll and the previously hidden yellow and orange pigments begin to appear.

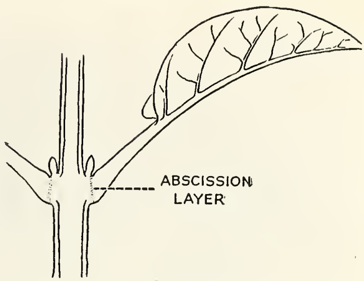
The cool weather results, also, in the production of a red pigment, *anthocyanin* [*antho sy'anin*] in many leaves. This red pigment does not form in the chloroplasts but in the cell sap contained in vacuoles of the leaf cells. It is formed from food materials. This accounts for the red leaves of the red maple, red gum, sumac, and other woody plants during the spring and fall periods of cool weather.

Brown coloration results from the death of leaf tissues and the production of *tannic acid* within the leaf. The leaves of many trees, including certain oaks, add rich brown color to the autumn landscape.

Autumn coloration reaches its height during autumn seasons in which the days are cold and bright with considerable moisture. Low temperature prevents chlorophyll formation, bright light destroys the existing chlorophyll rapidly, and moisture delays somewhat the drying out of the colored leaves. Low temperature and moisture also favor the formation of anthocyanin in leaves.

The falling of leaves. Autumn coloration is followed, usually, by the falling of leaves from their branches. Woody plants which shed all of their leaves seasonally are termed *deciduous,* to distinguish them from *evergreen* species which retain their leaves throughout the winter months.

The natural fall of leaves is caused by an *abscission layer* consisting of two rows of cells near the base of the petiole.



Petiole of a Leaf to Show Abscission Layer

These cells are joined firmly together during the growing season but, with the coming of winter, their walls disintegrate so that the slightest jarring or gust of wind will loosen the petiole from the stem, causing the leaf to drop from its position.

The shedding of leaves avoids loss of water through the winter months when the plant has ceased activity for the season. It also removes waste products which may have accumulated through the season. In the spring, new leaves with young, active tissues appear. These are ready to begin the activities of a new growing season.

While evergreen trees do not shed all of their leaves at any one time, new leaves usually appear during the spring and replace those of the previous season.

Special leaf modifications. Like roots and stems, leaves frequently are modified in performing special functions. They may be reduced to mere *tendrils,* or the skeleton of veins, which are helpful in climbing as in the pea, or they may develop as thorns which are useful in protection as in the barberry. The live-forever and other plants called Sedums have leaves thickened with stored food and water. These may even reproduce the plant. Perhaps the most curious adaptation of leaves is found in the tubular vase-like leaves of the pitcher plant

VENUS' FLYTRAP PLANTS

which form living flytraps and in the sundew and Venus' flytrap where the leaves form strange "double-jawed" traps for catching small insects.

These *insectivorous* plants secrete special enzymes that digest the small insects which they trap. They are the only plants which are able to do this.

Summary

The leaf is a specialized organ of the plant, concerned principally with food manufacture, transpiration, and respiration. It is the region of more activity than any other plant organ.

Externally, a leaf consists of a thin blade, veins, and a stalk or petiole. Leaves which lack petioles are termed sessile.

The internal tissues include an upper epidermis, palisade layer, spongy layer, and lower epidermis. Variation in these internal tissues is frequently caused by light. The stomates in the lower epidermis serve as pores for the exchange of water and gases between the leaf and the atmosphere. They are essential to food making, respiration, and transpiration or water loss.

Light, moisture, and temperature have an important effect upon the form of the leaf, its arrangement or position upon the stem and, in many localities, upon its seasonal coloration. The arrangement of leaves upon the stem is determined by the nature of the plant and upon the response of each leaf to light, called phototropism. Adjustments to light are made by turning or twisting of the petiole.

Following autumn coloration which is due to weather conditions at that season, leaves fall from the branches because of the separation of two rows of cells forming the abscission layer. Evergreen plants, while they do not shed their leaves at any one time, replace old leaves with active, new ones during the spring season.

Using Your Knowledge

1. Why are leaves usually thin and wide in structure?

2. Name two important functions of leaf veins.

3. Most of the cells in a leaf are thin walled. What functions would be interfered with or made impossible if they were thick walled? Explain.

4. Why does the spongy layer of the leaf have numerous cavities between the cells?

5. If you found that a leaf had a layer of palisade cells beneath each epidermis, what could you conclude about the manner of growth of the leaf?

6. Explain the relation between leaf area and light intensity.

7. Describe the arrangement of leaves in a mosaic.

8. Explain how a plant growing on a window ledge may illustrate phototropic response.

9. Explain the relation of factors of the environment to leaf coloration.

10. Explain why most broad-leaved trees growing in cold climates shed their leaves during winter.

Expressing Your Knowledge

venation	cuticle	heliotropism
vein	palisade layer	mosaic
palmate	chloroplast	leaf coloration
pinnate	chlorophyll	xanthophyll
netted veins	stomate	carotin
parallel veins	guard cell	anthocyanin
simple leaf	rosette	tannic acid
compound leaf	spongy layer	deciduous
stipule	phototropism	abscission layer

Applying Your Knowledge

1. Make a fairly accurate estimate of the number of leaves on a tree by counting the number in a small area and multiplying by the total estimate of such areas in the total tree.

2. Compare the relative sizes of the leaves on a typical tree by collecting leaves from the side exposed to the most intense light, some from the shaded side, some from the inside, and some from the top.

3. Extract some chlorophyll from a leaf by grinding it up and placing it into warm alcohol. Place one tube of extracted chlorophyll in bright light and another in a dark place. After a few days explain the results.

4. Make a collection of colored leaves in autumn. Try to get examples showing pure yellow, pure red, orange, red and green, and red and orange.

5. Make a collection of twenty-five different kinds of leaves of trees in your vicinity. See if you can classify them with the aid of a tree identification book.

Chapter 15

Leaf Activities

One early summer morning a transcontinental bus was passing through a southwestern Indian village on a trip to the Pacific Coast. One of the passengers happened to notice an old Indian sitting quietly on the flat roof of his crude hut, his face turned toward the east, awaiting the first rays of the morning sun. For centuries, his ancestors had carried on this primitive ritual of sun worship.

The passenger, somewhat amazed, remarked to a friend that if that Indian knew half as much about the sun as more civilized people in America, he would certainly not worship it. But to the Indian, the rising sun meant another day — a day during which his crops could grow to supply the needs of his family and his livestock. Without the sun, he would have nothing, and so in his humble way he gave thanks each morning.

What the passenger did not realize was that he, too, owed everything to the sun. His daily food, the clothing he was wearing — even the power which drove the bus down the highway — none could have existed without sunlight.

You will learn in this chapter how sunshine gets into food and gasoline. You will see, also, why the Indian, living close to nature, may have had a much better understanding of biology than the more informed passenger on the bus.

A mystery of plant life. Man has gone far in learning the secrets of the earth about him. Nature has gradually unfolded her truths to the ever-searching scientist. But with all of his knowledge and skill in scientific investigation, man has yet to discover the workings of a basic chemical process which occurs in nature all about him. Every green leaf performs this strange activity during the course of every day. We call it by name *photosynthesis.* We understand what happens but cannot explain how it goes on. Duplication of photosynthesis in the laboratory would probably be the greatest scientific achievement of all time. Yet, to date, it defies science. We can only discuss and try to explain what we know about this greatest of all chemical reactions.

The seat of photosynthesis. Probably the best explanation of the inability of science to duplicate photosynthesis is the association of the process with life. It is a function of a *living green cell.* However, only certain cells are capable of photosynthesis because it requires *chloroplasts.* Furthermore, it depends upon a substance within the chloroplasts called *chlorophyll.* We may assume then, and correctly, that all living plant cells containing chloroplasts with active chlorophyll are capable of carrying on photosynthesis.

Chloroplasts are found in many plant tissues. They are frequently contained in cells of the cortex of young woody stems and herbaceous stems. The *leaf* is, however, the organ of the plant given over to photosynthesis. It is commonly called, therefore, the *food factory.* The *production line* would be the palisade tissue and, to a lesser extent, the spongy tissue. The *machines* are the chloroplasts which these cells contain.

Chlorophyll, the agent of photosynthesis. Quite often, chemists find that two substances placed together do not react until a third substance is added. Then a reaction occurs, but the third substance does not enter into it — its presence merely causes it. Such a substance is termed a *catalyst.* Chlorophyll bears much the same relation to photosynthesis. It serves as a catalyst or *agent* without actually entering into the reaction which occurs.

Chlorophyll is a green substance which may be removed from a leaf quite easily by placing it into alcohol or other solvents. One might assume that this valuable catalyst could be so removed and used in the laboratory to carry on photosynthesis artificially. But such is *not* the case, for chlorophyll seems to require a living cell for its role as the agent of photosynthesis.

In addition to chlorophyll, chloroplasts contain substances called *enzymes* which are important to photosynthesis. Enzymes serve as *catalysts* and, together with chlorophyll cause the chemical reaction of photosynthesis without entering into the process. Quite probably, science will someday discover other substances in the cell which act with chlorophyll to produce photosynthesis. Even then, however, duplication of the process may be impossible.

Raw materials for photosynthesis. From what are paper, wood, coal, oil, sugar, starch, and literally thousands of other organic compounds formed? The answer is very simple — carbon dioxide and water. These two abundant inorganic compounds are the only materials necessary for photosynthesis.

Plant roots absorb *water* from the soil and carry it through the stem to the leaves. *Carbon dioxide* enters with air through the stomates and is removed in the leaf tissues. In living chloroplasts, these two substances are combined chemically, by means of chlorophyll, to form a compound quite different from either.

The energy factor. Carbon dioxide, water, and chlorophyll alone cannot result in photosynthesis, for one extremely important factor is missing. The product which they form must contain energy. This energy must be absorbed by living cells as *light.* The sun is the source of light in nature and is, hence, the source of energy for photosynthesis. Direct sunlight is not necessary, however. Artificial light may be used by plants in the process. Plants may be grown quite satisfactorily indoors with nothing but artificial light if they are given a sufficient supply.

Photosynthesis becomes even more wonderful when you consider that it involves not only a chemical change during which carbon dioxide and water unite to form a new product, but an energy change as well. Light rays, or *radiant energy,* which is quite useless in supporting life, is converted into *chemical energy.* It is locked into the product and is released in the body of a plant or animal as *vital energy* or energy for life.

The product of photosynthesis. We now have all of the requirements for photosynthesis — a living cell with chloroplasts which contain chlorophyll, carbon dioxide, water, and light energy. The result after a chemical reaction is an organic compound, *sugar.* Sugar forms in the chloroplasts of active cells during the daylight hours. Since sugar is soluble in water, it dissolves as it is formed in the water of the cells. It is invisible and does not show in cells when examined under the microscope.

Most plants immediately convert the sugar which is formed from photosynthesis into *starch.* This forms crystals which are quite visible on the chloroplasts under the microscope. Onion cells reveal large numbers of *oil* droplets scattered through the cells. In this case, sugar is converted into the oil which gives the characteristic odor to onions.

The original or *simple sugar* formed during photosynthesis may be changed to many other products in plants of different kinds. Woody plants, like trees, convert some of the sugar into *cellulose* which is used in forming the woody cell walls of the xylem. Sugar cane, sugar beets, and sugar maples form a complex type of sugar called *double sugar* because two parts of simple sugar are used to form one part of double sugar. Cane and beet sugar are very important items of commerce.

Literally thousands of organic compounds are formed in the living world from the original simple sugar of photosynthesis. The chemist has added greatly to this lengthy list for he has found it possible to form new organic substances from existing organic compounds. They all may be traced back to photosynthesis, however, for green tissue alone can link the inorganic world with the organic world in the making of simple sugar.

The waste product. When carbon dioxide and water unite to form sugar, some of the *oxygen* which they both contain is left over. Oxygen, thus, becomes a *waste product,* though it is in no sense waste. In fact, the oxygen is as important as the sugar! It passes out of the leaves into the air or, in the case of aquatic plants, into the water. Here it is taken in by all living things during respiration. In a balanced aquarium, photosynthesis supplies both food and oxygen for animal life. Indeed, much of the oxygen we use during respiration originally passed through leaf stomates following its release from photosynthesis.

Photosynthesis — a definition. This discussion of photosynthesis which has required several pages to present, may be condensed into one brief statement or definition. *Photosynthesis is the process by which certain living plant cells combine carbon dioxide, water, and light energy, by means of chlorophyll, to form sugar and release oxygen as a waste product.*

It may be stated even more simply in a chemical equation, showing the amount of each substance involved and the proportions of the elements included in each as follows:

$$6CO_2 + 6H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

(carbon dioxide) (water) (light) (sugar) (oxygen)

The above equation means that six molecules of carbon dioxide and six molecules of water combine, with energy included, to form one molecule of sugar with six molecules (twelve atoms) of oxygen left over. The sugar contains stored energy which is later released in the body of a plant or animal cell.

Conditions for photosynthesis. The rate of photosynthesis depends upon several important factors both within the plant and in its surroundings. Probably the most critical internal factor is the condition of the food-making cells. The chlorophyll content of their chloroplasts is related directly to the general condition of the plant as well as to the environment which supplies water, light, and the proper minerals for chlorophyll manufacture. In addition to these requirements for the making of chlorophyll, other factors of the environment are essential to the process of photosynthesis.

Philip D. Gendreau, N.Y.

BURNING BUILDINGS. Burning wood releases stored sunshine as light and heat energy. The tremendous amount of energy released by a burning building or a forest fire is completely wasted.

Water is necessary both as a material for the process and to maintain healthy cells, capable of food manufacture. The *carbon dioxide* content of the atmosphere is another critical factor since this gas serves, likewise, as an essential material. *Light* serves a double role, as the energy source for the process and as a requirement for chlorophyll formation.

Temperature is an extremely critical factor since it affects cell activity. Summer temperatures, ranging from 80°–90° F. are ideal for photosynthesis. As the temperature decreases, the process slows accordingly and ceases altogether near the freezing point. Likewise, an increase in temperature above 100° F. slows the process accordingly.

Significance of photosynthesis. Photosynthesis is a function of the green plant and, as such, has biological importance. But its real significance is much broader. It supplies the basic requirements for all life, both plant and animal.

The most direct importance of photosynthesis is food production. Sugar, the direct product, is an essential food. From this basic substance, plants and animals build other food substances including starches, fats, oils, proteins, and vitamins. They all contain the energy from photosynthesis and are related directly to the activity of green plant tissues.

The significance of photosynthesis is much broader when you consider that all organic compounds may be traced to this marvelous plant activity. Organic compounds are so numerous and so important that an entire phase of chemistry is devoted to their study. In estimating the value of photosynthesis to modern America, consider the part played by lumber, paper, fibers and textiles, drugs, turpentine, alcohols, and waxes. These are only a few of the plant products we use directly.

Energy from fuels. Our modern civilization runs on power — power obtained largely from natural fuels. One of man's earliest achievements was the use of fire from wood. Wood contains stored energy taken originally from the sun during photosynthesis. One need only start a chemical breakdown of wood by igniting it and thus releasing this stored sunshine as heat and light energy. Wood has served for ages as a simple source of energy for heating, cooking, and fueling machines.

As civilization advanced, other fuels were discovered to supply more complicated machines. Plant remains of past ages were unearthed in the form of coal and oil deposits. The sunshine of millions of years ago, still locked within the molecules of these substances, serves as the most efficient energy supply for modern civilization.

THE LEAF AS A FACTORY

The factory	Green leaves (or other green tissue)
The workrooms	The cells of palisade and spongy layers
The machines	Chloroplasts with chlorophyll
The power	Sunlight
Raw materials	Carbon dioxide and soil water
Supply department	Root hairs, ducts, air spaces, stomates
Transportation department	Ducts, sieve tubes, pith rays
Finished products	Sugar, starch
Waste product	Oxygen
Hours of work	Manufacturing department, daylight *only* Transportation and supply departments, day and night.

Storage and translocation of foods. During a bright, warm day, photosynthesis forms sugar in leaf cells much more rapidly than it can be removed to other parts of the plant. As a result, most leaves convert the sugar to starch either immediately or soon after it is formed. As the day's food manufacture progresses, starch grains become more and more abundant. About the middle of the afternoon, the starch content reaches its peak.

As evening approaches, light becomes reduced and photosynthesis slows, ceasing altogether with darkness. Through the night, the stored starch is *digested* in the cells and forms sugar which dissolves in water. *Translocation* or movement of the sugar solution through the veins into the stem continues all night. With the coming of dawn and the resumption of photosynthesis, the food-making cells are cleared of stored food and are ready to receive the product of a new day's activity.

Formation of fats. Sugar production during photosynthesis is the beginning of a series of food-making processes which occur in both plants and animals. One such group of processes results in the formation or synthesis of fats and oils. The process is by no means limited to leaf tissues since light and chlorophyll are not necessary. All living cells, both plant and animal, possess the " machinery " necessary for fat and oil formation.

Fats occur at ordinary temperature either as solids or liquids. Liquid fats are commonly called oils. Fats and oils are similar to carbohydrates (sugars and starches) in that they contain the same elements, carbon, hydrogen, and oxygen. They are formed largely as storage products, and are used later as energy foods. Many plants like soybeans, castor beans, cotton, flax, wheat, and others store oils in their seeds, which serve as important articles of commerce. Animals, too, change carbohydrates to fats and store them beneath the skin and in other regions of the body — a fact to be considered in regulating the carbohydrate content of the diet.

Formation of proteins. More complex than either carbohydrates or fats is the third class of foods called *proteins*. Proteins are essential to growth in both plants and animals since protoplasm contains, among other substances, large amounts of protein. An organism cannot grow or repair its tissues without adequate protein content in its diet.

As to the formation of proteins or *protein synthesis* little is known and the known facts are too complicated to present in a general biology course. The formation of a protein is another remarkable plant process. As animals, we can only rearrange these plant proteins in the formation of our body substances.

Proteins contain stored energy from photosynthesis, so we know that the plant uses carbohydrates in the process. In addition to the carbon, hydrogen, and oxygen contained in carbohydrates, proteins contain nitrogen, sulphur, and usually phosphorus. These elements enter the plant from the soil in the form of mineral salts. Nitrogen-containing salts are called *nitrates;* sulphur-containing, *sulphates,* and phosphorus-containing, *phosphates*. During complicated chemical reactions, these mineral salts are broken down in the plant cells, and together with carbohydrates are combined to form proteins.

Accordingly, plants require not only carbon dioxide and water, but fertile soil as well, in order to form proteins. Photosynthesis may produce abundant carbohydrates, but unless the soil can supply the nitrates, sulphates, and phosphates, proteins or growth foods cannot be formed.

Respiration. Respiration goes on in all living plant tissues, but especially in leaves because of their close contact with the atmosphere. During respiration, oxygen enters the leaf through its stomates and combines with foods, especially sugar, during the chemical process called *oxidation*. Oxidation breaks down the sugar and forms water and carbon dioxide, releasing energy which was stored in the sugar molecules. The substances which originally composed the sugar, now carbon dioxide and water, are released as waste products. The energy is used by the cells in which oxidation occurs to perform their life activities. Respiration may be summarized as follows:

sugar + oxygen → water + carbon dioxide + energy

Chemically, respiration may be shown as:

$$\underset{\text{(sugar)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2} \rightarrow \underset{\text{(water)}}{6H_2O} + \underset{\text{(carbon dioxide)}}{6CO_2} + \text{energy}$$

You will note that respiration is the exact *opposite* of photosynthesis. The respiration reaction reversed becomes photosynthesis.

Comparison of Photosynthesis and Respiration

Photosynthesis	*Respiration*
Constructive process	Destructive process
Food accumulated	Food broken down (oxidized)
Energy from sun stored in sugar	Energy released
Carbon dioxide taken in	Carbon dioxide given off
Oxygen given off	Oxygen taken in
Complex compounds formed	Simple compounds formed
Produces sugar, starch, etc.	Produces CO_2 and a little H_2O
Goes on only by day	Goes on day and night
Only in presence of chlorophyll	In all cells

Photosynthesis and respiration are by no means balanced in the plant. Since photosynthesis is limited to the daylight hours, it occurs much more rapidly than respiration, which goes on both day and night. Furthermore, a plant normally builds up a much greater supply of carbohydrates than it will require for its own oxidation needs. It is estimated that a corn plant oxidizes only about one-fourth of its food supply during a growing season.

During the daylight hours, the water and carbon dioxide released from oxidation supply only a fraction of the needs of photosynthesis. Likewise, oxygen is released during food making in much greater quantity than is needed for respiration. During the daytime, then, leaves take in carbon dioxide and release oxygen through their stomates. At night, when respiration alone is being carried on, oxygen enters the leaf and carbon dioxide is given off.

Plant and animal respiration is essentially the same. In both cases, gases are exchanged between the organism and the atmosphere. Respiration supplies oxygen for oxidation, and removes carbon dioxide as a waste product from the process. Since animals require much more energy for body activity than plants, their rate of respiration must be greatly increased. To make possible this more rapid exchange of gases, many animals carry on a muscular process called *breathing*. But breathing in animals is not respiration, and should not be confused with it. Breathing is merely a means by which animals take in oxygen and give off carbon dioxide. Plants have no lungs or other special organs for breathing, but take in and give off these gases directly through the stomates in their leaves.

Respiration may be defined as the process in which stored energy in foods is released by oxidation, and carbon dioxide and water are given off.

Transpiration. During the growing season a plant conducts a continuous stream of water upward through its roots and stem into the leaves. This flow of water bears mineral compounds in solution from the soil which are used in the manufacture of proteins, chlorophyll, and other products. Some water is used for growth, some for maintaining cell turgor, and some for photosynthesis. With all of its uses, however, much more water is absorbed than the plant can use. Accordingly, this excess water must escape from the plant through the leaves.

During *transpiration,* water passes from the spaces of the spongy areas through the stomates and into the air as vapor. While leaves primarily are concerned with transpiration, other plant parts may likewise pass water vapor into the atmosphere. Transpiration is carried on through the thin epidermis of many stems and such fruits as apples, tomatoes, and cherries. The results of transpiration by fruits is shown in their shriveling upon exposure to the air.

Control of transpiration. That transpiration is more than mere evaporation of water from a leaf surface is indicated by the difference in the rate at which it may occur under various conditions. The rate of transpiration is controlled *to a limited* extent because the opening of the stomates in the epidermis is regulated by the shape of their guard cells. A change in the shape of these guard cells alters the size of the opening between them. When these cells are full of water, they swell outward in such a manner as to spread out the stomate opening. Through such an open stomate, water escapes rapidly. During periods of excessive water loss, the stomates close due to the shrinking of the guard cells. A closed stomate retards but does not stop transpiration.

The opening and closing of leaf stomates is influenced to a great extent by external factors. Light, humidity of the air, and temperature affect the guard cells and, hence, the escape of water vapor. Shade leaves usually have their stomates open much of the time. The effects of temperature and humidity of the air upon stomates is shown in the daily fluctuation of the stomate openings. During morning hours on summer days, stomates are usually open. As the temperature rises with the approach of midday, water loss from the guard cells causes them to close.

That leaves cannot entirely stop transpiration, even with their stomates closed, is clearly shown in the wilting which frequently occurs on hot days. Such wilting is only temporary and is due to a more rapid rate of transpiration than absorption. In other words, the leaves are losing more water vapor into the atmosphere than the roots are able to absorb. This temporary wilting ceases when the atmosphere cools, and absorption makes up the water deficiency. Transpiration is especially dangerous to plants after transplanting. Such plants should be stripped of much of their leaf area in order to reduce transpiration until the roots have become well established in their new location and are able to carry on absorption at a normal rate.

Experiments with Leaves

Many of the interesting activities of the leaf may be demonstrated in the laboratory by experiments with living plants. These experiments must be set up very carefully. Observations must be accurate and it may be several days before results are obtained. In performing these experiments in plant physiology, you may obtain some very striking results.

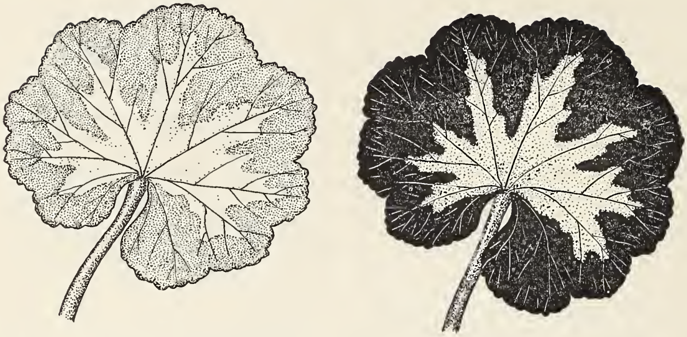
To show that leaves (and stems) turn toward light. Take two thriving plants. Place one in a light-proof box with an opening at one side for light to enter. Place the other under the same conditions of heat and moisture, but with light from *all* sides.

The plant in the box will be found to turn toward the light and to grow rapidly in that direction. Its stem will be weaker and slenderer, its leaves smaller and paler than the one with uniform lighting.

This experiment shows the response that plants make to light, and also the effect of a limited supply of light on their growth. Every time we see the leaves of house plants turning toward the window, we have a similar experiment in phototropism. The plant kept outside the dark box was a check for this experiment.

Not only do plants turn toward light to expose their chlorophyll, but the chlorophyll itself is dependent on light for its formation. When plants are kept in complete darkness the tissues lose their green color. Celery plants are partly covered to produce whitening or "blanching."

To show that green plants produce starch (photosynthesis). Leaves can be taken from active green plants, scalded to kill the protoplasm and to release the chlorophyll, and boiled in alcohol to remove the green color. Then, if tested with iodine, a dark blue color is produced, proving that starch is present in the leaves. The chlorophyll had to be removed so that this blue could be seen.



The Starch Test. The leaf on the left shows natural green and white areas before being treated with iodine. The leaf on the right, after being treated with iodine, shows the blue-black color only in those parts of the leaf which were green.

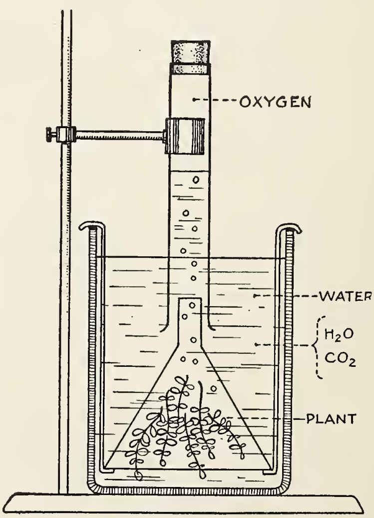
To prove that it is *made there,* by the action of light on the chlorophyll, requires further experiment. Sugar is formed before the starch, but it remains in solution and its presence is not so easy to prove.

To demonstrate that chlorophyll is necessary, a leaf from a green-and-white-leaved geranium may be treated as above. It will be found that little starch is revealed in the white portions. How do the cells of the white area get food?

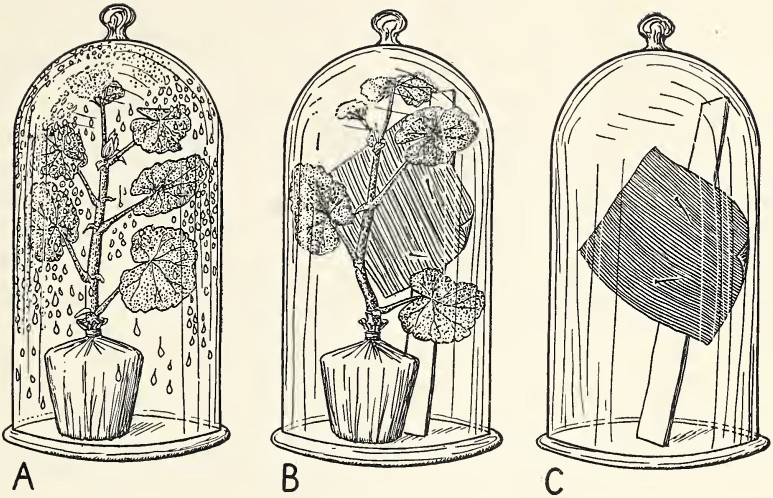
To show that light is necessary, areas of an active leaf are covered with corks, pinned through, on both sides. After a few days the covered portions will not yield the starch test, while the exposed parts will still do so. Another proof of the same thing is to keep a plant entirely in the dark, as a check experiment, and when it has become pale, test for starch, which will be found lacking. Of course the same kind of plant, under the same conditions except the light, should be used in both experiments as a control.

To show that green plants produce oxygen. Oxygen is the waste product of photosynthesis, given off when sugar and starch are made. It is easier to collect a gas over water, hence a water plant is used for this experiment; but all green plants carry on the same process.

The water plant (such as *Vallisneria, Sagittaria, Elodea,* or *Myriophyllum*) is submerged under a glass funnel whose stem is covered with a glass tube. The tube is corked at one end, filled with



Green Plants Give Off Oxygen. The oxygen bubbles can be seen rising in the tube from the green plants at the bottom of the funnel.



TRANSPIRATION. A. Water vapor has condensed on the walls of the jar. B. Water vapor turns the cobalt paper pink in fifteen minutes. C. Check experiment to show that water vapor in the air is insufficient to change the color of the paper.

water and inverted. If the apparatus is set in the sun bubbles of gas will rise in the funnel and collect in the tube. Before removing the cork to make a test for the gas which is collecting in the funnel, lower the tube so that the water in it is on the same level as that in the jar. This will prevent a downward rush of water in the tube when the cork is removed. Otherwise air would be sucked in from the top and the gas thus diluted. Test this gas by lowering a glowing splinter in the funnel. It will burst into flame and indicate the presence of oxygen. If carbon dioxide is dissolved in the water, the process will go on much faster because carbon dioxide is one of the materials used in photosynthesis, and that in the jar is soon exhausted.

Another similar experiment ought to be set up in the dark to prove again that light is the source of energy for this important process.

To prove that the oxygen did not come from the water, another check could be used with the apparatus the same but without a plant, in which case, no oxygen would be produced. How would this prove anything?

In experimental work of this kind, control experiments show almost as much as those which actually " work." Merely stating that the water plant was put under the funnel and that oxygen was produced would not prove anything. The questions would still remain: " How do you know that the oxygen came from the plant? " and " How do you know that light had anything to do with the process? " Both of these questions can be answered if you use a control experiment.

Still another experiment is the following. Procure two large bell jars with open tops, each securely corked. Put a lighted candle and a vigorous potted plant on a sheet of vaselined glass. Place

Summary of Leaf Activities

Process	Center of Activity	Apparatus	Materials required	Product	By-product
Photosynthesis	Palisade and spongy cells (cortex of green stems)	Protoplasm Chlorophyll Enzymes	Water Carbon dioxide	Sugar (may be changed to starch)	Oxygen
Digestion	All living cells	Protoplasm Enzymes	Starch	Sugar	
Fat formation	All living cells	Protoplasm	Sugar or starch	Fats and oils	
Protein formation	All living cells	Protoplasm	C, H, and O from carbohydrates; N, S, and P from minerals	Proteins	
Respiration	All living cells	Protoplasm	Foods (especially carbohydrates) and oxygen	Energy	Carbon dioxide Water
Translocation	Leaf cells and veins	Water as conducting medium	sugar (dissolved in water)		
Transpiration	Leaf epidermis	Leaf spaces (spongy layer) and stomates	Water	Water vapor	

one of the bell jars over the plant and the candle. Very shortly the candle flame will become weak and then go out. Put the other bell jar over another lighted candle also placed on a vaselined glass plate, and watch the flame disappear. From knowledge gained from previous experiments explain why the flames were extinguished. State your ideas as to the gases now in each bell jar.

Leave both jars for a day or so in the sunlight. Then test each by lowering a small lighted candle into each jar, being careful not to admit any more air than is necessary. The candle lowered into the jar with the plant should burn well for a few moments. The candle lowered into the other jar should go out immediately. Discuss the relative amounts of carbon dioxide and oxygen in the two jars, at the beginning of the experiment and at its conclusion.

To show that plants give off water vapor. A sturdy cutting is tightly sealed into a bottle of water and placed under a bell jar; a similar bell jar containing no plant is set alongside. On the inside of the jar with the plant, water drops will soon be seen but there are none on the other. As the bottle was sealed, no water could escape, except such as passed through the leaves of the plant. As the empty jar showed no water, it did not merely condense from the air, hence must have been passed off by the leaves. A potted plant could be used, but the pot and earth surface would have to be wrapped in oiled paper or sheet rubber to prevent evaporation from anything but the leaves.

To show which surface of a leaf gives off this water vapor, two watch glasses can be fastened, one on either side of a leaf.

More water will be found to condense on the glass fastened to the lower surface, showing that transpiration is more active here. This is as one would expect, since the stomates are found on the lower surface.

Cobalt paper, which turns pink when moist, can also be fastened to the upper and lower surfaces of a leaf, and will show the same result.

Summary

Of all of the processes carried on in leaves, photosynthesis is the most vital to the living world. During photosynthesis, the elements contained in carbon dioxide and water are rearranged to form sugar, and extra oxygen is released as a waste product. Radiant energy in the form of light is absorbed by the leaf and is stored as chemical energy in the sugar. Chlorophyll and certain enzymes serve as catalysts during the process.

Photosynthesis is vital to all living things because its product is the basis of all other organic compounds. Foods containing chemical energy from photosynthesis are used by all living things as a source of vital energy for life. During complex chemical changes, the sugar formed as a result of photosynthesis may be converted to other organic compounds which are essential to all living things.

During respiration, the photosynthesis process is reversed. Oxygen is combined with sugar with the result that the sugar is split up and forms carbon dioxide and water, the original raw materials of photosynthesis. The importance of respiration is not the chemical oxidation of sugar, but the release of energy stored within the sugar molecules. Respiration, unlike photosynthesis, is not limited to the green plant.

The elements contained in carbohydrates, resulting from photosynthesis, may be rearranged by the plant to form fats. During protein formation, these same elements are united with nitrogen, phosphorus, and, in some cases, sulphur, which are taken as minerals from the soil.

The process during which water passes from the leaves to the air as vapor is called transpiration. Transpiration is essential to the upward movement of water through the plant, but may become a great hazard when its rate exceeds the rate of water absorption by the roots. To some extent, it may be controlled by regulation of the stomate openings.

Using Your Knowledge

1. What evidence do we have that photosynthesis is a life process rather than a mere chemical reaction carried on by plants?

2. Explain the role of chlorophyll in photosynthesis.

3. Explain the relation of light to photosynthesis.

4. Why may sugar be regarded as the basic organic substance for all living things?

5. Light is composed of several visible rays which compose the spectrum. How could you determine which rays: red, orange, yellow, green, blue, indigo, or violet are most used in photosynthesis?

6. What gas is given off by leaves during the day; during the night? Explain.

7. Do you agree or disagree with the statement that plants should be removed from the sickroom at night? Explain.

8. Why is it important that the leaves of potato plants be rid of bugs, even though the insects cause no direct damage to the tubers underground?

9. Explain what is meant by the statement, " coal is bottled sunlight."

10. Explain the manner in which protein formation is more closely related to the soil than is photosynthesis.

11. Compare the processes, photosynthesis and respiration.

12. Explain how transpiration may be regulated to some extent.

Expressing Your Knowledge

photosynthesis	chemical energy	translocation
catalyst	vital energy	nitrate
enzyme	simple sugar	sulphate
raw material	double sugar	phosphate
radiant energy	waste product	transpiration

Applying Your Knowledge

1. Place some water plants in an aquarium and set them on a sunny window ledge. Watch for streams of bubbles coming from the leaves. What is the gas? Try to collect some in a tube or closed funnel and prove what gas is being given off by means of a test.

2. Select a green leaf which has been exposed to sunlight. Remove the chlorophyll from the leaf by soaking it in warm alcohol. (Do not use a flame for heating the alcohol.) Then rinse the leaf in cold water. Apply iodine to the leaf after the chlorophyll has been removed completely and explain your results.

3. Prepare a report on the subject, " The Relation of Photosynthesis to the Building of Civilization."

Chapter 16

Flowers and the Reproductive Process

" Say it with flowers! " This familiar slogan of the florist is an indication of the importance of flowers in the life of the average person. Flowers have long been associated with the sentiment of special occasions. Christmas, Easter, Mother's Day, birthdays, and other special events are usually associated with floral bouquets. We use flowers to express happiness at wedding ceremonies and sympathy at times of illness or death. Flowers seem to have a unique way of expressing our thoughts and sentiments.

The joy and satisfaction one finds in growing flowers has led to the development of extensive flower industries the world over. Tulips from Holland, lilies from the Orient, iris from Siberia and Germany, and lilacs from Iran (Persia) and France have long graced the gardens of the average American home. In all parts of America, we find plant growers engaged in the cultivation of roses, delphiniums, daisies, chrysanthemums, and scores of other flowering plants for the amateur flower grower.

To the plants producing them, however, a flower is much more than a thing of beauty. It is a specialized organ which performs one of the most important functions of the plant—the continuation of its kind through the processes of reproduction. The flower lives only a short time, and is supplanted by the fruit which contains the seeds. These develop into a new generation of plants.

The bright colors and sweet odors which are usually associated with flowers are only an advertisement to attract insects. Insects are necessary to fulfill the real purpose of the flower — reproduction of the plant. Long before this process is completed, the petals fall away and the flower becomes no longer a thing of beauty.

In this chapter you will learn the parts of a flower and the role that each part plays in reproduction. You will discover that bright petals are not an essential part of the flower and that many plants about you bear inconspicuous flowers each season which are quite small and lack brilliant color.

Vegetative and reproductive organs of the plant. The specialized organs of a plant may be separated into two distinct groups, based upon the functions with which they are associated. Roots, stems, and leaves are termed *vegetative* since they carry on the processes necessary to maintain life. Through absorption, conduction, food manufacture, respiration, transpiration, and the other processes, the plant maintains its own existence. At maturity, however, the vital process, reproduction, must occur if the plant will perpetuate its kind. At this time, much of the energy built up during vegetative activity goes to the formation of flowers for reproduction. Normally, flowers are followed by fruits which bear seeds. With the formation of these specialized reproductive parts, the plant has fulfilled its major activity.

Plant reproduction is accomplished in many ways. Vegetative organs may develop new plants from their tissues. Grafting, budding, and growth from tubers, corms, and bulbs are only a few examples of *vegetative multiplication.*

Methods of reproduction involving special cells and organs are very numerous in the plant kingdom. For the present, we shall consider only the reproduction of a seed plant.

Reproduction among the seed plants. In outlining the plant kingdom in Chapter 9, the highest plants were called *Spermatophytes,* or seed plants. This great division was, in turn, divided into two important sub-divisions called *Gymnosperms* and *Angiosperms.* Reproductive processes serve to distinguish these sub-divisions. Gymnosperms produce *naked seeds* which are borne on the woody *bracts* or scales of cones. They do not form flowers and fruits. Angiosperms, on the other hand, bear *flowers* followed by a *fruit* which encloses the *seeds.* This process is characteristic of about 150,000 kinds of Angiosperm plants, and gives them the familiar name, the *flowering plants.* The discussion of the flower which follows is, therefore, limited to flowering plants alone. This group produces the most perfect organ of plant reproduction.

The structure of a flower. A flower is really only a modified branch in which

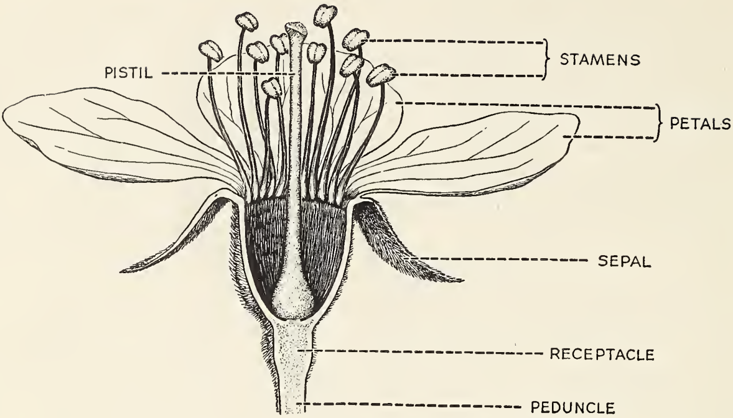


Diagram of a Flower Showing the Parts

the leaves are extremely altered to form the parts of the flower. A typical flower, such as the geranium, apple blossom, snapdragon, sweet pea, or petunia, is composed of four sets of parts. These parts grow from a special flower stalk or *peduncle* [*pee dung′k'l*], the end or tip of which is termed the *receptacle.* The outer ring of floral parts consists of several green leaflike structures called *sepals* [*see′pals*]. Together, they form the *calyx* [*kay′lix*]. The sepals cover and protect the rest of the flower in the bud condition and help in supporting the other parts when the bud opens.

Inside the calyx is the *corolla* [*ko rol′la*] which usually consists of one or more rows of *petals.* These are often, but not always, brightly colored. The calyx and corolla frequently serve to attract insects, as we shall see later. They may also help to protect the inner parts. In some flowers, like the morning glory, Jimson weed, and petunia, the petals are joined in a single funnel or bell-like structure. The calyx and corolla taken together constitute the *perianth* [*pear′ ianth*] or floral envelope. They play no part in the actual reproductive process and are, therefore, spoken of as *accessory* parts.

In certain flowers both the calyx and corolla are colored. The color of both parts is sometimes identical, so that the observer misses the fact that both parts are actually present, although only the petals seem evident. This condition is found most frequently in the lily family. The tulip, Easter lily, tiger lily, and meadow lily appear to have six colored petals. Careful observation shows, however, that the outer three petals are really brightly colored sepals which enclose three similarly colored petals.

Reproduction is concerned directly with two kinds of *essential* parts, the *stamens* [*stay′mens*] and the *pistil,* located in the center of the flower. Each stamen consists of a slender stalk or *filament* supporting a knob-like sac called an *anther.* The anther produces a yellow or reddish powdery substance called *pollen* [*pah′len*] which plays an important part in reproduction.

In the very center of the flower is the pistil, consisting of a sticky knob at the top, called a *stigma,* a slender stalk or *style* which supports the stigma, and a

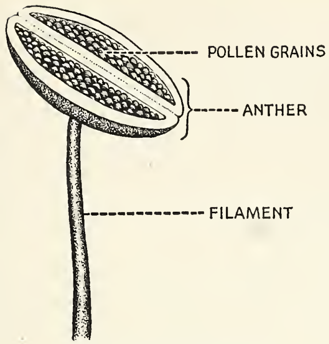


DIAGRAM OF A STAMEN

swollen base or *ovary* which is joined to the receptacle of the flower stalk. Within the ovary are the *ovules* which will later become seeds. The ovules are attached to the ovary either at its base, or along the side walls, or to a special stalk running lengthwise from the base of the ovary to the base of the style. Ovules may number from one to several hundred, depending upon the kind of flower.

Types of flowers. A flower which contains all four main parts — calyx, corolla, stamens, and pistil — is said to be *complete* (cherry, rose, lily). If one or more of these parts is missing, the flower is termed *incomplete*. Where the stamens and pistil are present, even though the floral envelope is missing, the flower is called *perfect* (wild ginger and maple). If either of the essential organs is missing, the flower is said to be *imperfect*.

Many common trees, including the willow, poplar, birch, and alder, produce imperfect flowers. Such plants must form two kinds of flowers, since both stamens and pistil are essential to reproduction. Flowers bearing stamens only are termed *staminate* to distinguish them from *pistillate* or pistil bearing flowers.

Some plants bear imperfect flowers on separate plants — that is, staminate flowers on one plant and pistillate on another. Botanists call these plants *dioecious* [*dy ee'shus*], as illustrated in the willow, cottonwood, white campion, and meadow rue. Other plants produce both kinds of imperfect flowers on the same plant, as in the corn, where the pistillate flowers form on the ear and the staminate flowers compose the tassel. Plants of this type are called *monoecious* [*moan ee'shus*] and include, in addition to the corn, the birch, the alder and the squash.

Pollination. Seed development occurs after flowering only if pollen is transferred from the anther of a stamen to the stigma of a pistil of the same kind of plant. This transfer of pollen from anther to stigma is called *pollination* and is a vital phase of the reproductive process.

Self-pollination is the transfer of pollen from anther to stigma in the same flower or to the stigma of another flower on the same plant. If flowers on two separate plants are involved, the process is termed *cross-pollination*.

The transfer of pollen from one plant

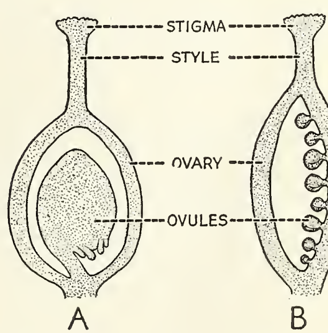
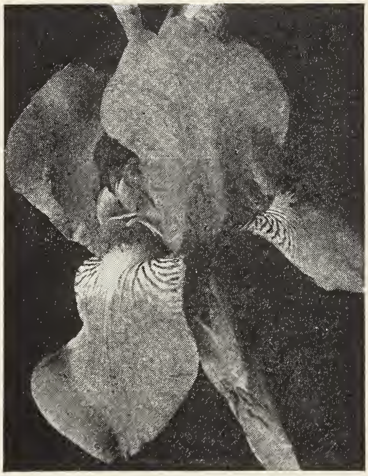


DIAGRAM OF TWO PISTILS. A. Ovule attached at the base of the ovary, as in the peach. B. Several ovules attached along the ovary wall, as in the bean or pea.



IRIS FLOWER. Note the bearded nectar guides, with the stigma just above.

to another in cross-pollination requires an outside agent such as *water, insects,* or *wind.* Curious adaptations of different kinds of flowers are frequently necessary to accomplish pollination by means of these outside sources.

Adaptations for water pollination. Of the cross-pollinated flowers, none is more curious than certain aquatic plants where water serves as the pollinating agent. We usually overlook these strange little flowers found floating on the water at certain seasons of the year.

The eel grass or Vallisneria, like many other aquatic plants, produces these curious water-pollinated flowers. Staminate flowers and pistillate flowers develop separately and at the same time. The pistillate flowers are produced at the end of long, twisted stalks which carry the flowers to the surface of the water. Staminate flowers develop under water, but break away from the parent plant at maturity and float to the surface. Pollen grains break out of the anthers while the flowers are floating and are carried by water currents to the pistillate flowers. After pollination, the pistillate flowers are drawn under water by the coiling of their twisted stalks. The development of these pistillate flowers under water, their rise to the surface during pollination, and their return under water is indeed a curious phenomenon of plant life.

Adaptations for insect pollination. Chief among the insect pollinators are bees, although moths, butterflies, and certain kinds of flies visit flowers regularly and in so doing carry on cross-pollination.

Insects come to the flower to obtain sweet *nectar* which is secreted deep in the flower from special glands at the base of the petals. Bees swallow nectar into a special honey stomach where it is mixed with saliva and converted into honey. Upon returning to the hive, the honey is deposited in six-sided cells of the honey comb and is used later as food.

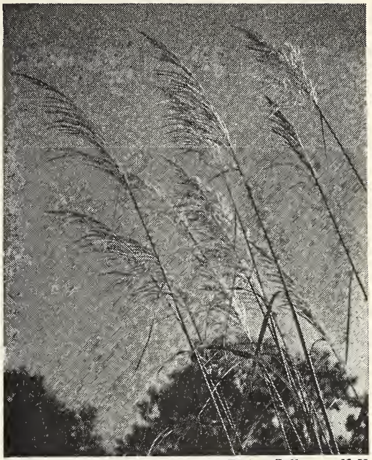
The plump, hairy body of the bee makes it an ideal pollinator. To reach the nectar glands, located at the base of the flower, the bee must rub its hairy body against the anthers. These are usually located near the entrance into the flower. When the insect visits the next flower, some of the pollen is sure to rub against the sticky stigma of the pistil as a new supply is brushed off to the stamens as it crawls out.

Brightly colored petals and sweet odors aid insects in locating flowers. Certain kinds of flowers, like the bearded iris, have special nectar guides along the colored sepals (or *falls,* as iris growers call them) which direct insects to the nectar glands and, incidentally, to the stigma and hidden stamens. Nectar guides in other flowers may be brightly colored stripes located on the petals. The arrangement of flowers in showy clusters makes them more conspicuous to passing insects. Nearly every insect-pollinated flower has some special attraction whether it be color, odor, curious shape, or an inviting landing place on the projecting petals.

While most animal agents of pollination are insects, at least one bird should be included in this special category of plant and animal relationship. Hummingbirds feed upon flower nectar which they sip from the flower by means of a long bill and an equally long tongue which can reach to the nectar glands while the bird hovers in mid-air.

Adaptations for wind pollination. Wind-pollinated flowers offer a sharp contrast to the bright colored, sweet-scented flowers adapted for insect pollination. These flowers are far less striking and are frequently hardly noticeable. They are borne, usually in dense clusters near the ends of branches. As a rule, petals are lacking as are nectar and perfume glands. The stamens frequently are very long and produce enormous quantities of pollen. The pistil, likewise, is much lengthened and the stigma greatly enlarged to catch the pollen grains which are blown through the air. Cottonwoods, willows, walnuts, corn, oats, and other wind pollinated plants literally fill the air with pollen when the stamens mature.

Artificial pollination. Artificial pollination is practiced by plant breeders in the development of new varieties of plants literally fill the air with pollen selected parent plants. The anthers are first removed from the flower buds before the pollen has matured in order to avoid self-pollination. The flower is then covered with a paper bag to prevent accidental cross-pollination. When the pistil has matured, the bag is removed and pollen from a selected plant is placed upon the stigma. The bag is then replaced and left until the fruit has begun to form, after which it may be removed. Crosses of this sort, involving carefully selected parent plants, have resulted in the many improved varieties and high quality strains which plant breeders have given us.



Ewing Galloway, N.Y.

GRASSES ARE WIND-POLLINATED PLANTS

Natural prevention of self-pollination. While not always the case, a great many plants form better seed as a result of cross-pollination than self-pollination. Accordingly, nature has provided various means of avoiding self-pollination in certain plants.

Imperfect flowers on separate plants is a guarantee of cross-pollination. Likewise, imperfect flowers on the same plant, as in the corn, usually results in cross-pollination since pollen usually is carried by the wind from the tassel to the ear of another plant.

The shape of many perfect flowers like the sweet pea and iris is such that pollen can hardly get to the pistil of the same flower except by accident, but is almost certain to be crossed when the

Artificial Pollination Used in Breeding New Plants

flowers are visited by insects. Often the stamens and pistil mature at different times in the same flower, so that when the pollen is ripe the pistil has not matured sufficiently to receive it, or the reverse. Sometimes plants have two different types of flowers: one with long stamens and a short pistil and the other with a long pistil and short stamens. Such are the primrose and the bluet. Which type of arrangement would be more apt to prevent self-pollination in an erect flower? In a drooping flower?

Some human aspects of pollination. To the hay fever sufferer, the discussion of pollination has probably brought unpleasant thoughts of the late summer and early autumn seasons. Pollen of the goldenrod, sagebrush, thistle, ragweed, and certain grasses, present in the air during late-season pollination of these and other plants, causes severe irritation of the membranes of the eyes, nose and throat of certain individuals. The disagreeable effects of hay fever seem to be caused by a reaction between these membranes and the content of certain types of pollen. The reaction is called an *allergy*.

Less common than late-season hay fever is a type which appears in the spring or early summer, during pollination of the maples, birches, willows, and early flowering grasses. Treatment for hay fever must begin with determination of the kind of pollen involved by administering a series of skin tests. Pollens to which an individual is sensitive will produce an irritation when injected under the skin. When a specific type of pollen has been determined as the cause of the irritation, a series of shots containing the content of the particular pollen grains may be administered in increasing doses, resulting sometimes in a partial immunity. In extreme cases of pollen sensitivity, relief can be found only by leaving the area during pollination of the plants involved.

GIANT RAGWEED. This plant is the source of a common type of hay fever and should be eradicated wherever it grows.

The anther and formation of pollen. Pollen grains develop, prior to the opening of the flower, from special cells located in cavities of the anther of a stamen. These cavities, called *pollen sacs,* are four in number, and run lengthwise through the anther. If the anther from a large stamen like the tulip or lily is sectioned lengthwise or crosswise, the pollen sacs are clearly visible under a hand lens or the lower power magnification of the microscope.

Pollen grains are formed by cell division in groups of four. They increase in size as the stamen matures until they nearly fill the pollen sacs. With the opening of the flower, the pollen sacs split lengthwise and spread open, thus discharging the pollen grains within.

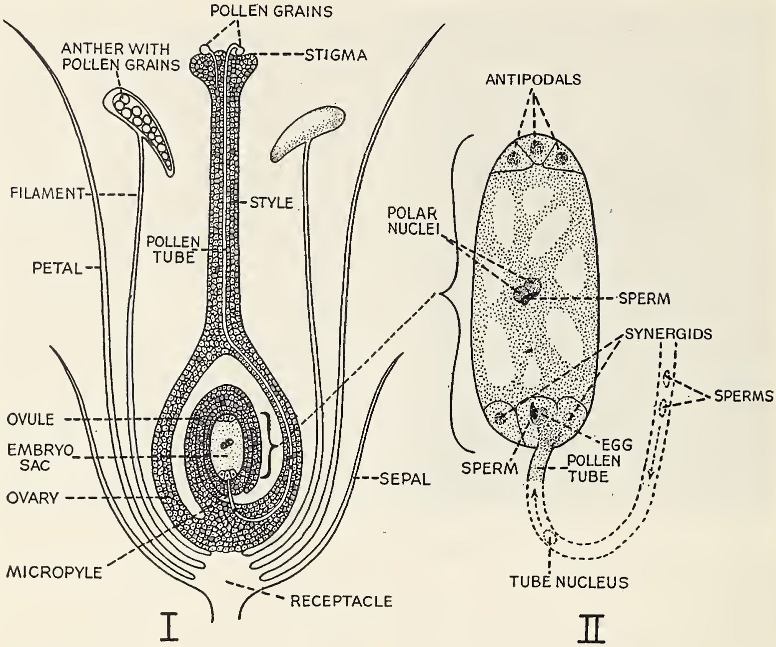
While pollen grains vary in size and shape in different kinds of plants, they all are similar in general structure. Each has an outer wall, or *extine,* and an inner wall, or *intine.* The body of the pollen grain is composed of protoplasm, including two important nuclei, the *tube nucleus* and the *generative nucleus.* The importance of these nuclei will be explained later in the discussion of fertilization.

Structure of an ovule. Formation of pollen in the flower is only half of the story of reproduction. The other half concerns the *ovules,* which develop within the pistil early in the formation of the flower.

A pistil sectioned lengthwise shows the *stigma* at the tip, the slender *style* and a swollen *ovary* at the base. Within the ovary are one or more *ovules.* For the sake of simplicity in studying the detailed structure of an ovule, an ovary containing a single ovule like the peach, plum, or apricot will be used for illustration. Many flowers produce ovaries with numerous ovules, like the bean, pea, orange, apple, and melon.

The ovule is attached to the ovary wall by a slender stalk or *placenta* which serves, also, as a tissue to nourish the ovule during its development. The walls of the ovule are in two layers, called coats or *integuments.* A tiny pore or *micropyle* leads through the integuments on the lower side to the interior of the ovule. Inside of the walls is an oval area or *embryo sac* containing eight nuclei. Three of these nuclei are situ-

POLLEN GRAINS



Fertilization in a Flower. I. Growth of the pollen tube down the style. II. Fertilization taking place in the ovule.

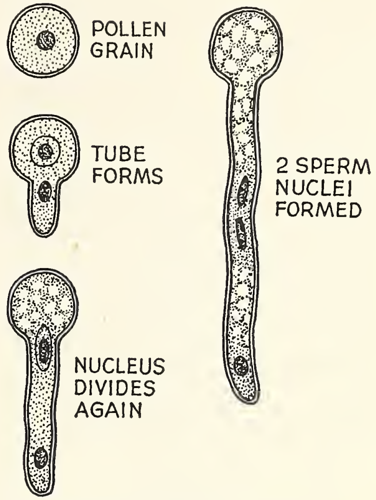
ated in each end of the embryo sac, with the remaining two near the middle. The two near the middle are termed *polar bodies* and unite, before fertilization, to form a single *endosperm nucleus.* The other six nuclei, likewise, have names, although only one, the *egg cell* is important in fertilization. This *egg cell* is the center nucleus at the lower end (nearest the micropyle) of the embryo sac.

Growth of the pollen tube and fertilization. To accomplish *fertilization,* the content of a pollen grain must reach the ovule. Pollination resulted in pollen reaching the stigma of the pistil. At this point, an interesting process occurs.

Each pollen grain resting on the sticky stigma surface is stimulated to form a downward growth through the soft tissues of the style. This *pollen tube* as it is called resembles, somewhat, a tiny root as it pushes its way downward toward the ovule below. During the growth of the pollen tube, the tube nucleus follows close behind the lengthening tip. The generative nucleus, likewise, moves through the pollen tube and divides, on the way down, to form two oval bodies called *sperms.* The pollen tube grows down the style to the ovary, where it enters the ovule through the micropyle and penetrates the embryo sac. At this point, the end of the tube dissolves and the two sperms enter the embryo sac. One unites with the egg, near by, while the other unites with the endosperm nucleus. The union of an egg and a sperm is termed *fertilization.* Since two sperms and an egg and an endosperm nucleus are involved in the flower, the process is called *double fertilization.*

One pollen grain is necessary to fertilize each ovule. Consequently, flowers containing large numbers of ovules require an equally large number of pollen grains to fertilize all of the ovules. Furthermore, ovules of one particular kind of plant can be fertilized only by sperms from pollen grains of the same species.

A fertilized egg is termed a *zygote* [*zy'goat*]. Immediately after the zygote is formed, it begins to grow within the ovule. It will soon give rise to an embryo or young plant which is ready to sprout from a seed as a new individual of its kind.



STAGES IN THE DEVELOPMENT OF THE POLLEN TUBE

With fertilization accomplished, the flower has served its purpose. The petals fall away and the stamens wither. Only the ovary of the pistil remains. This ovary develops into a fruit and encloses the ovules which by now have become ripe seeds.

Observing flowers. Wild flowers contribute much to the joy of being out of doors. Wherever a person goes, along a stream, through the woods, into the fields, high into the mountains, or deep in the valleys, floral beauty invites attention.

The succession of blooming flowers continues from the early spring until late fall. Even the inconspicuous wind-pollinated flowers of many of the trees, which appear in March or April before the leaves, are fascinating to observe.

One of the best ways to learn the flowers of native plants is to observe their seasonal appearance and to keep a list of those found. This list should include not only the names, but the habitat of the plant and the date on which the flowers were blooming. Through study of this sort, one soon learns which flowers to expect in the spring, which will bloom during the summer and which species will be at their best in the fall. Wherever you may live, interesting plants produce their flowers throughout the seasons, and add their natural beauty to the landscape.

A flower collection can be made easily by gathering specimens of the flowers and leaves and by pressing them between absorbent papers. Change the papers (newspapers will do very well) each day until the specimens are thoroughly dried. They may then be mounted in a scrapbook or on cardboards by fastening them with short strips of scotch tape or adhesive tape. Each specimen should be labeled in ink and should bear the name of the plant, habitat, place collected, and date of collection. Numerous books are available in your library which will assist you in the identification of native plants by means of their flowers.

In collecting wild flowers, trees, and shrubs, one should be very careful not to pull up or otherwise destroy valuable plants. Leaves are frequently necessary in identification and should be collected with the flowers, but plants should not be uprooted unless they are abundant at the collecting spot.

The beauty of our native flowers has led to the extermination of many plants. One such flower, the lady's slipper which has several species in certain parts of the United States, is a curious and very lovely member of the orchid family. It is exquisite to see and once grew in large numbers in the hilly sections of the eastern states. Now, a lady's slipper is such a rare occurrence that very few people have seen one in recent years. In every region there are many other examples of flowers which have already been exterminated or are so rare that to find them is an unusual occurrence. If, in your collecting you should happen to find one of these rare plants, or if you think it is uncommon in the vicinity, admire it in its native haunt, but do not pick it or dig it up. Do all that is possible to preserve it, and others like it. Perhaps future generations will be more fortunate in having more of these interesting plants because of our present appreciation of, and attitude toward, conservation.

Summary

A flower is a specialized organ of a seed plant, modified to carry on reproduction. It is limited to the highest group of seed plants, known as the Angiosperms.

A complete flower is composed of four sets of parts, the sepals or calyx, the petals or corolla, the stamens, and the pistil. Only the stamens and pistil function directly in reproduction, the other parts serving merely to protect the essential parts or to attract insects for the purpose of pollination.

Many plants produce imperfect flowers, containing either stamens or pistils only. Plants bearing both types of imperfect flowers are called monoecious, while imperfect flowers are borne on separate plants in the dioecious species.

Stamens produce pollen grains in pollen sacs contained in anthers. During pollination, pollen grains are transferred from the stamen to the stigma of the pistil. The function of pollen is the production of two sperms which reach the ovule through a special pollen tube.

The base of the pistil, called the ovary, develops one or more ovules. An inner region of the ovule, the embryo sac, contains seven nuclei at the time of fertilization. Two of these nuclei, the egg and the endosperm nucleus, receive sperms during fertilization.

Following fertilization, the petals and stamens wither, leaving only the pistil. The ovary then develops into a fruit, enclosing the matured ovules or seeds within it.

Using Your Knowledge

1. How does vegetative multiplication differ from reproduction by means of flowers?

2. How do Gymnosperms differ from Angiosperms both in the manner in which seeds are produced and in the characteristics of the seeds?

3. What parts must be present if a flower is termed complete?

4. Distinguish between essential and accessory parts of a flower.

5. Explain what is meant by the term monoecious and give an example of a monoecious plant; a dioecious plant.

6. Define pollination.

7. Name three distinctly different agents of pollination.

8. Distinguish between self-pollination and cross-pollination.

9. Explain how pollination may be carried on artificially and why it is done.

10. In what sense is fertilization in the flower double fertilization?

11. Discuss the maturation of the pistil after fertilization to form the seeds and fruit.

12. Name the parts of the flower which have no function after fertilization.

Expressing Your Knowledge

vegetative	style	intine
naked seed	ovary	generative nucleus
peduncle	complete	tube nucleus
receptacle	incomplete	sperm
sepal	perfect	ovule
calyx	imperfect	placenta
petal	staminate	integument
corolla	pistillate	micropyle
perianth	dioecious	embryo sac
essential part	monoecious	polar body
accessory part	self-pollination	egg cell
stamen	cross-pollination	endosperm
anther	artificial pollination	embryo
filament	allergy	pollen tube
pistil	pollen	double fertilization
stigma	extine	zygote

Applying Your Knowledge

1. Obtain a large flower and dissect it carefully. See how many of its parts you can identify.

2. Dissect a staminate flower and find out why it never produces seed.

3. Mount several different kinds of pollen grains on a glass slide in a drop of water. Examine them under the microscope. How do the various grains differ in form and size?

4. Select a particular flower and examine it daily from the time it opens until the fruit has developed. Make a record of daily changes which occur.

5. Prepare a list of native flowers of your vicinity which are rare and need protection.

Chapter 17

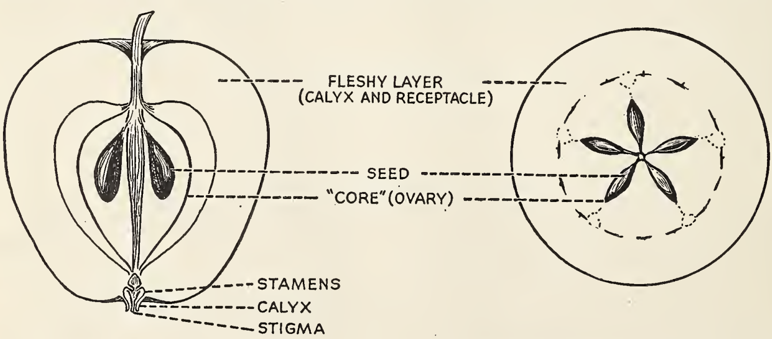
Fruits and Seeds—the Climax of Plant Reproduction

The cherry tree, white with spring blossoms, turns red in the early summer as its fruit matures. The pink of milkweed flowers gives place to green pods which finally turn brown and split open, filling the air with dainty, white parachutes. The red and golden apples in the orchard offer quite a contrast to the soft, pink blossoms of spring. Such is the transition from flower to fruit. Such are the changes in nature as flowers give up their brief existence when the fruit begins to grow.

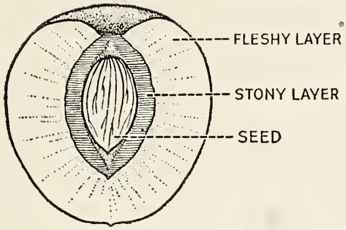
To the biologist, "fruit" includes much more than the cherries, peaches, oranges, and strawberries of the market stand. The kernels of corn, the nuts of hickory, the pods of the bean, and the sticky burrs of burdock are just as much fruits as the fleshy, juicy types. Regardless of what we may call them, all of these fruits originate from flowers, contain seeds, and serve the same purposes to the plant.

Vegetation travels by scattering seeds The plants of our fields and woodlands, unable to move about, must thrive or perish in the spot in which they grow. But through the mechanics of seed distribution, new plants may by chance find ideal places in which to grow, thus compensating for the less fortunate individuals of their kind.

Development of fruits and seeds. Fertilization marks the end of activity of the flower and the beginning of the development of the fruit and the seed. Immediately after the union of sperms from the pollen grain with the egg and endosperm nucleus of the ovule, a remarkable period of growth begins. The full energies of the plant are poured into development of the ovule as well as the surrounding tissue of the ovary. The re-



Longitudinal and Cross-Sectional Views of an Apple. This is a pome type of fruit.



Longitudinal Section of a Peach. This is a drupe type of fruit.

sult, usually after several weeks of rapid enlargement, is the mature fruit and seed. The growth of the ovary is accompanied in many plants with the enlargement of other near-by parts, especially the calyx and receptacle. When these parts enlarge, they become part of the fruit. A *fruit* may be defined, then, as a *ripened ovary with or without associated parts.* The *seed,* on the other hand, is a *ripened ovule* enclosed in the protective covering of the fruit.

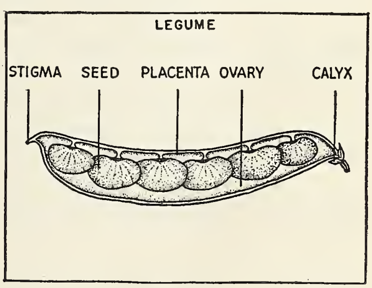
Functions of fruits. Important among the functions of the fruit is the protection of seeds from water loss and against damage from insects and disease. It serves, also, as a device for seed distribution, a function for which fruits of different plants are curiously modified. The wings of maple seeds, silken tufts of the dandelion, and the tempting pulp of the cherry and peach, are adaptations of fruits for seed distribution.

Structure of typical fruits. Fruits, like the flowers from which they develop, vary greatly in structure. As examples of familiar fruits, we shall use the apple, the peach, and the bean.

The apple is especially interesting since it involves more than the ovary and enclosed ovules in its development. The ovary in an apple blossom lies deep in the receptacle of the flower stalk, resulting in a prominent swelling below the calyx. As the fruit matures, the ovary as well as the tissues of the receptacle and calyx enlarge. The result is an outer fleshy layer formed from the calyx and receptacle, an inner core with a papery wall formed from the ovary, and the ripened seed or ovules within. An apple sectioned lengthwise or crosswise will show these parts clearly. At the blossom end, the dried remains of the sepals, stamens, and, sometimes, of the style and stigma, are visible. A fruit of this type is called a *pome* and includes, in addition to the apple, the quince, and pear.

The peach illustrates another type of fruit called a *drupe* or *stone fruit.* Here, the ovary wall ripens in two layers — an outer, fleshy layer and an inner layer which is extremely hard. The outer layer becomes the edible portion of the fruit, while the inner layer forms the familiar stone or pit. One or two seeds lie in a chamber within the hard wall of the pit. Other familiar stone fruits or drupes include the plum, cherry, apricot, and almond. In the case of the almond, however, the fleshy outer wall is discarded and the hard inner wall cracked open to obtain the edible seed.

The bean is a type of many seeded fruit called a *pod* or *legume.* At the stem end may be found the remains of the calyx. The bulk of the pod is the ovary; the pointed tip is the style, on which the stigma may sometimes be found as a



Lima Bean. A legume type of fruit.

Ewing Galloway, N.Y.

MILKWEED POD. The fine hairs attached to each seed act as agents of wind dispersal.

tiny knob. The " string " is a vascular bundle bringing nourishment to the seeds attached along one side of the pod. The point of attachment of each is a *placenta* and the scar left on the seed when it is removed is called the *hilum*. The bean, and other pod fruits like the pea, red bud, and locust, is green until it matures, after which it dries out and finally splits open.

Classification of fruits. In classifying the various kinds of fruits, the first distinction is made in the structure of the ovary wall. It is either *fleshy* or *dry* when mature. Fleshy fruits include the apple, pear, cherry, orange, and banana, while the bean pod, iris capsule, hickory nut, and the winged fruit of the maple are classified as dry fruits.

Dry fruits may be classified further as *dehiscent* or *indehiscent,* depending upon whether they split open of their own accord when ripe. The milkweed pod and iris capsule are familiar examples of dehiscent fruits since they open at maturity and discharge their seeds. They are quite different from indehiscent fruits like the hickory nut and grain of corn which, while fruits and not seeds, do not open when ripe.

A complete classification of fruits would be quite an involved undertaking because of the great numbers and varieties involved. The more familiar types may be classified as follows:

CLASSIFICATION OF FRUITS

Type	Structure	Examples
	FLESHY FRUITS	
Pome	Ovary forms a papery core containing seeds. Outer fleshy layer developed from the calyx and receptacle	Apple, quince, pear
Drupe or stone fruit	Ovary ripens into two layers. Outer layer fleshy; inner layer hard, forming a stone or pit, enclosing one or more seeds	Plum, cherry, peach, olive, almond
Berry	Entire ovary becomes fleshy and often juicy. Thin-skinned and containing numerous seeds	Tomato, grape, gooseberry
Modified berry	Like berry, but with a tough outer covering	Orange, lemon, watermelon, cucumber
Aggregate fruit	Compound fruit composed of many tiny drupes clustered on a single receptacle	Raspberry, blackberry

Accessory fruit	Edible portion formed from the enlarged stem receptacle. Fruits small and hard; scattered over the surface of the receptacle	Strawberry
Multiple fruit	Compound fruit formed from several flowers in a cluster	Mulberry, pineapple
	DRY FRUITS (DEHISCENT)	
Pod	Ovary wall thin, fruit single chambered, containing many seeds. Splits along one or two lines when ripe	Bean, pea, milkweed
Capsule	Ovary containing several chambers and many seeds; splits open when mature	Poppy, iris, cotton, lily
	DRY FRUITS (INDEHISCENT)	
Nut	Hard ovary wall enclosing a single seed	Hickory nut, acorn, pecan
Grain	Thin ovary wall fastened firmly to single seed	Corn, wheat, oats
Achene	Similar to grain but with ovary wall separating from the seed	Sunflower, dandelion
Winged fruit or samara	Similar to achene but with a prominent wing attached to ovary wall	Maple, ash, elm

Seed dispersal. When seeds mature, they become separated from the parent plant by one means or another. The scattering or distribution of seeds is called *dispersal.* Sometimes only the seed is transported, while at other times the entire fruit is carried to a new location. Seed dispersal results in the establishment of plants in new localities and is the only method by which plants are able to migrate. Chance alone determines where a seed may fall — whether the new plant will thrive in its surroundings or die in an unfavorable environment. The large number of seeds produced by a single plant compensates, however, for this chance dispersal of seeds.

Seed dispersal may be accomplished by purely mechanical means, or it may require outside agents like the wind, water, birds, or other animals. Pods and capsules open when ripe, frequently with considerable force. The ovary walls spring apart suddenly, throwing the seeds a considerable distance from the plant. Capsules like the poppy do not split along the sides, but form holes around the top when mature, much like a salt shaker. As the capsules sway in the breeze at the top of long stems, seeds sift out.

Wind acts as an agent of seed dispersal in many other ways. Seeds of maple, elm, ash, and pine are equipped with wings which cause them to sail through the air with a propeller-like motion, frequently for considerable distance. Even more suited for riding through the air are the tufted fruits of the milkweed, thistle, and dandelion which may be carried great distances on their tiny parachutes. The open fields where these plants grow are ideal places for the dispersal of seeds by wind, because they are usually unbroken by tall trees or shrubs.

The delicious flesh of the apple, grape, or cherry is a sort of biological bribe.

The seeds of such fruits are indigestible and so are likely to be discarded far from the parent plant. The fondness of squirrels for nuts has resulted in the planting of innumerable nut trees in our forests. Squirrels frequently bury nuts for future use and fail to dig them up — thus not only dispersing the seeds but planting them as well. Hickory and walnut trees especially are often planted in this manner.

Seeds of fruits of many plants like the burdock, tick trefoil, and "pitchforks" are equipped with hooks which become entangled in the fur of passing animals. They may thus travel great distances before being shaken off. One who hikes during late summer or fall is very apt to assist in the dispersal of these hooked fruits as he stops from time to time to remove a collection of burs, "pitchforks," and "beggar's lice" from his clothing.

A considerable number of plants are dispersed by having fruits that float on river, lake, and ocean currents to favorable places along the shore. Sedges and coconuts are examples of this type of water dispersal.

Civilization has provided other means of dispersal in the form of automobiles, railroad trains, and airplanes. By means of these devices, seeds are frequently carried far from their parent plants. Biologists have found railroad tracks to be extremely interesting areas for plant collecting. The railroad right-of-way often supports a strange assortment of plants from the eastern woodlands, the Midwestern prairies, and the Far West — the result of seed dispersal by transcontinental trains.

The Structure of Seeds

The reproduction of a whole plant by a seed is so common that the wonder of it is often overlooked. The beginnings of the full-grown future plant, together with nourishment to start growth, must exist in the seed, and in a living condition. Also, there must be sufficient protection to prevent these tissues from drying up. The *seed* is a young plant which consists of three parts: the *embryo, stored food,* and *protective coverings.*

Seed coats. The outer covering of most seeds, the *testa,* is usually thick enough to protect them from injury by contact, moisture, or insects. A second inner thin coat (*tegmen*) is usually present.

Since the seed was once a part of the parent plant, it bears a scar on the testa, called the *hilum,* which marks the point of previous attachment. Near this scar is usually visible a tiny opening called the *micropyle,* from two Greek words meaning "little door." This little door has two uses; through it the pollen tube enters the ovule when it is fertilized (see Chapter 16) and from it, in certain seeds, the first sprout of the young plant emerges when it begins its growth. Most seeds, however, burst the seed coats in germination.

Kernel. Within these coats is the kernel or seed proper. It may consist wholly of the undeveloped plant (embryo); or may have, *outside* the embryo, a store of nourishment called the *endosperm.*

Embryo. If endosperm is present, the embryo may be poorly developed, even showing no sign of its usual parts, as in the orchids. On the other hand, the embryo may be highly developed and show well-defined stem and leaves, as in the bean. The embryo, or miniature plant, consists of three parts: one or more *cotyledons, plumule,* and *hypocotyl.*

Cotyledons. These are the seed leaves or the first leaves of the plant, and though often they do not resemble ordinary leaves either in appearance or use, still they play an important part in the early growth of the seedling. They may be leaflike and come up when the plant begins to grow, forming true green leaves, as in the squash. In this case they are thin and have little stored food, because they get all they need as soon as they rise above the soil.

On the other hand the cotyledons may be so well supplied with food that they cannot act as leaves at all, merely coming above ground, giving over their stored food to the growing seedling, and then withering and dropping off, as is the case with most beans. In other cases, such as the pea, the cotyledons are not lifted from the soil at all, and so supply the plant from their place in the ground below. In cases where the food is stored outside the embryo as the endosperm, the cotyledon often remains in contact with it to digest and transfer food from endosperm to embryo, as is the case in corn.

Not only do the cotyledons vary in size and use, but also in number. The seeds of monocotyledons, such as corn, grasses, lilies, and palms possess only one cotyledon. Dicotyledons like the bean, squash, apple, and buttercup have two. Pines and other gymnosperms have more than two cotyledons.

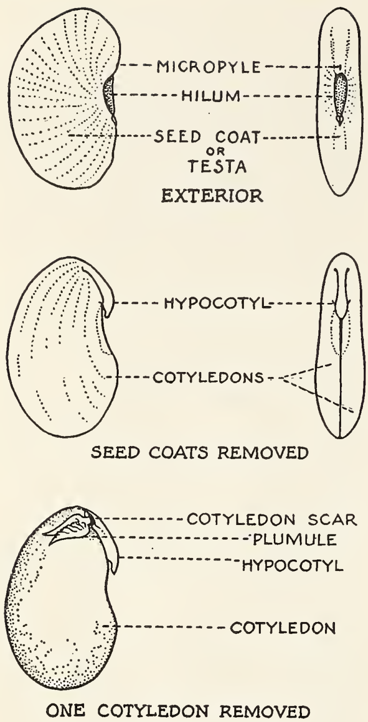
Plumule. The *plumule* is that part of the embryo above the cotyledons, from which develops the shoot proper, consisting of stem, leaves, and flowers. It may vary greatly in size and development. If much food is stored, either in cotyledons or endosperm, the plumule may be small. On the other hand, if little food is provided the plant must early shift for itself, and so the plumule may have several well-formed leaves, wanting only exposure to light to become a self-supporting plant.

Hypocotyl. The primitive stem, or all that part of the embryo below the cotyledons, is the *hypocotyl.* From its lower end the root system develops. Upon its upward lengthening depends whether the cotyledons shall emerge from the soil when germination takes place.

Endosperm. Though the endosperm is usually present at some stage, it is not found in all seeds when they are mature. In such cases the function of food storage is performed by the cotyledons. The endosperm is, however, very important in many seeds, especially the grains. Its ample store of starch also provides an important food supply for man.

Nutrition in the embryo. Laboratory tests show that the stored food of seeds consists largely of starch, together with considerable protein, a little fat or oil, and some mineral matter. Thus the seed has within itself all the nutrients, except water, needed for the growth of the miniature plant, or embryo. The seed must get water from the soil before it can grow.

The growth of a seed is a wonderful process. Though inactive, dry, and apparently dead, the protoplasm is really alive and only awaits favorable conditions for growth. The insoluble, stored foods must be digested by the embryo, made soluble, united with the water which has been absorbed from the soil, and assimilated, to form all the new kinds of tissue in the growing seedling. It may seem strange to speak of a seed as digesting food, but there is an enzyme (*diastase*) in the seed which digests its food just as truly as fluids of our stomach digest our food. Here, then, are digestion, absorption, and assimilation going on in the seed as it begins to grow. The



Structure of the Bean Seed

foodstuffs stored in the seed are normally in a dry and insoluble form, otherwise they would start to grow or would dissolve and decay. Therefore, if seeds are kept over winter or longer, they must be dry.

Variation in seed structure. Each seed differs somewhat from the general description just given; the parts of the embryo may be poorly developed; the number of cotyledons may vary; and the endosperm may be large or lacking altogether. However, there are three things which every seed possesses, namely, the embryo, stored food, and protective coverings. These are often very different in structure and adapt the seeds to various surroundings.

The bean is presented as a type of dicotyledonous seed without endosperm, while the corn is taken as a type of monocotyledonous seed in which there is a very large endosperm.

The bean: external structure. This familiar seed is usually kidney-shaped or oval in outline, several being borne in a pod, which is the true fruit of the plant.

The testa is usually smooth and may be variously colored; on the concave side is the hilum, marking the place where it was attached to the pod. Through this attachment it received nourishment from the parent plant.

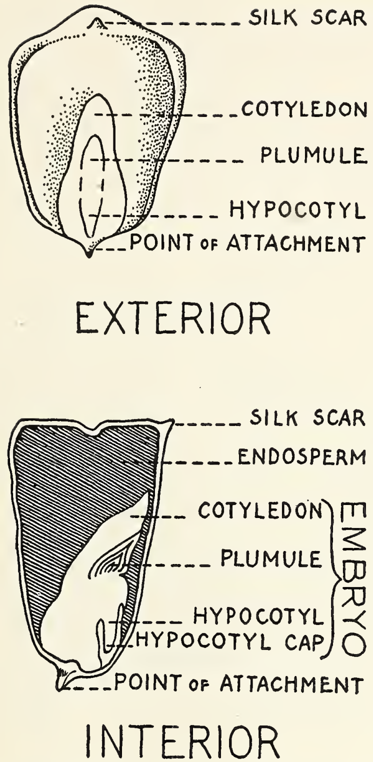
Near the hilum is the micropyle. Toward this there sometimes extends a ridge showing the location of the hypocotyl, which is directly beneath it, which will emerge here on germination. The tegmen is a very thin white skin and often cannot be separated from the testa.

The bean: internal structure. When the seed coats have been removed only the embryo will be seen, since there is no separate endosperm. All the nourishment is stored in the cotyledons which are large, not at all leaflike, and contain much protein and starch.

The hypocotyl is seen as a finger-like projection, fitting into a protective pocket in the seed coats. To it the cotyledons are attached on either side.

By removing one " half " of the bean (one cotyledon), the plumule is exposed, attached to the hypocotyl above the cotyledons and closely packed in between their ends. It is fairly well developed and can be seen to consist of two small leaves with well-marked veins, folded over each other.

It will be noted that the upper end of the hypocotyl is the one point where all three parts of the embryo are united. When the cotyledon is removed, a scar



STRUCTURE OF THE CORN SEED. Why does iodine turn the endosperm blue-black?

showing its place of attachment is left on the side of the hypocotyl.

Corn: external structure. The corn grain, or "seed" as it is usually called, is really a *fruit* corresponding to the bean pod, rather than to the bean itself. One seed completely fills the fruit, so that the seed coats and fruit coats cannot easily be distinguished in the grain of corn.

As a result, the hilum and micropyle are covered by the fruit coats and what might be mistaken for the hilum is really the point of attachment of the corn fruit to the cob.

On one side of each grain can be seen

COMPARISON OF TYPICAL DICOTYLEDONOUS AND MONOCOTYLEDONOUS SEEDS

Bean	*Corn*
Has testa with hilum, and micropyle plainly visible	Hilum, etc., covered by fruit coats
Two cotyledons	One cotyledon
Large embryo	Small embryo
No separate endosperm	Large endosperm
Plumule fairly large	Plumule rather small
Plumule leaves folded	Plumule leaves rolled
The fruit a pod, with many seeds	The fruit a single grain, with one seed

a light-colored, oval area, which marks the location of the embryo, visible beneath the coats. On the same side, but at the end opposite the point of attachment, is located a tiny point, the *silk scar,* where the corn "silk" formerly grew.

Corn: internal structure. Internally the corn consists of a large endosperm, containing much starch, protein, and some oil, and at one side near the point of the grain, a much smaller part, the embryo.

This embryo has only one cotyledon, a rather irregular, oval structure, wrapped around the plumule and hypocotyl, and lying in close contact with the endosperm. Its function is to digest and distribute to the growing seedling the food stored in the endosperm. Because it makes the food soluble it is as truly a digestive structure as is an animal's stomach or intestine.

The hypocotyl of the corn is a small pointed organ, aimed toward the attached end of the grain. It is covered with a cap which protects it as it passes through the soil when the root begins to develop.

The plumule is also protected by a sheath or cap, and consists of several very small leaves rolled, not folded, into a compact " spear " which can safely push upward through the earth.

Fruits and seeds — their importance to man. Our study of fruits and seeds has centered around their biological importance as reproductive structures of the plant. Fortunately, plants produce fruits and seeds in a quantity sufficient to maintain their reproduction and, in addition, to supply the needs of a large portion of the animal kingdom as well. Wild birds and animals, domesticated farm animals, and man himself, rely upon fruits and seeds as a principal source of food.

The importance of fruits and seeds to man led to the first cultivation of plants. No one knows just when man began this cultivation. However, it must have been during the prehistoric period. Wheat was found in the Pyramids, built during the early Egyptian age. When the white man first came to North America, he found a pecular kind of grass called Indian corn which the Indian tribes cultivated. From this first Indian corn, new, more productive strains were developed. Today, highly developed strains of field and sweet corn are grown as major crops in large sections of America.

From the fields and orchards of our land, fruits and seeds flow to the markets in an endless stream. From these valuable plant products, modern America obtains much of its food supply, valuable oils, vitamins, and substances for the manufacture of plastics and countless other articles of commerce.

In this modern age, when fruits are shipped great distances in order to get to the purchaser in the best condition, specially constructed refrigerator cars are used. The cars are iced at regular stations during the trip, and the fruit remains fresh for many weeks. This procedure insures good fruit for the buyer.

Summary

Fertilization in the flower results in the rapid development of the fruit and seed. The maturing ovary becomes the fruit, sometimes including other parts such as the receptacle or the calyx.

Fruits are either fleshy or dry, depending upon the structure of the ovary wall. Dehiscent dry fruits burst open of their own accord when mature, thus discharging the seeds. Indehiscent dry fruits do not open, but decompose after dispersal and release the seed from its confinement within the ovary wall.

Fruits, and in some cases seeds, are dispersed from the parent plant to new places. Only during the fruit and seed stages are most plants able to travel to new localities. Seeds may be dispersed directly from the parent plant by the opening of the fruit with force sufficient to throw them considerable distance. Other plants require wind, water, birds, or other animals as dispersal agents.

The seed is the final product of plant reproduction since it contains the embryo plant. A seed consists of three main parts: the embryo, a store of nourishment called the endosperm, and protective coats, the outer of which is called the testa. The seed is an independent unit capable of germinating immediately or of remaining dormant for long periods, thoroughly protected by the seed coats.

Using Your Knowledge

1. Explain the relation between the flower and the fruit.

2. State at least two purposes which the fruit serves the seeds which it encloses.

3. A bean is a seed, while a kernel of corn and a sunflower "seed" are fruits. Explain.

4. Explain how fruits are classified on the basis of the structure of the ovary wall.

5. Describe various modifications for dispersal of fruits by the wind.

6. Describe modifications of fruits for dispersal by animals.

7. Account for the fact that many unusual plants are found along railroad right-of-ways.

8. What are cotyledons, and what purpose do they serve?

9. What structure in the corn seed replaces the cotyledon as a region of food storage?

10. Explain how seed plants are classified on the basis of cotyledon structure.

Expressing Your Knowledge

fruit	accessory fruit	dehiscent
seed	multiple fruit	indehiscent
fleshy fruit	pod	dispersal
dry fruit	legume	testa
pome	placenta	hilum
drupe	capsule	micropyle
tegmen	nut	cotyledon
berry	grain	endosperm
modified berry	achene	plumule
aggregate fruit	samara	hypocotyl

Applying Your Knowledge

1. Make a collection of seeds and fruits distributed by the wind, arrange them in a Riker or similar mount, and label them. Do the same with seeds and fruits possessing hooks.

2. Visit a well stocked fruit store and make a list of the different kinds of fruits shown there. Try to get some information from the fruit dealer concerning the region in which each fruit was grown.

3. Prepare a collection of seeds which are used by man for food.

4. Examine a number of bean or pea pods to determine variation in the number of seeds which have matured. Select very ripe pods for best results.

5. Pulverize some seeds which seem to be entirely dried out. Heat them in a test tube and test for water, which will condense on the sides of the tube during heating.

Chapter 18

Seed Germination—Reproduction Accomplished

Great oaks from little acorns grow. Such are the marvels of seed germination. A forest of mighty oaks is a sight to behold, but when you consider that at one time you could have carried the entire forest in your pockets, nature becomes even more wonderful.

The protoplasm which a seed contains is like the plant which produced it. It is capable of growing into another plant of its kind. While seeds may appear lifeless, they are by no means dead. The protoplasm they contain is in a state of rest, waiting only for favorable conditions to awaken and begin growth activity.

You have learned that a seed is really a tiny plant packed with a supply of food inside of protective covers. The growth of the new plant from the seed is called *germination*. You will learn, in this chapter, how the tiny, new plant pushes its first root into the soil and bends its crown upward to escape from the seed coats and to take its place in the vegetation of the earth.

Dormancy in seeds. During the resting stage, seeds may endure conditions which would have been fatal to the parent plant. Drought, cold, or heat do not injure the tiny plant enclosed within the protective seed coats. Throughout unfavorable conditions for growth, seeds remain dormant. Favorable conditions bring an end to dormancy and the resumption of active life or germination.

The period of dormancy may vary from a few days to several months or even years, depending upon conditions outside of the seed and the kind of seed involved. Some years ago, a story was circulated that grains of wheat found in the Pyramids were still alive and capable of germination. Such a report was never verified and, as far as biologists are concerned, is just good newspaper reading.

Some seeds, like the maple, germinate almost immediately, forming a characteristic group of maple seedlings beneath the parent tree in the late spring. In the case of annuals growing in colder climates, seeds are the only form in which the plants survive the winter months. Hence, the period of dormancy must extend from one growing season to the next. The seeds of many perennial plants, likewise, rest through the winter months and germinate the following spring or summer. Foresters have found that cold weather increases the percentage of germination of seeds of the tulip tree or yellow poplar.

The ability of seeds to germinate after dormancy is called *viability*. Seed viability depends upon the conditions during dormancy, and upon the amount of food stored in the cotyledons and endosperm. Cool, dry places are ideal for storing seeds artificially. Warmth and moisture during dormancy lower viability considerably. Viability tests, conducted prior to the sale of seeds commercially, determine the percentage of germination one may expect from a certain lot of seeds. These tests consist, merely, of selecting a representative sample of seeds and sprouting them under normal conditions for germination. If 90 out of 100 seeds germinate, the viability is 90 per cent.

Conditions for germination. For the germination of most seeds, at least three conditions are required. These are: moisture, heat, and air (oxygen). The amount of each of these external factors necessary to induce germination varies widely in different kinds of plants.

Seeds of water plants will germinate under water, while desert plants retain enough of the scant dew of the desert night to awaken the seed into growth. Usually a moderate supply of water is ideal for seed germination. Prior to germination, seeds absorb considerable quantities of water and swell to several times their original size. This intake of water results in softening the seed coats which is necessary for growth to begin. Too little water may fail to induce germination, while too much water may cause the seed to rot.

The temperature at which seeds germinate best is, likewise, extremely variable. A maple seed will germinate on a cake of ice. Just as some seeds germinate best during cooler weather, others require heat. Temperatures ranging from 60° to 80° F. are, however, ideal for most seeds.

The beginning of activity in the seed brings about important food changes. Stored food is digested and oxidized. It supplies the young plant with the energy necessary for rapid growth. This activity requires a corresponding increase in the rate of respiration within the seed. During this period, the air (oxygen) supply is critical. Seeds deprived of sufficient air cannot undergo even the first stages of germination.

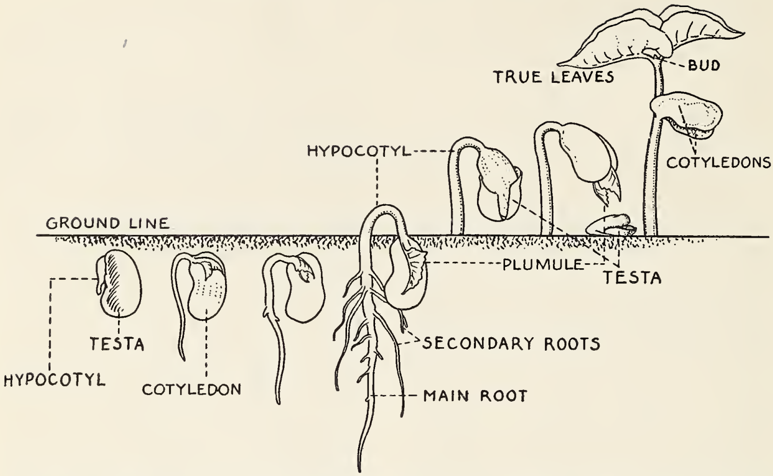
Some seeds require still other conditions for germination. The role of certain fungi was discussed in Chapter 6 in relation to the roots of beech trees and certain orchids. These plants, as a rule, require these same organisms for seed germination. Orchid seeds were almost impossible to germinate commercially in greenhouses until a process for sprouting them among the strands of certain kinds of molds was discovered. Now they are germinated in peculiar flasks and look like mold or bacteria cultures.

With sufficient moisture to soften the seed coats, sufficient heat to stimulate the protoplasm to activity, and sufficient air to supply the oxygen required for oxidation of the stored food, the new plant emerges from the seed and begins its independent existence. The manner in which the young plant emerges from the seed and establishes itself in the ground is most interesting.

Stages in germination. Germination consists of three steps: (1) emergence from the seed coats, (2) penetration of the soil, and (3) the obtaining of nourishment.

The hypocotyl appears first, frequently emerging by way of the micropyle. The rest of the embryo follows by various methods which enable the seedling to escape uninjured from the testa, on whose protection it has depended for so long.

Penetration of the soil may be either from above or from below. When seeds are scattered on the surface of the soil they are enabled to gain a foothold in the earth by various contrivances so that the roots may be sent down into the soil. In the case of buried (planted) seeds the process of penetration not only has to do with sending down roots, but the plant must find a way out of the earth, unharmed by its passage. The latter is accomplished most often by the young plant being started from the seed in an



STAGES IN GERMINATION OF THE BEAN. The second, third, and fourth stages have been drawn with one cotyledon removed to show the growing plumule.

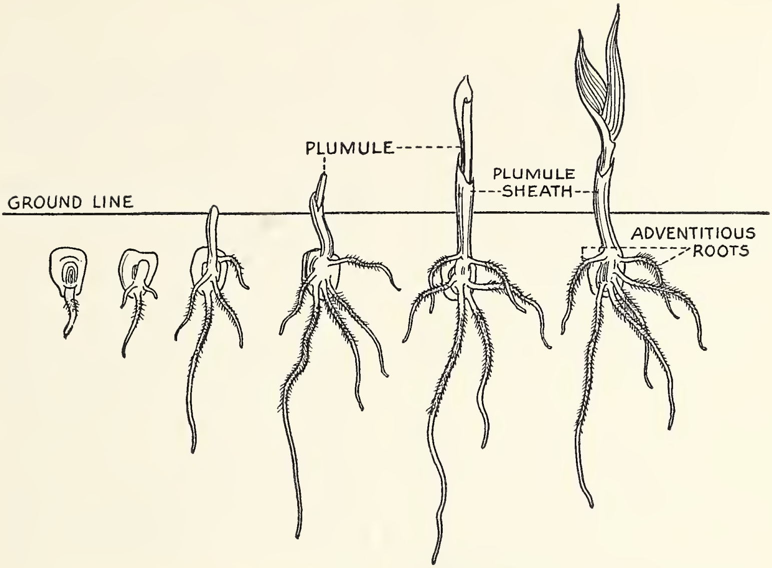
arched position. One end of the arched hypocotyl takes hold of the ground and sends out roots, while the other, attached to the wide cotyledons or the delicate plumule leaves, gently pulls these through the ground after the growing arch has broken a way to the surface. If forced directly upward these appendages would be stripped off by the pressure of the soil.

This arch may be caused by the weight of the cotyledons and soil (as in the case of the bean), which hold back the bulky end of the young plant until the stem is strong enough to lift it out of the ground, or (as in the case of the pea) by the tip of the plumule being held tightly between cotyledons that are not lifted from the ground at all. In the latter case the hold of the cotyledons weakens after their store of food has been partly exhausted and the plumule is released.

Another method of penetrating the soil is found in the corn and usually in those plants whose first leaves are long and slender. In these cases protection is secured by the leaves being tightly rolled into a point and covered by a cap, so that they pierce the soil directly, thus meeting less resistance and securing safety.

The lifting force of germinating seeds is seldom noticed, but is very great. Masses of earth many times their weight are lifted by our garden seedlings as they force their way through the hardest soil.

The last and most important step in germination is the establishment of the young plant in its new environment. In describing this process it is necessary to deal with the development of each part of the embryo by itself. The hypocotyl first penetrates the testa. Protected by its root cap, and directed downward by gravitation, it begins at once the production of the primary root from its lower end. From this, in turn, the whole root system rapidly develops. The region of growth is just back of the tip, which, protected by the cap, is safely pushed downward into the earth.



Stages in Germination of the Corn

The cotyledons, as before explained, may rise above ground if the hypocotyl lengthens upward, or if not may remain below. In either case they act as a source of food for the seedling. The development of the plumule usually attracts most attention since from it arise the leaves, stem, and later, the flowers and fruit. It constitutes the shoot of the plant.

The first organ to develop in germination is the root, because the function first required by the seedling is absorption, which the root performs.

Sprouting seeds in the laboratory. The stages of germination may be observed at firsthand by sprouting seeds under special conditions in the laboratory. Seeds of corn, bean, pea, or radish germinate readily when given favorable conditions. Lay the seeds between layers of moistened blotting or absorbent paper and place them in a covered dish. Put the dish in a warm, dark place for several days. After the appearance of the hypocotyl, examine them daily. Seeds grown between blotters show root development especially well, although stem development may be abnormal.

To show development above the ground, plant the seeds in a shallow container filled with sandy soil, sawdust, or peat. Water daily and cover them to prevent drying out between watering periods. After a few days, the shoots will appear and the unfolding of the first leaves may be observed. Bean seedlings will show a hypocotyl arch and cotyledons, while corn seedlings will show quite a different type of growth with the plumule enclosed in a protective sheath. In planting your seeds you need have no fear in planting them upside down. Normal responses of the root will send it downward, while the shoot will invariably grow upward, regardless of the position of the seed.

Summary

The development of the plant from the seed is termed germination. It occurs usually following a period of rest or dormancy which may vary from a few days to several months. The viability or ability of the seed to germinate following dormancy depends, to a great extent, upon the external conditions during the dormant period. In nature, these conditions may be the cold of the winter months. Seeds stored artificially should be kept in a cool, dry place.

Germination is induced by ideal growing conditions. Water is necessary for the softening of the seed coats. In the early stages of germination, seeds swell to several times their original size because of water absorption. In the case of most seeds, temperatures ranging from 60° to 80° F. are ideal for germination. Air is essential for the supply of oxygen to the seed for carrying on respiration. The energy requirements for growth and other activities necessitate rapid oxidation of the stored food.

Germination begins with the pushing of the hypocotyl through the seed coats. The lower end of the hypocotyl develops the first root, while the upper end forms the plumule or young shoot. Until established in its new location, the seedling lives on the stored food in the seed, stored food from the cotyledons, as in the bean, or from the endosperm, as in the corn. The establishment of the root system and unfolding of the leaves makes the plant an independent organism.

Using Your Knowledge

1. Explain how seeds are able to undergo a period of dormancy which would be fatal to a vegetative plant.

2. Explain the relation between seed dormancy and the life cycle of an annual.

3. Discuss seed viability and the methods used in its determination.

4. Name the three principal conditions necessary for seed germination.

5. How does germination of the seeds of orchids and certain other plants illustrate a peculiar relationship between totally different plants?

6. Of what great importance are the cotyledons and endosperm during germination of a seed? Why is the dependence of the seedling upon these parts temporary?

7. Describe the appearance and development of the young root of a seedling.

8. Describe the manner in which the aerial parts of the seedling (bean) emerge through the ground and develop the stem and leaves.

9. How does the young shoot of the corn plant force its way up through the soil?

10. During germination, how are stored food materials changed chemically?

11. Certain seeds, like the sweet pea and larkspur, will not germinate unless the weather is cool. Other seeds, like the squash, cantaloupe, and watermelon, will germinate only when the temperature is warm. Can you explain what advantage to the plant these facts are?

Expressing Your Knowledge

germination
dormancy
viability
hypocotyl arch
plumule
seedling
cotyledon
endosperm
vegetative plant

Applying Your Knowledge

1. Plant some seeds in covered glass dishes containing absorbent paper. Watch from day to day, the development of the root system.

2. Plant seeds of bean and corn in boxes containing soil, sand, and peat, thoroughly mixed. When the seedlings begin to emerge above the soil, start recording all changes from day to day in the form of notes or sketches.

3. Soak lima beans and kernels of corn in water for several hours to soften their outer coverings. Then, open the beans and section the kernels of corn longitudinally and laterally. Locate the parts of the embryo plant and the cotyledons in the bean, and the embryo, cotyledon, and endosperm in the corn.

4. Collect seeds of native trees and see how many you can get to sprout. Germination may be very slow, requiring weeks or months. Be sure to keep the sand, soil, or other germinating medium moist during this period.

5. Plant 100 corn, bean, radish, or flower seeds and determine the percentage of viability.

Increasing Your Knowledge of This Unit

Burbank, Luther. *Partner in Nature* (edited and transcribed by Wilbur Hall). D. Appleton-Century Co., New York. 1939

Chamberlain, James Franklin. *How We are Fed*. The Macmillan Co., New York. 1923 (reprint 1938)

Clute, Willard N. *Our Ferns*. 2nd Ed. Revised. Frederick A. Stokes Co., New York. 1938

Collingwood, G. H. *Knowing Your Trees*. The American Forestry Association, Washington, D. C. 1937

Coulter, Merle Cowles. *The Story of the Plant Kingdom*. The University of Chicago Press, Chicago. 1935

Ditmars, Raymond L. *The Forest of Adventure*. The Macmillan Co., New York. 1933

Dunham, Elizabeth. *How to Know the Mosses*. Houghton Mifflin Co., New York. 1916

Durand, Herbert. *Field Book of Common Ferns for Identifying Fifty Conspicuous Species of Eastern North America, with Directions for Their Culture*. G. P. Putnam's Sons, New York. 1928

Emerson, Arthur I. and Weed, Clarence M. *Our Trees and How to Know Them*. Garden City Publishing Co., Garden City, New York. 1936

Fairchild, David. *The World Was My Garden*. Charles Scribner's Sons, New York. 1938

Fuller, Harry J. *The Plant World*. Henry Holt and Co., New York. 1941

Grout, Abel Joe. *Mosses with a Hand Lens*. 3rd Ed. Revised. The Author, 1 Vine Street, Brighton, Staten Island, New York. 1924

Harwood, W. S. *New Creations in Plant Life*. Revised Ed. The Macmillan Co., New York. 1941

House, Homer D. *Wildflowers*. The Macmillan Co., New York. 1934

Hylander, C. J. *World of Plant Life*. Imperial Ed. The Macmillan Co., New York. 1942

Kumlien, L. L. *The Friendly Evergreens*. The D. Hill Nursery Co., Dundee, Illinois. 1946

Lucas, Janette M. *Fruits of the Earth*. J. B. Lippincott Co., New York. 1942

Maugham, Sidney. *The Earth's Green Mantle*. The Macmillan Co., New York. 1939

National Geographic Society. *Book of Wild Flowers, An Introduction to the Ways of Plant Life*. 2nd Ed. The Society, Washington, D. C. 1933

Peattie, Donald C. *Flowering Earth*. G. P. Putnam's Sons, New York. 1939

Peterson, Maude Gridley. *How to Know the Wild Fruits*. The Macmillan Co., New York. 1923

Platt, R. H. *This Green World*. Dodd Mead and Co., New York. 1942.

Quinn, Vernon. *Roots; Their Place in Life and Legend*. Frederick A. Stokes, New York. 1936

Quinn, Vernon. *Seeds; Their Place in Life and Legend*. Frederick A. Stokes, New York. 1936

Quinn, Vernon. *Leaves; Their Place in Life and Legend*. Frederick A. Stokes, New York. 1937

Rogers, Julia Ellen. *Trees*. Doubleday Doran and Co., New York. 1920

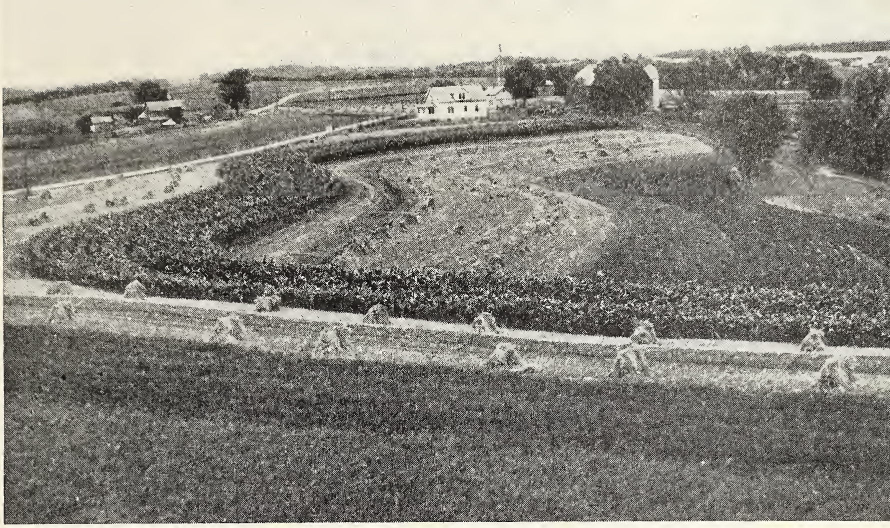
Skinner, Charles M. *Myths and Legends of Flowers, Trees, Fruits and Plants*. J. B. Lippincott Co., Philadelphia. 1939

Synge, P. M. *Plants with a Personality*. E. P. Dutton and Co., Inc., New York. 1940

Transeau, Edgar Nelson. *General Botany*. World Book Co., Yonkers, New York. 1937

Verrill, A. Hyatt. *Wonder Plants and Plant Wonders*. D. Appleton-Century Co., New York. 1934

Verrill, A. Hyatt. *Foods America Gave the World*. D. Appleton-Century Co., New York. 1942



Unit 4

How Plants Affect Our Lives

MAN, more than any other organism, depends directly upon the plant resources of the earth for his daily needs. All animals obtain food from plants, and many of them depend upon plants for cover. Human ingenuity has, however, developed a great many other uses for plant life. Consequently, extensive plant industries center in all civilized lands and supply plants essential to modern living.

Without crop plants there could be no modern cities. The native plants of any region could not possibly supply the concentration of human lives which is found in the city. As civilization advanced, crop plants were developed as a highly efficient source of food materials, closely supervised by skilled growers. In addition to food crops, other crops are grown extensively to supply materials for textiles, industrial products, and a great many other plant materials necessary to the economy of the present day world.

Chapter 19

Uses of Plants

Suppose our forefathers had, by chance, landed upon the shores of Africa or South America or, possibly Greenland or northern Canada. Could they have carved out of those lands the nation we enjoy today? They had the courage and determination to overcome most obstacles, but the good fortune of coming to one of the richest lands on earth made possible the development of America.

The colonists who landed on our eastern shores found a land of rich soil, ideal climate, and almost inexhaustible plant resources. The land needed only to be cleared to open vast areas for crop production. As the pioneers pushed westward, beyond the wooded hills and fertile valleys of the East, they found the rich prairies of the Middle West, the rolling plains and, finally, the rich valleys and forest lands of the Pacific coastal states.

With civilization came plant industries in all of these regions — grain farms, truck gardens, orchards, vineyards, and cotton fields — each contributing to the advance of America to first place among the agricultural nations of the world.

Uses of plants. Some of the most direct uses of plants to man include:

1. Food for man and animals
2. Fibers for clothing and other articles
3. Fuels
4. Drugs and narcotics
5. Industrial products derived from plants
6. Lumber and other forest products

Forests are of such great importance that the next chapter will be devoted to their study. The importance of molds, bacteria, and other flowerless plants, likewise, will be reserved for other chapters. For the present, we shall consider only the importance of the most significant seed plants used by man, other than forest trees.

Plants as Food Producers

Cereal grains. Of all the plant parts used for food by man, seeds are the most important, and among them the cereal grains easily take first place.

These cereals are the fruits of various grasses and include wheat, corn, rice, rye, barley, and oats. They constitute the most important group of foodstuffs used by man and other animals. Cereal grains contain very little water, hence they may be stored in cribs, bins, and elevators for considerable periods without spoilage. All are rich in starch. Some, like wheat, contain much protein, and others, like corn, are rich in oil.

The protein of wheat, which is called *gluten,* makes a flour with a texture especially good for baking and yields a " light " loaf which no other grain will form. Fats, lacking in most cereals, are provided in butter, milk, or cheese which are often used with these cereals.

All cereals, especially if the whole

Different Types of Wheat. Reading from left to right: Turkey, Kanred, Marquis, Red Fife.

grain is used, supply such essential elements as phosphorus, sulphur, potassium, calcium, magnesium, and sodium through compounds taken from the soil. They are easily cultivated, ripen quickly, and yield plentifully, if grown in proper soil. The history of cereals is the history of the human race. Wheat was mentioned in Chapter 18 as dating back to the early Egyptians and corn to the North American Indians. Rice has been cultivated by the Chinese for more than four thousand years.

Cultivation of cereal grains. *Wheat* is the most important vegetable food both in Europe and in America. The United States leads in its production, with Russia second. Our wheat producing lands are the " bread basket " of the nation, extending through much of the Middle West. Several kinds of wheat, requiring quite different conditions for growth, are grown in different regions of the wheat belt.

North Dakota, South Dakota, and parts of Minnesota are the center of *spring wheat* production and have made such cities as Minneapolis the milling centers of the nation. The rich soils and bright sunshine of these northern prairie states are ideal for varieties of spring wheat, which is planted in the spring and harvested in the autumn. Wheat of this type produces a hard seed with abundant gluten, making it ideal for flour. The area of production of *winter wheat* occupies a belt farther south and more extensive in area. Although grown in many other states, the principal winter wheat belt includes Ohio, Indiana, Illinois, Iowa, Missouri, Nebraska, Kansas, and Oklahoma. This extensive area produces a large portion of the wheat supply of the nation. A third type of wheat called *Durum* or *hard wheat* is grown still farther west in the states of the Great Plains.

Corn is another important crop of the Middle West. Although corn is grown in two-thirds of the states, the area of heaviest production occupies a belt extending from western Ohio through In-

HYBRID CORN. Corn is the great American cereal.

diana, Illinois, Iowa, Missouri, and Nebraska. Its various forms supply much of the food for both man and farm animals. Varieties of sweet corn find their way directly to the vegetable markets or to canning factories, while the so-called " field " varieties, including hybrid corn, are grown extensively for flour and animal food.

Rice feeds more people in the world than any other grain, being the chief cereal of China and India. The widely varied climate and soils of America are not without rice producing regions, as residents of Louisiana, Texas, Arkansas, and California can testify. Rice is grown in low areas or areas which can be flooded readily.

Oats are an important item in the diet of livestock, both as a grain and as fodder. The ripened stalks and leaves of the oats plant, together with wheat stalks, are used as straw. By various mechanical processes such as rolling, oats are prepared for human use as an important cereal food.

Barley and *rye,* likewise, are grown as crops in many sections of the nation. Barley is widely used in preparing various food products as well as for fodder and malt, while the use of rye to the baking industry is well known.

Legume fruits. Next in importance to the cereal grains are the legumes, which include the bean, pea, soybean, and peanut. Legumes are rich both in protein and starch and, like the cereals, may be stored. *Bush beans, pole beans,* and *lima beans* are important crops in gardens of all sizes. *Peas,* likewise are an important crop in the spring garden. Both as fresh vegetables and as material for the cannery, peas are a very important food.

Soybeans are rapidly becoming a major crop due to the development of many new uses of their seeds. Aside from the use of soybeans as food for man and animals, various commercial uses have been developed. As a source of material for plastics, soybeans have found their way into the manufacture of automobile parts, radios, and other products of industry.

In the sandy soils of the southeastern coastal states, the *peanut* is grown extensively. Its greatest use is for food after the nuts have been roasted and crushed into peanut butter. Peanut oil is also extracted for food and industrial uses. In the region where peanuts are grown extensively, the leaves and stems of the plant are used for animal food much as clover is used. The peanuts are frequently fed to livestock, especially hogs.

Nuts. While larger and richer in protein and oil than cereals, *nuts* are used less for food because the crop takes so long to mature, requires so much space to grow, and is too bulky to store.

For the most part, the walnuts, chestnuts, and hickory nuts of commerce are gathered from native trees. In many places, however, English walnut and pecan (species of hickory) trees are cultivated as crops.

Other seed foods. Many seeds important to the diet of America are imported or are grown in the United States in small quantity. While not a food in the strict sense, *coffee* is a valuable product. It is the seed of a fleshy berry, borne on a shrub about fifteen feet high. It grows only in tropical regions, mainly in Brazil, Arabia, and the East Indies.

Cocoa is valuable as a food and, like coffee, is obtained from the tropics. It comes from the seed of a small tree growing in Central America, South America, Africa, and Ceylon. From the cocoa bean, as the fruit is called, are made cocoa, chocolate, and cocoa butter. It must be noted that cocoa has nothing to do with the *coconut,* which is the fruit of a palm tree, or the *coca* plant which supplies the drug, *cocaine.* Notice the different spellings: COCOA, the plant supplying the beverage; COCONUT, the palm fruit; COCA, the plant supplying the drug, cocaine.

Among other seeds used for food or flavoring are mustard, anise, nutmeg, celery, and caraway.

Fruit crops. From the orchards, vineyards, and " berry patches " come much of the nation's food supply in the form of widely varied fruit crops.

Apple, peach, cherry, plum, and pear orchards range across our nation. *Apples* are an important tree fruit in many states, although the leading states in apple production are Washington, Illinois, New York, and Virginia. *Peaches,* likewise, are grown over nearly all of the nation. In many of the northern states the peach crop is frequently damaged or destroyed by severe winter weather. The climate of parts of Michigan is modified by the Great Lakes and makes this northern state an important peach growing center, in addition to California, and Georgia which lead in peach growth.

Soybean Plant

Washington, Oregon, and California lead in *cherry* production, although the large, sweet cherry is an important crop in Michigan, Wisconsin, and New York. The states of the Northwest lead in production of *plums* and *pears,* although these fruits are extensively grown in Michigan and New York.

The *citrus* fruit areas are more limited than other fruits because of rigid climate requirements. Ideal conditions for growing oranges, lemons, grapefruits, and other citrus fruits are found in California, Arizona, Texas, and Florida. These four states produce nearly the entire crop.

The *grape* is the only important vine fruit grown in the United States. Grapes are grown over a wide area of the nation, although the largest commercial

Monkmeyer Press Photo Service

A California Orange Grove

vineyards are located in California, Michigan, and New York.

Smaller fruits, including *raspberries* and *blackberries,* are scattered over much of the central United States. The supply of these fruits comes from small "patches" as well as extensive, field grown crops. *Strawberries* are another important small fruit crop in the south central states, where they are grown in extensive fields.

Root crops. Root crops were discussed in Chapter 10, hence they need only be reviewed in our discussion of food plants. Beets, turnips, parsnips, radishes, carrots, and sweet potatoes are the better known examples of roots which are used for food. All but the sweet potato are grown over a wide area of the nation. The sandy soils of the southeastern states are ideal for the production of this important root crop.

Sugar crops. Three important crops are grown extensively in the United States for the sugar they yield. They are *sugar cane, sugar beets,* and *sorghum cane.* Sugar cane is produced in the Gulf states, the center of production being located in Louisiana. The cane is planted in rows and cultivated much like corn. When mature, the plants are stripped of their leaves, after which the stems are harvested and shipped to the refineries. At the refineries, the stalks are run through presses which extract the juice. Raw sugar is produced by boiling the juice in large vats. After further purification, pure, white, granulated sugar is obtained. The sugar cane crop produced in the United States is far below the amount required by the nation. Hence, we must depend upon imported sugar from Hawaii, Puerto Rico, and Cuba for some of our supply.

Publishers' Photo Service, N.Y.

HARVESTING SUGAR CANE IN PUERTO RICO

Nearly half of our sugar supply now comes from the sugar beet which is extensively cultivated in our western states, including Nebraska, Colorado, Utah, and California. Another center of sugar beet production is in northern Ohio and lower Michigan. The sugar obtained from the sugar beet is of the same high quality as that obtained from sugar cane.

Sorghum is used in the manufacture of syrup and molasses. It is cultivated much like corn, which it resembles in general appearance. Juice is extracted by crushing the plant, after which the thick syrup is produced by boiling the extract in large kettles. The sorghum growing area extends over much of the eastern United States, especially the southern half.

Plants for Uses Other than Food

Fiber plants. For his second great necessity, *clothing,* man has long turned to the plant kingdom. *Fiber* plants constitute a second group of plants widely cultivated as crops the world over. Chief among these fiber plants is *cotton,* the principal crop of our southeastern states. Cotton was found originally in the tropics, where it grows as a perennial plant both in the Old World and in the New. It is one of the oldest cultivated crops, having been grown in India and Egypt centuries before the birth of Christ. It was, likewise, cultivated in Mexico and South America long before the discovery of America by Columbus.

Cotton was first grown in America in the colony of Virginia by the early colonists who brought seeds with them. From Virginia, it spread through the southern states to Texas, forming what we call, today, the cotton belt. "King cotton" has always been the major crop in North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, and Texas. In smaller quantity, cotton is grown in limited areas of Arizona and California.

Cotton Plant

The cotton plant is shrub-like and grows to a height of about three feet. The flowers are large and creamy white, turning pink before the petals fall off. They resemble the flowers of the hollyhock, okra and mallow, to which the cotton is related. The fruit is a large pod or boll which is green at first, turning brown at maturity. The pod bursts open when ripe and exposes numerous seeds covered with long, grayish, twisted fibers. The cotton gin separates the fibers from the seeds mechanically and has been indispensable in the economy of the South.

The strong, twisted fibers are not only spun into thread from which we obtain cotton cloth, but are used in making many other commercial products. Among these are surgical cotton, batting, gun cotton, celluloid, artificial silk, and paper. Cottonseed oil, a valuable oil of commerce, is extracted from the seeds as a valuable by-product.

Flax ranks next to cotton as a fiber plant, although its cultivation in the United States in no way compares with cotton. Quite in contrast to cotton, flax is grown in the cool northern prairie areas. It is a slender annual, about two feet in height and bearing light blue flowers.

Flax is grown both for its fibers and for its seeds, from which flaxseed oil is extracted. In the flax growing region of North Dakota, South Dakota, and Minnesota, the crop is used principally for the seeds. The flax producing areas of northern Europe supply most of the fibers from which linen thread, lace, canvas, duck, oilcloth, fine paper, and parchment are produced.

Other plant fibers include *jute,* obtained from certain plants in India, and *hemp,* which is grown in Europe and Asia. Jute is a rather coarse fiber used in making burlap, sacking, and cordage. Hemp is a strong fiber used in making sailcloth and rope. *Manila fiber* is obtained from the coarse leaves of a banana-like plant in the Philippines. From this material, the best ropes, binder twine, bagging, and sailcloth are made. *Coconut fibers* come from the outer husk of the coconut and are used for cordage and for the familiar brown door mats.

Plant drugs and narcotics. Many plants form substances in their leaves, bark, flowers, or other parts which are important to man in the form of drugs and narcotics. These substances seem to have little effect upon the plants which produce them, but produce a definite reaction in the human system. For this reason, many of the drug producing plants are dangerous to man and yet are of tremendous importance in the practice of medicine.

Quinine [*quy'nine*] is obtained from the bark of the Cinchona [*sin ko'na*] tree in Peru. Until the recent discovery of a method for producing synthetic quinine, the entire supply used for the treatment of malaria came from these South American trees.

The poppy supplies three important narcotics: *opium, morphine* [*mor'feen*] and *codeine* [*co'deen*]. The powerful effect of these drugs upon the nervous system has led to their wide use in medicine for the relief of pain. *Strychnine* [*strick'nin*], *atropin,* and *nicotine* [*nick'ko teen*] are obtained from various plants of the nightshade family, the latter from the tobacco plant. *Cocaine* was previously mentioned as coming from the leaves of the coca plant.

Among the important gums are *camphor,* obtained from a laurel tree of the Far East and *arabic* which comes from a plant native to Africa. The native American shrub, witch hazel, yields the extract used in preparing the familiar ointment used in treating bruises.

Tobacco. North Carolina, South Carolina, Kentucky, Virginia, Tennessee, Georgia and Pennsylvania lead the nation in production of *tobacco* for industry. While tobacco may be grown in most states, the warm, moist climate of these eastern states is ideal for the tobacco crop.

Tobacco is distinctly an American crop and was cultivated by the Indians long before the white man arrived. From America it was taken to other countries, including India, Turkey, England, and France. However, America still leads the world in tobacco production.

The crop is started in seed beds which are covered with glass or cheesecloth to protect the young plants from spring frosts. Later in the spring, they are moved to a well-cultivated field, where they are planted in rows. The large leaves turn yellow when mature and are then harvested and hung in special ventilated barns to dry. The dried or "cured" leaves are then tied into bunches and sent to the market.

TAPPING A RUBBER TREE

The best leaves are sent to manufacturers of smoking products, while inferior grades are used for the extraction of nicotine, an important ingredient in insect sprays (insecticides).

Plant products in industry. The uses of plant products in the industries of the nation are so numerous that only a few can be mentioned here.

Rubber is manufactured from the milky juice or *latex* [*lay'tex*] obtained from several kinds of rubber trees growing in the East Indies and South America. With the perfection of synthetic rubber, the demands upon the crop have been reduced, although natural rubber will continue to be in great demand throughout the civilized world.

Alcohol is important as a solvent, fuel, preservative, an ingredient in anti-freeze solutions, and in many other ways. It is made by the action of yeast on several kinds of sugar. Plant products used in the manufacture of alcohol include corn, rye, barley, grapes, apples, and potatoes.

Important vegetable *oils* include, in addition to peanut oil, cottonseed oil, and flaxseed oil already mentioned, olive oil, and palm oil. Among the oils used in flavoring are oil of mint, almond oil, and vanilla. Other highly aromatic oils include oil of lavender, oil of bergamot and oil of wintergreen, which are also used in the drug industry.

Resins, gums, and *waxes* serve as the base for paints and varnishes in addition to many other products of industry.

Resins will be discussed in the next chapter. Gums are important as a principal ingredient in chewing gum. Many different plants furnish this interesting product, but the most important is the *chicle* which grows in Central America. Waxes are not now produced from plants in any great quantity, although certain tropical species yield excellent wax which has some industrial use.

The next chapter, dealing with forests and forest products, will greatly expand the list of plant products essential to the life and activity of America.

Summary

Man, through his intelligence and ingenuity, has learned to make use of the almost limitless plant resources of the world. Through extensive plant industries, both native and cultivated plants are grown for the valuable products which they yield.

The greatest of plant industries is the cultivation of food crops. Of these, cereal grains are the most important because of the rich food content of their seeds. Legumes rank second among the food crops. The principal sugar crops are the sugar cane and sugar beet which yield white sugar, and the sorghum, from which syrup and molasses are obtained. Root crops, likewise, occupy an important place.

Cotton is the most important fiber crop of United States and is centered in the southeastern and Gulf states. Other fiber plants include flax, hemp, jute and manila.

Other uses of plants include drugs and medicines, and industrial products.

Using Your Knowledge

1. How does economic biology differ from other phases of the science?

2. What properties make the cereal grains ideal both from the standpoint of storage and of food value?

3. Name six kinds of cereal grains which are grown as food crops in America.

4. Distinguish between spring and summer wheat as to the nature of each crop and the area in which it is grown. Name four different types of wheat.

5. Name four legume crops grown in America.

6. Make a list of native forest trees which supply nuts which are valuable as articles of food. List, also, varieties of nuts which are obtained from imported trees or are imported as fruits.

7. Name six kinds of fleshy tree fruits grown in groves or orchards in America.

8. Tree fruits are grown in nearly all parts of the country. Name four areas of the nation which are especially important fruit growing centers.

9. Make a list of edible roots which you have seen in your grocery store.

10. Name three important sources of sugar in America.

11. What two fiber plants are most widely grown in our country?

12. Make a list of plants grown for the supply of drugs and narcotics.

Expressing Your Knowledge

economic biology	sorghum cane	morphine
cereal grain	fiber plant	codeine
spring wheat	flax	strychnine
winter wheat	sugar beet	atropin
hard wheat	hemp	nicotine
legume fruit	Manila fiber	cocaine
cocoa	gluten	camphor
coca	jute	arabic
coconut	drug	latex
tree fruit	narcotic	alcohol
root crop	tobacco	resin
sugar cane	quinine	gum

Applying Your Knowledge

1. Prepare an outline map of United States showing the various centers of each cereal crop, legume crop, and fruit crop.

2. Prepare a report on the processing of cotton and flax fibers in the textile industry.

3. Prepare a report on the processing of sugar cane, sugar beets, or sorghum cane.

4. Consult a druggist to find out what drugs and narcotics are obtained from plants. Present your list, including the drugs and the plants which supply them, to the class.

5. Ask your grocer from what plants the table oils on his shelves come.

Chapter 20

Forests and Forest Industries

To what extent do we depend upon trees for the products our nation requires? Can our forests meet the demands which will be placed upon them in the future years? These questions would not have disturbed the nation fifty years ago. Forest trees were plentiful then and no one worried much about the timber supply. But with advances in science and industry, demands upon trees have constantly increased through the discovery of new uses for forest products. As demands increase, the supply of trees decreases.

To appreciate the problems faced by the foresters in maintaining the timber supply, one needs to understand the uses we make of the forest crop. We think of trees as supplying lumber, but this is only one of many products the forest must supply. Aside from these products, living trees are absolutely essential to the control of our water supply, the prevention of floods, and in other indirect but extremely important ways. Without them life would be difficult.

You will learn in this chapter about many of the uses made of wood and other forest products, and the effect of forests upon other resources. You will discover, also, the effect which the building of America has had upon our forests, considered at one time an almost unlimited resource.

Forest facts. Originally, forests covered nearly half of our land — a total of more than 800 million acres. The original forests, if moved to the eastern part of the country, would have covered all of the land east of the Mississippi River with 120 million acres left over.

These forests were scattered over the eastern and western sections of the land, with prairies and plains occupying much of the large central area. The two great forest belts of the east and west were, in turn, divided into distinct types of forests. Like all other plants, trees are influenced by temperature, rainfall, soil, topography of the land, and other physical factors of the environment.

All of these forest areas may be seen today, although some are mere remnants of once luxuriant stands of trees. To obtain a picture of the total forest lands of America, we shall take a brief journey into each forest area. The analysis of each forest will include some of the most important species or kinds of trees, the general climatic conditions, and other factors such as soil characteristics which may be important.

Forest areas of America. The first division of the forests is the two great belts, the eastern forests and the western forests. Each belt is, in turn, divided into smaller areas due to variations in the environment. They may be summarized as follows:

Eastern forest belt

1. Northern evergreen forest
2. Deciduous forest
3. Southeastern evergreen forest
4. Mississippi swamp forest

Western forest belt

1. Rocky Mountain forest
2. Pacific coastal forest

Northern evergreen forest. We shall begin our journey in the region of the Great Lakes and the St. Lawrence River Valley in a region called the northern evergreen forest. This forest continues into Canada, where it broadens out and extends from the Atlantic to the Pacific — the only forest extending completely across the continent. The Canadian area of the northern forest differs from that portion in the northern United States, though both are dominated by evergreen (conifer) trees. The Canadian forest is composed largely of Canadian or white spruce, black spruce, and balsam fir. It is truly a land of Christmas trees. Foresters call this the *boreal forest* to distinguish it from the lake forest in the region of the Great Lakes and the St. Lawrence River Valley.

The *lake forest* extends from Minnesota, through northern Wisconsin and Michigan northeast to Maine. It has been exceedingly important since it contains several valuable species of pine. Among the trees composing the lake forest are white pine, red or Norway pine, jack pine, hemlock, white cedar, and larch or tamarack. While pines are most abundant, northern hardwood trees, including the beech, maple, birch, aspen, and balsam poplar are also common in the region. Much of the lake forest grows on sandy soil. It is here that pine forests grow in nearly pure stands. Northern hardwood forests occupy areas of more fertile soil and would probably replace the pines in time if they were suited to the barren, sandy soil of the region.

The deciduous forest. Continuing southward, we enter one of the largest forest areas, extending from the prairies

Philip D. Gendreau, N.Y.

EVERGREEN FOREST IN CANADA

west of the Mississippi River to the Atlantic coastal states and from the lake forest to the Gulf. This broad forest is called the *deciduous forest* because the trees which compose it drop their leaves annually. The deciduous forest is a region of rich soils, for the most part, and moderate climate. It was, at one time, one of the largest areas of broadleafed or hardwood trees in the world. Among the great variety of deciduous trees forming the deciduous forest are beech, maples, oaks, hickories, elms, ashes, walnuts, sycamore, cottonwood, tulip or yellow poplar, and red gum. In some places, white pine and hemlock mingle with the hardwoods. The eastern red cedar is the most abundant conifer of the region. As one travels from north to south through this forest, the tree species change. Hence, certain trees may be classified as northern or southern and still belong to the same forest.

Southeastern evergreen forest. The coastal area extending from New Jersey to eastern Texas lies in a narrow belt along the Atlantic and Gulf coasts. The sandy soils of the coastal region are not suited to deciduous trees and, like the lake forest, support pine trees. Four principal species of pine compose this forest; the southern yellow pine, loblolly pine, shortleaf pine, and longleaf pine. In the extreme southeastern section, the slash pine is another important species. One is impressed, upon entering the southeastern evergreen forest, with the sudden change from hardwoods to pine.

Mississippi River swamp forest. In the region of the Mississippi delta in Louisiana, the southeastern evergreen forest is interrupted by a swamp forest occupying the rich bottom lands. Characteristic of this region are the cypress, black gum or tupelo, water oak, and live oak.

Rocky Mountain forest. Approximately half of the western forest belt occupies the slopes of the Rocky Mountain range. Forests grow in this region

PACIFIC COAST FOREST

because of the decreased temperature and increased rainfall due to elevation. Deserts, sagebrush lands, and plains occupy the valleys between mountains. Among the most prominent trees of the Rocky Mountain forest are the western yellow pine, limber pine, ponderosa pine, lodgepole pine, Engelmann's spruce, Colorado spruce, Douglas fir, and western red cedar.

Pacific coast forest. The most beautiful of all evergreen forests extends from the Pacific Coast eastward to the mountains and along the moist canyons of Washington, Oregon, and California. The most famous trees of this luxuriant evergreen forest are the redwoods and Big Trees of California. Farther north, the Douglas fir dominates much of the forest, together with sugar pine, Sitka spruce, western hemlock, and white fir.

All of these forests have contributed greatly to the building of America. The varied trees which form them have supplied wood for nearly every purpose. They constitute a major portion of the natural heritage of America.

Value of Forests

Lumber. The greatest drain on the forests has been the demand for construction lumber. At one time, the deciduous forest supplied much of this lumber, which was used to construct houses, barns, and other buildings. Barns containing oak, maple, tulip tree, and even black walnut beams are still standing, having endured more than a century in some cases. These woods are no longer used for barn construction.

The evergreen forests supply most of the construction lumber today, due to a shortage of hardwood trees and to the greater ease with which softwoods can be worked.

The chief kinds of trees now supplying lumber are:

1. Yellow pine from the southeastern evergreen forest.
2. Douglas fir and redwood from the Pacific coastal forest.
3. Western white pine from the Rocky Mountain forest and the Pacific coastal forest.
4. Eastern white pine and red pine from the lake forest.
5. Hemlock from the lake forest.
6. White spruce and balsam fir from the Canadian boreal forest.
7. Cypress from the lower deciduous forest and the Mississippi swamp forest.
8. Red cedar from the deciduous forest.
9. Maple from the deciduous forest.
10. Oak from the deciduous forest.
11. Black gum or tupelo from the Mississippi swamp forest and the southern deciduous forest.
12. Birch from the lake forest and the northern deciduous forest.

Furniture. Much of the supply of hardwood timber now goes to the furniture industry. Among the hardwood trees supplying lumber for the making of furniture are the oak, maple (hard or sugar), black walnut, wild cherry, and birch. The furniture industry has centered in Michigan, New York, Pennsylvania, Ohio, and Indiana, because these trees are more abundant there.

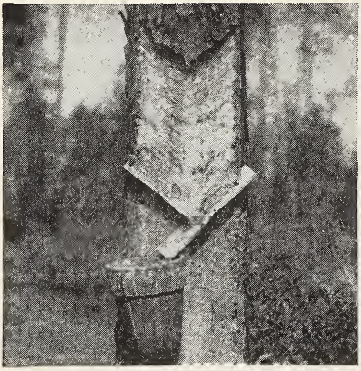
Transportation and communication. Wood has been used in enormous quantities in our transportation industries. Railroads use 2,500 crossties per mile of track. There are about 200,000 miles of railway in the United States and untreated ties have to be replaced as often as every seven years. It is estimated that railroads use between 50 and 100 million crossties per year. Maintenance of railroad right-of-ways alone is a considerable drain on our forests.

Communication depends, to a great extent, upon wood for the countless telephone poles which run across the nation. An entire tree is required for a single pole. In the case of high voltage lines, trees of considerable size are required. The tall, straight trunks of the spruce, fir, pine and white cedar are ideal for use as telephone poles.

Paper. The amount of wood needed for paper production is almost beyond imagination. A single New York daily newspaper requires paper from 44 acres of timber to print a single edition! When you consider the number of daily newspapers in the nation, the timber required for a day's supply of newsprint is almost staggering. In addition to newsprint, high quality book paper, writing paper, packaging paper, toweling, and a great number of other kinds of paper must be supplied daily.

While many kinds of trees are used as pulpwood in papermaking, the finest quality book print and stationery is made from the spruce. Spruce wood is soft, white and free of resin — qualities especially desired in the paper industry. In New York, Wisconsin, and the New England states, piles of logs thousands of feet in length may be seen along the riverbanks awaiting processing in the numerous paper mills. From these mills finished paper is shipped.

Distillation products. Various kinds of hardwoods yield valuable products as a result of distillation. When wood is heated in closed iron cylinders, various products are given off as vapor. These vapors are condensed by cooling and are separated into various substances called *distillation products*. The wood turns black during distillation and becomes pure carbon or charcoal. Some of the products of distillation and their uses include:



Pine Tree Yielding Turpentine

Wood alcohol, used as a solvent
Lampblack, used in ink
Oxalic acid, used for dyeing and bleaching
Charcoal, used as a fuel, in water purification, and in other industrial processes

Beech, maple, and birch are used principally in wood distillation. Consequently, the distillation industry is located in Wisconsin, Michigan, New York, and Pennsylvania where these trees grow in abundance.

Pine products. Pines, especially in the southeastern evergreen forest, supply valuable commercial products which are removed from the wood and processed by boiling in large vats. Turpentine is such a product and is the principal forest product of the southeast. Resin is removed from the pine by cutting diagonal gashes through the bark into the wood. The substance removed from the tree is called *resin*. After turpentine is extracted from the resin, other products including rosin and tar remain. Pine tar should not be confused with the familiar tar extracted from petroleum.

Maple sugar. Maple sugar is an important product in Vermont, New York, Ohio, and other states of the northern region of the deciduous forest. Maple sugar is obtained from the sap of the sugar maple tree, which is collected in buckets attached to tapped trees in the early spring. The sap is boiled to remove much of the water, after which it becomes a thick syrup. Maple sugar is sold also in solid cake form. It is a high quality sugar, similar to cane sugar except for impurities which give it the characteristic flavor. Maple sugar is one of the few examples of food products in which impurities are desirable.

Tanning materials. The tanning industry depends directly upon the forests for bark, containing tannic acid, which is used in the tanning of hides. Hemlock bark is ideal for tanning, although oak, willow, chestnut, birch, and other trees are also used. The presence of both hemlock and fur-bearing animals in the northern and northwestern states has centered the tanning industry in these regions.

Control of the water supply. Living forests are essential in ways just as important as the products they yield. One such vital use of forests is in the control of the water supply. The forest area acts like a sponge absorbing the rainfall in its layers of humus. The foliage prevents the rain from falling directly upon the soil and washing it away. The network of roots accomplishes the same result and the deep layers of humus on the forest floor retain the water, and allow a gradual " run off."

This secures the following important results:

1. Prevents floods and causes steady stream flow by reserve water held in humus.

2. Prevents spring freshets by slower melting of snow due to the shade of forests.

Monkmeyer Press Photo Service

MAPLE SUGAR TREES. Buckets are attached to the trees in early spring and the sap flows slowly into them.

3. Prevents drought by storing water in the wet season.
4. Prevents washing of soil into rivers.
5. Keeps rivers at uniform level.

The effect of forests in this regard can only be appreciated when compared with an area which has no forest protection and is subject to heavy rainfall, such as the Bad Lands of South Dakota. Here the water runs off at once in floods, while between rains the land is almost a desert, due to drought, and the rivers are so filled with mud and so changeable in levels as to be useless for commerce or power.

Benefit to soil. The early settlers regarded the forests as the enemy to agriculture, and so they were, because some clearings had to be made to make room for the farms. But in a larger sense, the forests are a distinct benefit to the soil. Erosion, the washing away of soil by rain, is one of the worst enemies of agriculture and this is prevented by the forest areas, whose roots hold back the earth and whose leaves protect the surface. Furthermore, the organic matter (humus) which collects on the forest floor supplies an essential element to all fertile soils.

In some areas the forest performs another function in preventing the spread of wind-blown sand over fertile areas which are thus saved for use.

Effect of forests on climate. While this may not rank in importance with the two preceding, yet it is certain that by their retention of moisture, forests modify the climate over large areas and apparently influence rainfall also. To a less extent, forests affect climate by giving protection from wind and sun.

Homes for birds and animals. Forests supply shelter, homes and food for a great many birds and animals which are of direct importance to man. Many valuable birds seek the shelter of forest trees for their nests, and feed upon the wild fruits and berries which grow there. Fur-bearing animals like the racoon, opossum, and squirrel, likewise, depend upon the forest for food and cover. Forest streams supply cool, clear water for many varieties of game fish, as well as smaller aquatic animals such as frogs and salamanders. Destruction of a forest destroys the entire woodland society of life. The loss of these forest birds and animals would be nearly as tragic as the loss of the trees themselves.

Forests — their Use and Misuse

Forests should be regarded as a crop, to be harvested when mature and replaced as they are used. Our forests lands could have supplied all of the timber required for the building of America without their serious depletion if they had been used wisely. Instead, they were thoughtlessly destroyed by a rapidly growing nation with little regard for the future.

Forest destruction began with the clearing of farming land by the early pioneers. The deciduous forest especially fell to the pioneer's ax because it grew in rich land, ideal for agriculture. The clearing of land for agriculture was a necessity. But in a great many cases, land quite unsuitable for crop growing was stripped of valuable forest trees and left idle when it was found to be unproductive. Trees were burned, poisoned, and girdled in a campaign to clear the land. Now, extensive stands of timber are rare in the deciduous forest; and walnut, white oak, and yellow poplar timber has become scarce and extremely expensive.

Following the Civil War, construction timber in the eastern states was becoming scarce and it became necessary to import lumber from other regions. Accordingly, lumber companies formed rapidly in the Great Lakes region and the slaughter of these forests began. First

Logged Area. The stumps are all that remains of a fine forest.

The National Forests of the United States

the white pine, then the red pine and white cedar were cleared from the lake forest. Woodsmen worked all fall and winter piling up logs for movement down the rivers during the spring thaws. Millions of board feet of these valuable timber trees were left in the woods when cutting exceeded transportation facilities. Branches and tops were piled up and burned, often starting fires which destroyed seeds and seedlings alike. Forest lands became desolate, treeless areas. During the first World War, men grew rich from the sale of timber from the lake forest. White pine was supplied to the entire world. The beautiful evergreen forests of Minnesota, Wisconsin, and Michigan were dealt a blow from which they have not yet recovered.

The destruction of the lake forest was followed closely by a movement into other timber lands. Forest industries developed rapidly in the South and yellow pine, longleafed pine and shortleafed pine assumed a prominent position in the timber market. Other lumber industries developed rapidly in the western states. California, Oregon, and Washington became lumber centers of the nation. The Pacific Coast forests, the last forest stronghold, began to dwindle at an alarming rate.

As early as 1905, officials in Washington, among them President Theodore Roosevelt, became alarmed about the critical condition of the forests. Accordingly, Congress created the United States Forest Service under the control of the Department of Agriculture. When Theodore Roosevelt signed the act creating this agency on February 1, 1905 the forest conservation movement in America was begun. Vast tracts of timber, especially in the West, were set aside as national forests. Today, there are 161 national forests totaling more than 175 million acres.

The United States Forest Service has established a splendid record through its years of activity. State and local agencies of conservation have looked to this agency for guidance and assistance in carrying out forest conservation programs. A well-trained staff of foresters work untiringly in research laboratories in an effort to discover better conservation methods, controls for forest diseases, more efficient lumbering practices, and new uses for timber products. No small task is the administration of the national forests and protection of these valuable timber lands from fire.

Tomorrow's forests. America has become conservation minded. You will see forests in the future which will resemble the original forests of the land. They will not be natural forests, but will far exceed the natural forest in value. The most valuable kinds of trees will compose these forests of tomorrow. There will be no diseased and dying trees wasting valuable space. Young trees will rapidly replace older trees which are harvested for timber. Lumbering will be a thinning out process rather than total destruction. When trees are harvested, a forest will remain for future use. There will be no desolate wastelands in the timber areas.

Conservation in America. What conservation programs are doing for forests, they are also doing for our soil, water resources and wildlife. Ours is a program of *total conservation*. To discuss forest conservation measures independently of these other phases would divide the conservation program. Unit eleven will deal with the entire program of conservation in America. We shall then discuss the specific measures which have been taken to preserve and to restore our forests.

Summary

Forests were a part of the rich heritage of America and contributed immeasurably to the building of the nation. Forest lands occupy two great belts in America — the eastern belt which extends from the Great Lakes to the Gulf of Mexico and from the prairies to the Atlantic, and the western belt in the Rocky Mountains and the Pacific states.

Forests supply timber for the construction of homes and buildings, lumber for furniture and for large numbers of other wood products. Transportation and communication are directly dependent upon the forest for railroad ties, telephone poles, and other necessities. Wood industries produce numerous products from wood by various processes such as distillation.

Because of excessive carelessness and thoughtlessness, the timber supply of the nation has now become critical. If these wasteful and destructive methods had been allowed to continue, our forests would have soon been completely destroyed. Through a well organized conservation program, however, the picture is changing and the restoration of forest lands is becoming a reality.

Using Your Knowledge

1. Name the forest regions of the two great forest belts.
2. What factors of the environment determine the nature of the various forests of the nation?
3. Generally speaking, what great area of the United States is not a native forest region?
4. Name at least ten valuable timber trees of the United States.
5. Prepare a list of the most valuable timber trees of your vicinity.

6. Enumerate specific uses of timber in the transportation and communication industries.

7. Name several products of hardwood distillation.

8. Name several species of trees which furnish bark for the tanning industry. Do these trees grow in your locality?

9. Explain the relation between forests and the water supply of the nation.

10. In what respects are forests essential to birds and other kinds of wildlife?

Expressing Your Knowledge

forest belt	Rocky Mountain forest	wood alcohol
forest area	Pacific coastal forest	lampblack
northern evergreen forest	timber	oxalic acid
boreal forest	transportation	charcoal
lake forest	communication	resin
deciduous forest	newsprint	pine tar
southeastern evergreen forest	pulpwood	maple sugar
Mississippi swamp forest	distillation	tannic acid

Applying Your Knowledge

1. Prepare a map of your state showing the location of state and national forest preserves (if your state is a forest state).

2. Make a canvass of your neighborhood to determine the species of forest trees most widely used for street planting.

3. Prepare a report on the maple sugar industry in America.

4. Talk with one of the older members of your community to see if he can recall the extent of the forests in your neighborhood fifty years ago.

5. Through correspondence with the Department of Agriculture, prepare a list of colleges and universities which offer forestry courses.

6. Inaugurate a program of tree planting in your school. This can be accomplished by gathering seeds of especially desirable species and growing young trees in a nursery on the school grounds. They may then be transplanted to the school grounds and in various places along your streets. Your city will probably be glad to have you conduct such a project.

Increasing Your Knowledge of This Unit

Collingwood, G. H. *Knowing Your Trees.* The American Forestry Association, Washington, D. C. 1937

Crump, Irving. *The Boy's Book of Forest Rangers.* Dodd Mead and Co., New York. 1924

DeKruif, Paul. *Hunger Fighters.* Harcourt, Brace and Co., New York. 1928

Dural-Reynals, M. L. *The Fever Bark Tree: the Pageant of Quinine.* Doubleday Doran Co., New York. 1941

Eberle, Irmengarde. *Basketfull: the Story of Our Foods.* The Thomas Y. Crowell Co., New York. 1946

Meador, Stephen W. *Lumberjack.* Harcourt, Brace and Co., New York. 1934

Mills, Enos A. *The Story of a Thousand Year Pine.* Houghton, Mifflin Co., Boston. 1913

Montgomery, Edward Gerrard. *Productive Farm Crops.* 4th Ed. Revised. J. B. Lippincott Co., New York. 1928

Pack, Arthur Newton. *Our Vanishing Forests.* The Macmillan Co., New York. 1926

Pack, Charles Lathrop. *Trees as Good Citizens.* The American Forestry Association, Washington, D. C. 1922

Pack, Charles Lathrop and Gill, Tom.

Forest Facts for Schools. The Macmillan Co., New York. 1931

Phillips, Harry A., Cockfair, Edgar and Graham, James W. *Agriculture and Farm Life.* The Macmillan Co., New York. 1939

Read, Arthur Davis. *Profession of Forestry.* The Macmillan Co., New York. 1934

Robbins, Wilfred William and Ramaley, Francis. *Plants Useful to Man.* 2nd Ed. P. Blakiston's Sons and Co., Philadelphia. 1937

Rocheleau, William Francis. *Products of the Soil.* (Great American Industries series, Vol. 2). A. Flanagan Co., Chicago. 1922

Sargent, Frederick Leroy. *Plants and Their Uses.* Henry Holt and Co., New York. 1913

Saunders, Charles Francis. *Useful Wild Plants of the United States and Canada.* 3rd Ed. Revised. Robert McBride and Co., New York. 1934.

Taylor, Norman. *Cinchona in Java. The Story of Quinine.* Greenberg, Publishers, Inc., New York. 1945

United States Department of Agriculture. *The Year Book, 1938, Soils and Men.* Superintendent of Documents, Washington, D. C.

United States Department of Agriculture. *The Year Book, 1939, Food and Life.* Superintendent of Documents, Washington, D. C.

United States Department of Agriculture. *The Year Book, 1940, Farmers in a Changing World.* Superintendent of Documents, Washington, D. C.

Wilson, Charles Morrow. *Trees and Test Tubes, The Story of Rubber.* Henry Holt and Co., New York. 1943

Yeager, Dorr G. *Bob Flame, Ranger.* Dodd Mead and Co., New York. 1934

Monkmeyer Press Photo Service

Unit 5 —

The Microscopic World of Life

It is amazing how much biology may be studied in a single drop of pond water. With the invention of the microscope, a new field of biology was made possible. Man first looked into the unseen world of life — a vast community of tiny plants and animals in which a drop of water is a lake and a thimble full an entire ocean.

Any pond or stream or roadside ditch teems with these tiny organisms, strangely different from creatures of the greater world of trees and shrubs, game animals, and men. Here, tiny plants and animals lead their lives, living and dying and struggling with each other for survival, quite unknown to all but the biologists. Each microscopic society has its plants and animals living in a close balance. There are green plants and non-green plants; strange stalked animals and animals which swim about; cannibals and victims of cannibals. Indeed, this would be a strange and terrifying world if these tiny creatures should suddenly become our size.

Chapter 21

Algae—the Simplest Green Plants

Just as trees, shrubs, vines, and herbaceous plants form the major portion of the vegetation of the world in which we live, so the *algae* [*al'jee*] (sing. *alga* [*al'gah*]), compose a large part of the plant life of the miscroscopic world. We learned, in Chapter 9, that algae are included in the plant phylum called *Thallophytes,* the simplest group in the plant kingdom. Another group of Thallophytes, the *fungi* [*fun'jye*], differ from the algae in lacking chlorophyll. This lack of chlorophyll makes the fungi so different in their life habits that we shall study them in another chapter.

The plant body of a Thallophyte does not have roots, stems, or leaves, but is merely a single cell, or a group of many cells, which carries on all the activities of the plant. Thallophytes vary in form from microscopic organisms like bacteria and some algae, to such large structures as the *kelps.* Kelps are seaweeds which look like long straps or belts, and grow in salt water. Certain ones in the Pacific are several hundred feet long. Yet, even so large a Thallophyte as a giant kelp is, really, just a great mass of similar cells and lives no more efficiently than an alga only a fraction of its size. The phylum, Thallophytes, includes a tremendous number of widely varied plants. Here, we classify not only the *pond scums* and *seaweeds,* which the biologist calls *algae,* but also the mushrooms (toadstools), yeasts, bacteria, rusts, smuts, mildews, and various other *fungi* which are of extreme importance to man.

Classification of algae. This large group of fresh and salt water plants is a fascinating one for study. If you have ever noticed the shores of ponds, lakes, and even smaller bodies of water such as roadside ditches, you have undoubtedly seen the greenish, gray or brown scum which often occurs on the surface of the water. If you have tried to pick it up, you have found that it is slimy, stringy, or sometimes tough. This scum includes many different kinds of algae. Other green algae cover the rocks in a rapids with green, hair-like tufts or give an entire body of water a deep green color, due to the presence of literally millions of tiny green cells. Perhaps, on the other hand, you have been to the seashore and have seen the green, red, and brown seaweeds attached to rocks or thrown on the beach by the waves.

Biologists recognize about 30,000 different species of algae. Many of them are microscopic; others like the kelps just mentioned are of large size. All of them may be classified on the basis of their color because, in many cases, they contain *pigments* in addition to chlorophyll. This fact makes it easy to group them into various classes. Although several other groups are included in the algae, we shall limit our study to a few representatives of each of the following:

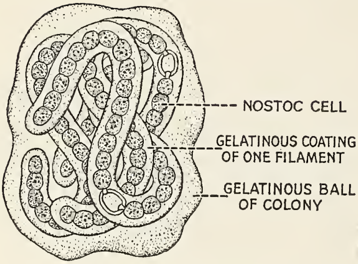
1. Blue-green algae
2. Green algae
3. Flagellates and diatoms
4. Red algae
5. Brown algae

Characteristics of the algae. Algae all have certain characteristics in common, even though they vary greatly in size and in the environments in which they live. Their cells contain *chlorophyll* and are therefore able to manufacture food by photosynthesis just as flowering plants do. They carry on all the life processes which are by now familiar to you, and in every way are independent organisms. The water and carbon dioxide necessary for photosynthesis are absorbed either from the fresh or salt water in which they live, and the light energy is likewise absorbed by their cells from the sun's rays.

Their reproduction is simple compared to that of the flowering plants which develop complex flowers, fruits, and seeds. *Fission,* or simple splitting of a cell into two parts, is the only method of reproduction of certain of these primitive plants. Other forms, considered more advanced, produce special reproductive bodies called *eggs* and *sperms* which unite to form a fertilized egg or *zygote* [*zy'goat*]. Many types likewise produce *spores* which are specialized reproductive cells capable of growing into a new plant directly without uniting with another cell, as in the case of eggs and sperms. Some spores are provided with whip-like appendages which enable them to swim about for a considerable time before coming to rest and growing into a new plant. Other spores surround themselves with a thick wall and, when the pond or other body of water dries up during a hot summer, rest over the unfavorable period and do not grow into new plants until suitable weather conditions occur. Algae may reproduce by one or more of these methods. All carry on cell division, but many form eggs and sperms under certain conditions and, at other times, reproduce by means of spores. Biologists refer to reproduction by cell division and by spores as *asexual,* since no union of cells is involved. *Sexual reproduction* by sperms and eggs, on the other hand, involves cells with a definite sex, and the union of two cells of opposite sexes.

Many algae spend their entire lives as solitary cells. Each time a cell divides, the two cells separate into two *one-celled* organisms. Others live in *colonies*, consisting of two or more cells attached to each other. When attached to each other, however, each cell in the colony leads an independent existence. They do not depend upon each other as do the cells of a root or leaf of a higher plant. The pond scum which you pick up out of the water consists of thousands of colonies of one-celled algae. Some of the colonies comprise thread-like groups called *filaments,* while others consist of globular or spherical colonies comprising thousands of individual algae surrounded by a jelly-like substance which protects them from heat, cold, and other unfavorable climatic conditions. This jelly-like substance is characteristic of many of the algae, both fresh and salt water forms, and accounts for the slimy texture which makes them difficult to grasp in the water.

Blue-green algae. These are all one-celled plants, and usually exist in colonies. Some are filamentous, while others consist of masses of slimy material called the *matrix* [*may'trix*] in which the cells are embedded. Blue-green algae live in almost every roadside ditch, pond, and stream. While they may be found throughout most of the spring and summer, they are especially abundant during the hot summer months. Blue-green algae are a constant problem in drinking water and swimming pools. Their presence often gives the water a foul



A Colony of Nostoc

odor, characteristic of stagnant streams during the summer months. Bacteria, often associated with green algae, may make the water unsafe to drink. For these reasons, the content of blue-green algae in sources of water for drinking and swimming is checked very carefully.

Nostoc, a typical blue-green alga. Of the common examples of blue-green algae, one of the most curious is *Nostoc* [*noss'tock*]. You will find it in mud and sand, usually just at the point where the ripples from the pond or lake hit the shoreline. It looks much like a mass of greenish or blackish jelly. In some cases, it appears like small peeled grapes. Actually, the jelly-like substance is secreted by thousands of *Nostoc* cells, arranged in filamentous colonies. If a portion of one of these gelatinous balls is crushed upon a clean glass slide and examined under the microscope, the plants will appear as small, round cells, arranged in chains much like a string of beads. Each cell is a complete plant which manufactures its own food and carries on all the life processes.

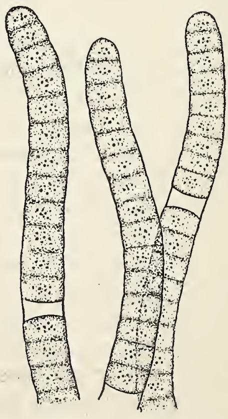
Nostoc reproduces by *fission*, the simplest method known. When a cell divides, it splits into two equal parts each of which becomes a new *Nostoc* plant. These two cells may divide again to form two more cells each, and the chain becomes longer and longer. Usually, it breaks into two pieces when the cells number sixteen or eighteen. Each jelly-like mass, in turn, contains hundreds of small chains or filaments of *Nostoc* plants.

Nostoc produces no spores, and has no organized nucleus within the cell. Furthermore, the chlorophyll is scattered throughout the cytoplasm rather than being localized in plastids as in the case of the cells of higher plants. It is one of the simplest of the green plants.

All blue-green algae are simple, and in many respects resemble *Nostoc*. One such blue-green, called *Oscillatoria* [*os sill ah tor'ia*], is composed of narrow disc-shaped cells arranged end to end in a filament. Filaments of *Oscillatoria* are characteristic in having a swaying or oscillating motion in the water, a peculiarity for which it is named.

Green algae. Green algae vary from one-celled forms to those consisting of many cells. Some grow in salt water, but the great majority of them are found in fresh water. Some occur on land, especially on rocks and tree trunks.

Cells of green algae show considerable

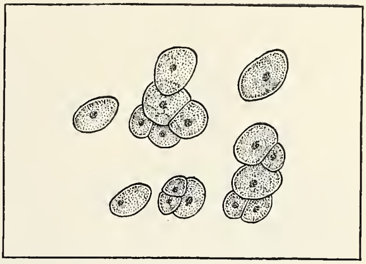


Several Filaments of Oscillatoria

advance over the primitive cells of blue-greens. Each has an organized nucleus and chloroplasts containing chlorophyll. They range in color from bright grass green to yellowish green.

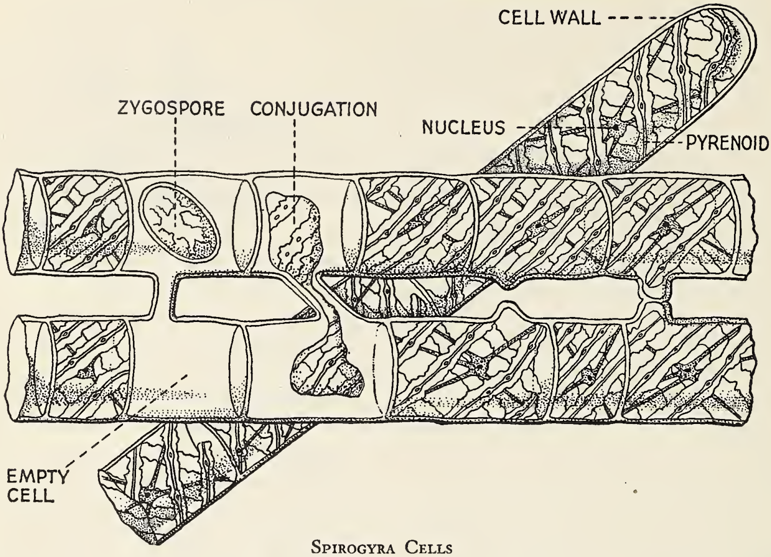
Protococcus, a common green alga. *Protococcus* is one of the commonest plants in the world. Everyone has seen it, although few have realized that it is an alga, because it grows on the trunks of trees. It is particularly green after a rain or during moist weather on account of the activity of its chlorophyll. During dry weather it is hardly noticeable, but in wet weather is very much in evidence. Usually, it is more common on the north side of tree trunks because that side is more sheltered from the hot sun.

The plant body of *Protococcus* is composed of a single, spherical or oval cell. Each cell contains a nucleus and a single, large chloroplast. *Protococcus* cells live in colonies like *Nostoc* but are not included in a jelly-like secretion. The colonies are not in chains, but comprise two, four, or six cells which are grouped together in small squares, often two cells on the top and two on the bottom. Colonies are formed as a result of division of the *Protococcus* cells. When a cell divides, the two resulting cells remain attached. Since division occurs first crosswise then, during the next division, lengthwise, the colonies spread in two directions to form a sheet of growth one cell in thickness. This accounts for the thin, spreading growth resembling green paint, which one sees on the trunks of trees. *Protococcus* cells are so tiny that millions are required to cover a few square inches of bark. They may be carried from tree to tree by various means, most frequently by birds and by the wind during dry weather. Since *Protococcus* is a green plant it requires no nourishment from the tree.



Cells of Protococcus

Spirogyra, a filamentous green alga. *Spirogyra* [*spy ro jy′rah*] is one of many thread-like or filamentous green algae found abundantly in fresh water, such as ponds and streams. These masses of green threads cover large areas during the spring and fall months and make the water in which they grow look a brilliant green. The filaments are unbranched, range from a few inches to a foot or so in length, and are slimy because of a thin, jelly-like sheath which coats each strand. Under a microscope, a thread of *Spirogyra* is seen as a series of transparent cells, arranged end to end like small barrels. In each cell there is a spiral band which looks like a green ribbon. This is the chloroplast, containing chlorophyll. Certain kinds of *Spirogyra* have two or more chloroplasts. The name, *Spirogyra,* was appropriately selected to describe these peculiar spiral chloroplasts. In the center of each cell is a rather large nucleus from which strands of cytoplasm radiate to the cell walls. On the ribbon-like chloroplasts are small protein bodies surrounded by starch, called *pyrenoids* [*pir′en oids*]. Like other green plants, *Spirogyra* absorbs carbon dioxide and water, out of which it manufactures sugar and starch in the presence of sunlight. The excess oxygen, released in the process, causes the mass of green threads to float to the surface. Such floating masses may



SPIROGYRA CELLS

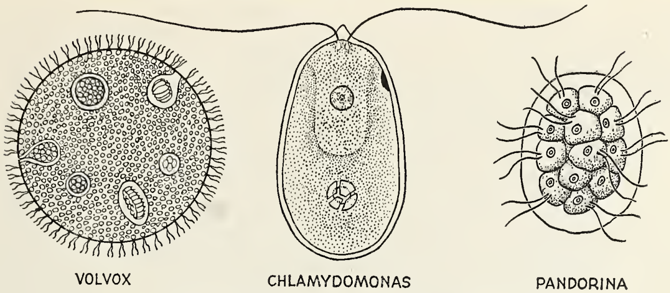
be seen frequently during the afternoon on a bright day. When photosynthesis stops during the night, the oxygen gradually disperses into the water, causing the threads to settle back into the water.

Spirogyra reproduces in two ways, and is therefore more complex than either *Nostoc* or *Protococcus*. The first, and most common method, is by regular cell division. Cells always divide crosswise, and in so doing add to the length of the filament. Theoretically there is no limit to the length a *Spirogyra* filament may become. Actually they seldom reach a length of more than a foot because water currents, moving fish, and other outside forces are continually breaking them in two. This does no harm to the plant because each cell lives independently.

The most curious method of reproduction occurs when weather conditions are unfavorable for normal growth. It is called *conjugation* and may be observed in material which is collected during the hot days of the summer when there is danger of the pond or stream drying up.

Conjugation involves two filaments of *Spirogyra*. The filaments line up parallel to each other and a small knob grows out from each cell on its inner side, as shown in the diagram. Each knob elongates until it touches the knob of the cell across from it in the parallel filament. A ladder-like structure results because the knobs of the cells in one filament touch those across from them in the other filament. Then the tips of the knobs break open and form a passage between the two cells. Through this passage the contents of one cell flows into the other cell. The contents of the two cells unite and form an oval mass of protoplasm which quickly becomes surrounded by a thick, heavy wall and is called a *zygospore* [*zy'go spore*].

When conjugation is completed one of the two parallel filaments contains only empty cells while the other contains only zygospores. The thick wall sur-



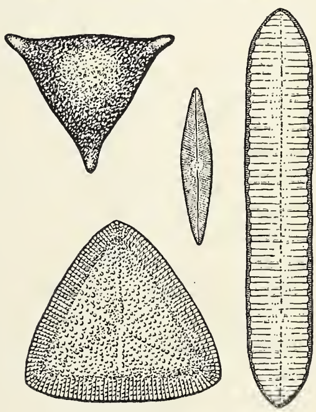
Some Interesting Types of Flagellates

rounding these spores enables them to withstand severe weather conditions such as excessive heat, dryness, and freezing. Such adverse conditions would soon kill the ordinary filaments of *Spirogyra.*

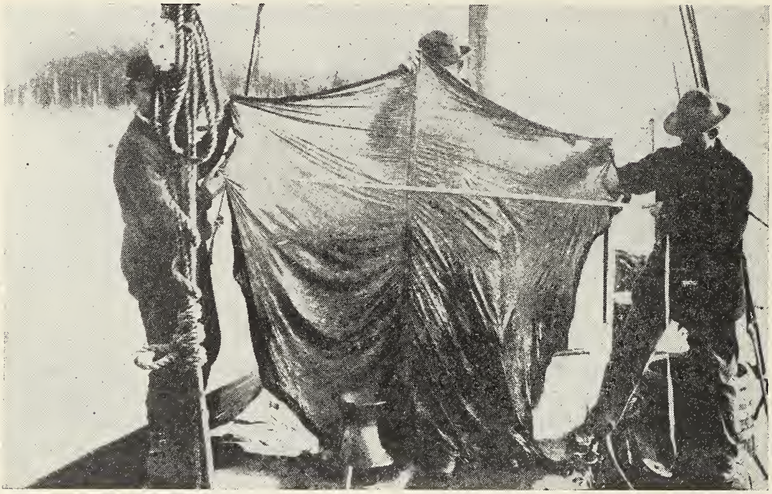
The zygospores fall to the bottom of the stream or pond as soon as the cell walls which hold them disintegrate. There they remain for long periods until favorable environment conditions appear. When the weather becomes suitable again each of them grows immediately into a new *Spirogyra* cell which, by the usual process of cell division, develops into a new filament.

Flagellates and diatoms. If you examine very many cultures of green algae you are almost sure to find certain one-celled forms which will immediately attract your attention. Among these will be *flagellates* [*fla'jell ates*], which possess a slender whip of protoplasm with which they propel themselves through the water. Usually the whip or *flagellum* [*fla jell'um*] is invisible, but the tiny green cells may easily be seen moving rapidly about. The term *flagellate* is commonly used to include a variety of these free-swimming algae. It is not the name of any particular group or kind of algae. Many flagellates are green algae, while others belong to groups which we have not studied.

Diatoms are found abundantly in both fresh and salt water. They are one-celled, free-floating algae which vary in shape from rectangular, round, triangular, or oval to spindle-shaped or boat-shaped forms. They are sometimes green and more often golden brown, although they all contain chlorophyll in their cells. Their walls contain small amounts of *silicon,* the substance which is found in sand. The wall is in two sections or valves, one fitting over the other like the top and bottom of a pill box. Diatoms are especially attractive not only because of their curious shapes, but because of the many fine lines which form intricate and beautiful designs on their walls.



A Group of Diatoms



A Giant Kelp

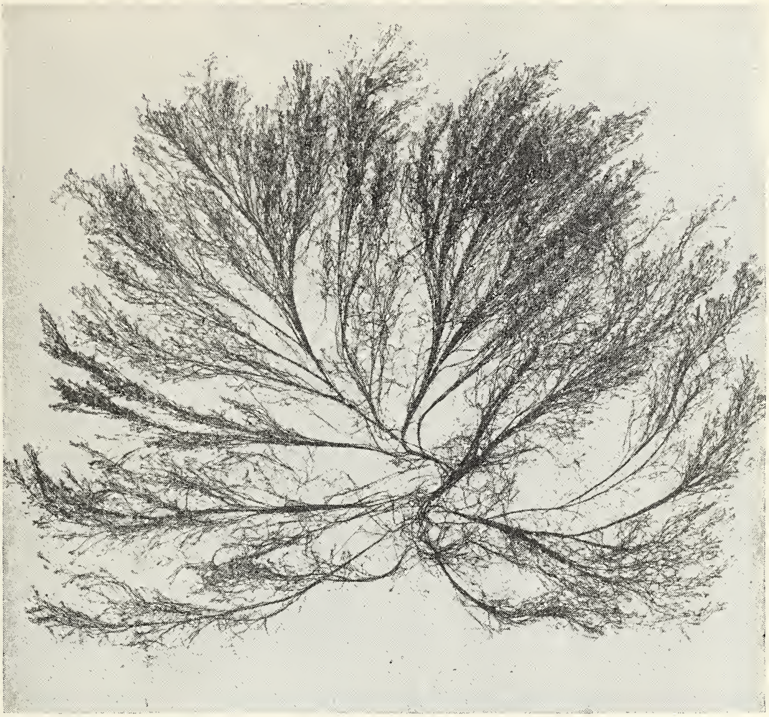
When they die, they drop to the bottom of the pond, stream, or ocean and form deposits of *diatomaceous* [*dia tom ay′ shous*] earth. In California and other parts of the world, deposits of this earth are removed and sold as articles of commerce. It is used extensively in various scouring powders and also as insulation material.

Red and brown algae. These are mostly salt water forms, commonly known as seaweeds. Certain kinds inhabit hot springs where they endure very hot water. They vary from quite small, thread-like forms such as some of the reds, to the giant forms of the Pacific Ocean kelps, which are a familiar sight to anyone who lives on the shores of that ocean. They live mostly in shallow water near the shore, but some of the reds live in deeper water, where they grow attached to rocks at the bottom. Because they vary so much as to structure and as to reproduction, and because they are often difficult to obtain, we cannot study any particular type. They are truly the most beautiful of all algae, and, when they grow in their native haunts, present a gorgeous sight of different shades of red and brown.

Economic importance of the algae. Algae in reasonable quantity are necessary in most bodies of water where they serve as food for fish. Small fish live almost entirely on these plants and even larger fish of certain varieties eat quantities of algae. Their importance to aquatic life in supplying oxygen as a waste product of photosynthesis cannot be overlooked. Unless the plants become too numerous they are highly desirable; it is only when they reproduce their kind too freely that they become a menace.

As a source of food, they are not limited to fish. Man has eaten certain species of algae for many years, either raw or cooked. In the oriental countries especially, they are a staple food, and certain dishes cooked from seaweeds are considered a great delicacy.

Many of them are valuable sources of



A SINGLE RED ALGA. This photograph shows a red seaweed about actual size. Some are larger, some smaller, but none are the size of the giant kelp.

fertilizer. This is true of the reds, browns, and a few greens like sea lettuce, especially. The seaweeds are dried and then spaded into the soil in gardens.

Most important of all is their use in the preparation of agar-agar [*ah'gar ah' gar*]. This important material is used in making culture media for bacteria, as you will learn in a later chapter. Agar-agar is obtained from certain brown algae which inhabit the Pacific Ocean and is shipped in large quantities to hospitals and laboratories.

Many algae are so beautiful that they serve as designs and patterns for those who make fabrics and textiles. *Spirogyra, Protococcus* and *Nostoc,* as well as thousands of other algae, have been the inspiration for many a beautiful piece of printed cloth which has been made into a dress or drapery.

As well as serving helpful purposes, algae can also do great harm. Their greatest harm comes from the fact that they may become poisonous when they die and disintegrate, thus polluting water. Not only is the water rendered unfit for humans, but often fish and other animals which inhabit it are killed. Some of the larger algae grow in such profuse mats that they become dangerous places for young fish, which frequently get caught in the threads and are unable to swim out. Too many algae in fish hatcheries can cause considerable damage, and great care is taken to prevent hatchery ponds from becoming "weedy." The most universal treatment for water which is contaminated by algae is a mild solution of *blue vitriol* crystals (copper sulphate.) These crystals are either thrown directly into the water where they dissolve and kill the algae, or they are placed into bags which are slowly pulled through the water by rowboats. A weak solution of blue vitriol crystals almost immediately kills the algae, but does not harm the fish or other animals, nor does it poison drinking water.

Summary

Algae belong to the phylum Thallophyta and are the simplest green plants. They are divided into several groups, the largest of which are the blue-greens, greens, browns, and reds. Diatoms constitute a smaller group, while the name, flagellates, is given to examples of several groups which swim about by means of flagella. There are about 30,000 known species of algae varying in size from one-celled forms which can be seen only with the microscope to enormous forms like the giant kelps which reach a length of several hundred feet.

Algae are characteristic as a group in reproducing in several different ways. All carry on cell division which results in new individuals in the case of one-celled forms, and enlargement of the colonies in those forms which grow attached to each other. Certain algae form spores which are able to withstand severe environmental conditions which ordinary cells could not endure.

Algae are economically important, not only as plants which contaminate the water reservoirs, swimming pools, and fish hatcheries, but also as sources of fertilizer, food for fish, food for man, and in the production of agar-agar, a substance necessary in the making of bacteria culture media.

Using Your Knowledge

1. Why are all of the algae classed as independent plants?
2. What is the essential difference between sexual and asexual reproduction?
3. Describe a typical filamentous alga.
4. Of what great economic importance are the blue-green algae?
5. In what respect is *Protococcus* an exception to the rule among green algae in respect to habitat?
6. What characteristic of *Spirogyra* is responsible for its name?
7. Describe conjugation in *Spirogyra*. Why is it considered a type of sexual reproduction?
8. Describe the characteristic form of the diatoms.
9. In what respect are the flagellates different from other algae?
10. Describe the typical habitat of red and brown algae.

Expressing Your Knowledge

Thallophyte	red alga	colonial
pond scum	fission	oscillate
blue-green alga	conjugation	pyrenoid
green alga	zygote	zygospore
flagellate	spore	asexual
brown alga	sexual	filamentous

Applying Your Knowledge

1. Make a collection of fresh water algae from the ponds and streams of your vicinity. They may be preserved in five percent Formalin solution. (Ask your teacher about this.) See how many species you can identify with the use of books on algae.

2. Visit your local water purification plant and find out what measures are used to destroy algae in drinking water.

3. If you live near the seashore, make a collection of brown and red algae. If not, try to locate a friend or relative who lives in such a community who might send some specimens to you.

4. Prepare a report on the relation of algae to aquatic animals.

5. Locate some masses of *Spirogyra* in a pool and take samples of it frequently through the late spring and early summer. See if you can obtain some conjugating specimens. They will probably be black because of the zygospores in the cells.

Chapter 22

A Notorious Group of Thallophytes—the Fungi

Algae are interesting to study, but they are relatively unimportant in comparison with their relatives, the fungi. Most algae live quite harmlessly in ponds and streams, but fungi affect our lives more directly. Man has engaged in an endless struggle to control this group of plants which continually threaten his very life. But this notorious group is not without its beneficial examples. While many fungi are destructive in their activities, others are essential to our existence. They do either definite good or definite harm. In either case, they are subjects of constant attention in biological research laboratories.

Your study of the fungi will be something like a journey through a rogues' gallery. You will learn about plants which destroy trees, others which attack cereal grains and other food plants. Among these fungus plants is a group which threatens the very existence of man himself and still defies the best efforts of our highly advanced medical science. An important part of your study of this group will be to distinguish the beneficial from the harmful fungus plants.

What are the fungi? The fact that fungi are classified as Thallophyte plants would indicate that they are structurally similar to the algae. This is true, especially of certain kinds of fungi. The fact that all fungus plants are grouped together does not mean that they are similar in form. As a matter of fact, some fungi are much more like algae in this respect than they are like other fungi. But all fungi are similar in one extremely important respect. *They lack chlorophyll and therefore cannot pro-*

duce their own supply of food. Therein lies the great economic importance of the fungi. They depend upon green plants or upon animals or other organic matter for their food, either directly or indirectly, and, therefore, live in direct competition with man and the other animals.

Parasites and saprophytes. The manner in which fungi obtain their nourishment leads to their classification into two distinct groups. Many of the fungi obtain nourishment from another living organism. These fungi are called *parasites* [*par'ah sites*]. The organism upon which they live is called a *host.* Any living plant or animal may serve as a host to a particular kind of parasite. Naturally, the presence of the parasite upon the host produces damaging results caused by the sapping of nourishment. If the damage is noticeable, we speak of the condition as *disease.* A struggle begins during which the host overcomes, or is overcome by, the parasite. Often, however, the damage done by the parasite is not sufficiently great to produce a diseased condition. In such cases, the host plant is not injured.

Saprophytes [*sap'ro fites*], like parasites, live upon organic matter, but attack a nonliving host rather than a living one. A fungus living upon a dead tree, in a sugar solution, or upon a piece of bread or cheese is termed a saprophyte. While saprophytes never cause disease, many are very damaging when they attack lumber or the food supply of man.

Examples of fungi. Biologists group the fungi on the basis of structure much in the manner in which algae are classified. These groups are somewhat difficult for the beginner, so we shall use a simple arrangement of classification as follows:

1. Mushrooms and puffballs
2. Bracket fungi
3. Molds
4. Mildews
5. Rusts
6. Smuts
7. Blights
8. Yeasts
9. Bacteria
10. Lichens

The mushroom, a typical fungus plant. *Mushrooms* are among the largest of the fungi and are also the best-known. We find them in orchards, fields, and woodlands, and popping up suddenly in the lawn after a warm spring or autumn rain.

The familiar mushroom is merely a *fruiting body* and represents only a portion of the complete mushroom plant. The *vegetative* part consists of a tangled mass of colorless, cobwebby threads or *hyphae* [*hy'fee*] (*sing.* [*hy'fah*]) which penetrate the soil. This mass of hyphae comprising a complete mushroom plant is called a *mycelium* [*my seal'ium*]. The hyphae of the mushroom resemble filaments of algae, except for the fact that *they lack chlorophyll.* They penetrate large areas of the soil, wood, bark, or other host material in which they grow. Nourishment is obtained from organic matter which is absorbed through the thin hypha wall and is carried through the flowing protoplasm to all parts of the plant body. The hyphae secrete *digestive enzymes* which penetrate the host and break down the organic materials of which it is composed. While the mushroom fruiting body lives only for a short time, the mycelium may live on for many years, gradually penetrating more and more area of the host.

The familiar mushroom fruiting body is composed of a great number of hy-

Development of a Mushroom Plant

phae, tightly packed together. It consists of a stalk or *stipe* which supports an umbrella-shaped *cap*. The stipe is often set in a cup or *volva* [*vol′vah*] which protrudes slightly above the ground. During penetration of the soil, the cap is folded downward around the stipe to form a hard knob-like structure. After forcing its way through the soil, the cap opens out, leaving a ring or *annulus* [*an′yule us*] around the stipe marking the point where the rim of the cap and the stipe were joined.

Most mushrooms bear numerous plate-like *gills* on the lower side of the cap, radiating out from the stipe like spokes of a wheel. At the end of each hypha along the surface of a gill, *spores* develop in groups of four. The spores of some mushrooms are pink, while others are white, yellow, brown, or black. Each fruiting body produces a tremendous quantity of spores, usually estimated to be several hundred million. These spores drop from the gills when mature and may be carried to a new location by animals or by the wind. Each spore is capable of forming a new mushroom plant if its new environment is favorable for growth. Fortunately, however, most spores fail to reach a suitable host and die without developing a new mycelium.

If all the spores lived and reproduced, the entire earth would soon be covered with mushrooms. One can appreciate the tremendous number of spores a fruiting body produces by making a spore print in the laboratory. Cut a cap from the stipe and lay it gill side down on a piece of white paper. As the spores are discharged, they fall to the paper, forming a design which shows the arrangement of the gills. Spores may thus be obtained easily for examination with the microscope.

The word "toadstool," frequently used as a popular term for poisonous mushrooms, is erroneous, as both edible and poisonous types are truly mushrooms. While many people claim to have methods of distinguishing edible from poisonous varieties, experts tell us that there is no rule or sign which can be used to distinguish the two types. Actually, many more mushrooms than we realize are edible. But the method of finding this out is dangerous. Fre-

A "Fairy Ring" of Mushrooms. What causes the plants to grow in a definite ring?

quently some of the most harmless looking forms are poisonous and produce severe, or in some cases, even fatal effects if eaten. The only safe advice which can be given is to leave them alone unless you know exactly which forms are edible and which forms are poisonous.

Puffballs. These resemble mushrooms except that the fruiting body never opens to discharge the spores. They appear as round or pear-shaped growths, usually white in color. They are edible if collected before the spores mature. Large puffballs weighing several pounds are not uncommon.

Bracket fungi. *Bracket* or *pore fungi,* as they are often called, are the familiar shelf-like growths one sees on the stumps or trunks of trees. They may be either parasites, doing great harm to living trees, or saprophytes, living on dead wood. They are the most destructive of the wood rotting fungi. The mycelium of the bracket fungus penetrates the woody tissue of the host and causes it to disintegrate internally. The shelf-like fruiting body is telltale evidence of the damage which is occurring within the host. Fruiting bodies of the bracket fungus are woody in texture and remain attached to the host year after year. New spore producing hyphae form on the underside of the shelf, forming layers or rings of growth. Spores are discharged through tiny pores located on the underside of the shelf-like growth.

Molds. The term *mold* is applied to numerous kinds of fungus plants which grow upon wood, paper, leather, and various food substances. They cause tremendous damage to food supplies in storage. Yet even this notorious group of fungi is not without highly beneficial examples.

Molds thrive in dark, moist places. While warmth stimulates the growth of many forms, others grow luxuriantly at temperatures near the freezing point. This great range in growing tempera-

BRACKET FUNGI ON A TREE TRUNK

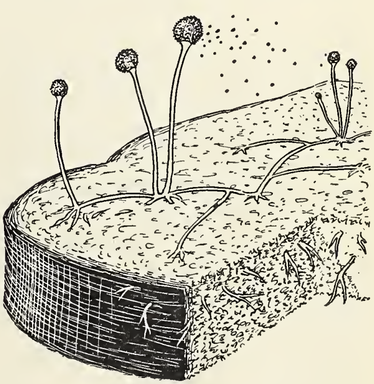
ture causes serious difficulty in cold storage plants.

One of the commonest of molds is *bread mold,* which all too frequently invades our kitchens and breadboxes. One tiny spore is sufficient to start a cottony growth on a piece of bread which soon completely covers it. Each tiny silken thread is a hypha, and the tangled mass, a mycelium. A portion of a bread mold plant viewed with a lens reveals several distinct kinds of hyphae composing the mycelium. Those which spread over the surface of the host are called *stolons.* At intervals along the stolons, clusters of tiny root-like hyphae called *rhizoids* penetrate the host and serve as absorbing structures. Rhizoids produce digestive enzymes which dissolve the starch and sugar contained in the bread, after which it is absorbed into the plant body. The characteristic odor and color spots which mold produces in bread are due to these enzymes and to the products formed during action of the mold upon the host.

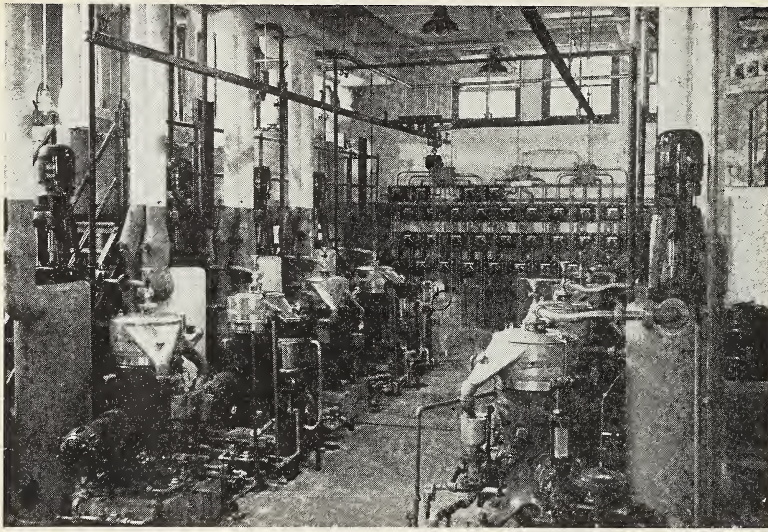
After a few days of growth, tiny black spots appear among the mold threads. Each black spot is a spore case or *sporangium* [*spore an'gium*] produced at the tip of a special hypha called an *ascending hypha.* Under the microscope, these sporangia appear as thin-walled sacs containing millions of spores. At maturity, the sporangium covering ruptures and the spores are discharged into the air. Like spores of mushrooms, each bread mold spore may form a new mold mycelium if it chances to fall upon a piece of bread, leather, paper or any other suitable host.

Blue and *green molds* form the familiar powdery growth on oranges, lemons, and other citrus fruits. The powdery substance consists of spores in tremendous numbers which are formed at the tips of hyphae. The mycelium of these molds is deeply embedded in the tissues of the host. In addition to citrus fruits, these molds live upon meat and other food products.

It is in this group of molds that we find several of the most valuable of all fungus plants. Several species of one of the blue molds, called *Penicillium,* are used in the processing of fine flavored mold cheeses. Cheese manufacturers



BREAD MOLD



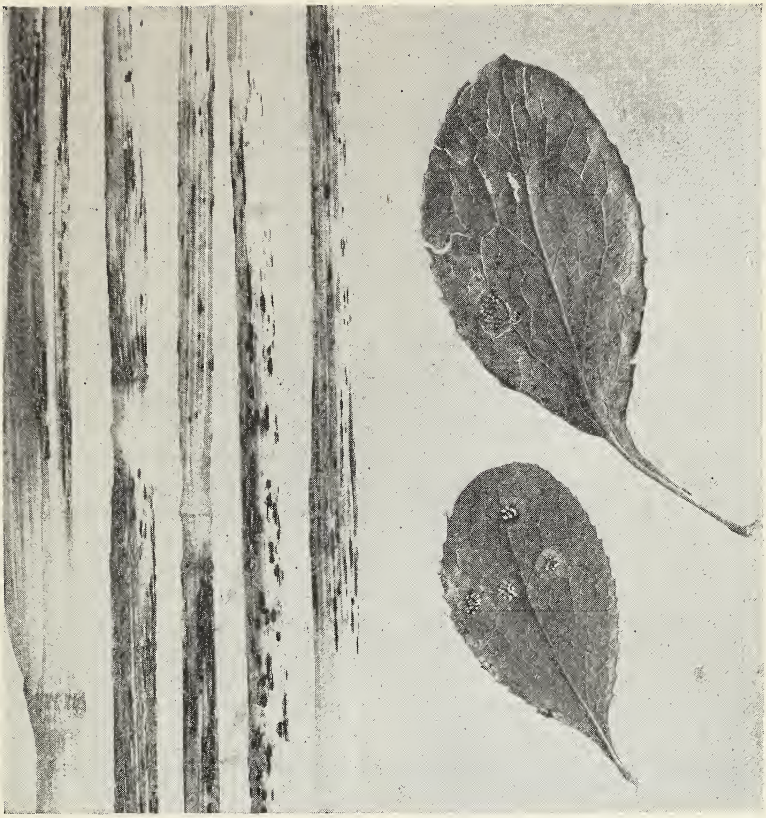
Penicillin Production. A battery of separators is used in extracting and purifying penicillin after it has been produced in the fermentation liquor.

carefully grow these molds and add them to cheese at a certain point in processing. During the aging period the mycelium of the mold grows through the cheese and, by chemical activity, forms substances which add distinctive flavors. Among the more popular mold cheeses are Roquefort and Camembert. Both are cheeses in which *Penicillium* molds are used.

Today, however, *Penicillium* means much more than an organism for the flavoring of cheese. It is associated with one of the most notable medical advances of our time, the discovery of the wonder drug *penicillin* [*pen ih sill′ in*]. Because of this, *Penicillium notatum,* a mold resembling the bluish-green growth on citrus fruits, has become the most famous member of its group.

Penicillin, the drug, is a secretion of *Penicillium notatum,* formed during normal activity of the mold upon a host. The powerful effects of penicillin upon the growth of certain kinds of bacteria were known to science before World War II, although the full significance of the knowledge was not realized at that time. However, the opening of the war created a medical emergency and the medical genius of two nations, Great Britain and the United States, was called upon to begin an extensive study of penicillin and its medical possibilities. The result was a medical triumph. A new and powerful weapon against disease was made available to science.

During the early years of the war, penicillin was produced only in limited quantity from cultures of *Penicillium notatum* grown in flasks or pans. The entire output was reserved for the armed forces, except in a few cases of extreme emergency. Within a few years, however, biological companies perfected methods for large-scale production of the drug and it became increasingly available. Today, entire plants have been



WHEAT RUST. On the left: Infected stems of wheat. On the right: Infected barberry leaves. This fungus cannot complete its life cycle without the common barberry.

devoted to its production. Huge tanks of several thousand gallon capacity have replaced flasks and pans as cultures. The mold is grown in a solution containing lactose (milk sugar), corn steeping liquor (containing sugar and starch), and mineral salts. *Penicillium notatum* is added to these giant cultures and grows freely throughout the solution. After a few days, the penicillin is separated from the other parts of the solution after which it is purified, tested, and packaged in dry form.

The further story of penicillin — its discovery by Dr. Alexander Fleming, its development during the war years, and its use in the treatment of disease — will be presented in Chapter 52 with the discussion of the treatment of disease. Its producer, *Penicillium notatum,* is an outstanding example of a fungus which is beneficial to man.

Mildews. *Mildews* are the white or grayish powdery patches which appear on the leaves of lilacs, roses, potatoes, onions, and grapes. Some types of mildews form their mycelia on the outer surface and send root-like branches into

Corn Smut

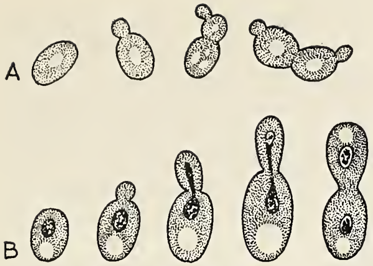
the epidermal cells where they absorb nourishment. Other types form mycelia within the tissues of leaves and stems and do considerable damage to the plant.

Rusts. Several types of *rusts* are among the most destructive plant parasites. Wheat rust attacks wheat, oats, barley, and other cereal grains, causing millions of dollars of damage to these crops annually. There are two stages of the parasite on the grain, the red spore stage and a black spore stage. The red stage is responsible for the name, because a field of wheat which is heavily infected has a distinct reddish color. The red stage appears on the stem and leaves of the wheat plant in the spring. Tiny cracks or *pustules* appear along the stem and leaf surfaces where the internal mycelium of the mold grows to the surface to discharge spores. These red spores are carried to other wheat plants by the wind and thus may spread the infection rapidly. During the late summer and early fall, when the wheat is mature, a second kind of spore called the black stage, is produced from the same pustules. These spores cannot re-infect wheat but infect another plant, the common barberry. This infection occurs in the spring of the following year, some rather complicated changes having taken place between the wheat and barberry stage. Infections in the form of tiny cups on the lower surface of the barberry leaves produce spores which return to the wheat plant and infect it during the spring growth of a new crop. Both hosts, the wheat and barberry, are absolutely essential to completion of the life cycle of wheat rust. Consequently, wheat rust can be controlled by eradication of the wild barberry plant (not the cultivated form).

Another rust, the *white pine blister rust,* causes severe damage to this valuable timber tree. Like the wheat rust, this rust infects two hosts, the white pine and wild currant bushes.

Smuts. *Smuts,* like rusts, are parasites which do great damage especially to cereal grains. One type infects wheat and barley, while another causes extensive damage to corn. Smut spores infect the plants while young and, within a few weeks, show as a moist swelling on the leaves or stem. Corn smut often affects the ears and appears as large swellings containing millions of black powdery spores. These spores are blown about, rest over the winter in the soil, and infect young plants the following season. Protection against smut consists of burning the infected parts and in not leaving stalks and stubble in the field through the winter.

Blights. The plant diseases called *blights* are characterized by a sudden wilting of the leaves, stems, or flowers. Among the most famous blight diseases is the chestnut blight which has practically exterminated the chestnut tree in the eastern United States. It started in New York City in 1904 and spread rapidly to other parts. The chestnut blight attacks the tree beneath the bark and leaves the bark hanging in dry shreds. Root sprouts often grow from diseased trees and appear to withstand the dis-



YEAST CELLS. A. Budding yeast cells, unstained. B. Stained cells showing division of the nucleus as the bud grows.

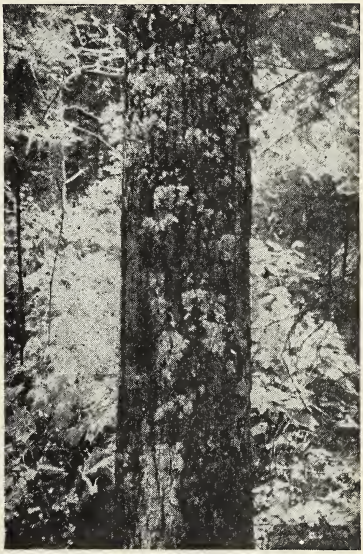
ease for a short time, but usually succumb within a few years. Potato blight and fire blight of the apple are other common blight diseases. The causes of blights are varied. They may be due to bacteria or other types of fungi.

Yeasts. *Yeasts* are among the better-known examples of fungus plants. They are microscopic, single-celled fungi, somewhat resembling bacteria. They are one-celled plants, living on dilute sugar solutions which they ferment, forming *alcohol* and *carbon dioxide*. This fermentation of sugar makes yeast very important to two industries. Commercial alcohol manufacturers use yeasts to ferment various carbohydrate mashes. Bakers, on the other hand, use yeast to form carbon dioxide in dough. Yeast "works" in the dough forming tiny bubbles of carbon dioxide which swell during baking and make the loaf "light." This gas as well as the alcohol is driven off in the baking process.

Yeast cells reproduce very rapidly if kept warm and moist and supplied with sugar for food. Buds develop on each parent cell and soon become full-sized cells which again reproduce, the process resulting in long chains of attached cells. Wild yeasts live in the air and ferment fruit sugars of various sorts. The familiar commercial cake of yeast is a piece of starchy material to which yeast cells have been added. The yeast cells remain inactive as long as the cakes are kept cool, but begin active fermentation when allowed to become warm.

Bacteria. *Bacteria* are the largest and most important group of fungus plants. They are of such extreme importance to man that the following chapter, as well as a part of Unit 9, will be devoted to their study.

Lichens. The *lichen* is an example of a community relationship of plants, for a lichen is not one plant, but two. They consist of certain types of algae held in a mass of colorless filaments of fungi. The fungus is dependent upon the alga for food which it manufactures through photosynthesis. The fungus is, then, a parasite upon the alga. Although the algae are, in a sense, "slaves," they are protected and kept moist by the fungus filaments, and are thus able to grow in ex-



LICHENS ON A TREE TRUNK

posed positions on rocks and trees, where they could not exist alone. This curious relationship of parasite and host living together with mutual benefit is called *symbiosis* [*sim bee o'sis*].

Lichens are abundant on the tops of mountains, along rocky seacoasts, and in the treeless Arctic regions. They may also be found on rocks and dead trees in open fields and woods. A widespread lichen called *Cladonia* is so valuable as food for reindeer that it is commonly called *reindeer moss*. Certain lichens yield valuable dyes such as *litmus*.

Summary

The fungi are a group of Thallophyte plants which lack chlorophyll and are, therefore, unable to manufacture their own food. The fungus must grow in association with a host which serves as the food supply. Fungi which attack living plants or animals are termed parasites, while those which live upon nonliving organic or decayed matter are termed saprophytes.

Among the most important groups of fungi are mushrooms, bracket fungi, molds, mildews, rusts, smuts, blights, yeasts, bacteria, and the curious combinations of an alga and a fungus, called lichens.

Fungi may be very beneficial or very harmful, depending upon the kind of host they invade and the manner in which they affect the host. Among the valuable fungi are certain of the mushrooms, some of the molds, yeasts, and, as we will find in the next chapter, certain kinds of bacteria. Certain molds, mildews, rusts, smuts, blight-causing organisms and many of the bacteria are among the most destructive plants in the entire plant kingdom.

Using Your Knowledge

1. What one characteristic do all fungi have in common?
2. How do parasites and saprophytes differ in respect to the nature of the host they invade?
3. Name at least six different kinds of fungus plants.
4. Describe the mycelium of a typical fungus.
5. Discuss the problem of distinguishing edible mushrooms from poisonous forms.
6. Describe the structure of a common mushroom and explain its relation to the vegetative body of the plant.
7. Bracket or pore fungi may be either parasites or saprophytes. Explain.
8. Explain how bread may become infected with bread mold even though there is no mold growing close by.
9. Explain how rust fungi cause extensive damage to cereal crops.
10. Discuss symbiosis as it is illustrated in a lichen.

Expressing Your Knowledge

fungus	smut	spore
saprophyte	blight	sporangium
parasite	yeast	penicillin
host	bacteria	alternate host
mushroom	lichen	mildew
puffball	hypha	rust
bracket fungus	mycelium	budding
mold	gill	symbiosis

Applying Your Knowledge

1. Moisten a piece of bread and expose it to the air for about thirty minutes. Place it in a covered dish and keep it in a warm, dark place. After a few days, a growth of mold should appear. You should remove pieces of mold growth for microscopic study.

2. Make a collection of mushrooms, puffballs, and bracket fungi in your vicinity. The fleshy forms will require preserving in alcohol or Formalin solution. (Ask your teacher about this.) The woody types will need no preserving fluid.

3. Obtain a mature mushroom fruiting body, cut the cap from the stipe, and place it with the gills facing a piece of white paper. As the spores ripen and fall from the gills, they will form a spore print on the paper.

4. Visit a local mushroom farm or obtain a bulletin on mushroom growing. Present your data to the class.

5. Prepare a report on the production of penicillin. You can probably obtain information from one of several biological companies which manufacture the product.

6. Prepare a report on wheat rust, including the various stages of the infection, and the annual damage to the wheat crop. Use Dept. of Agriculture bulletins.

Chapter 23

Simple Plants of Great Significance—the Bacteria

This is an age in which science deals with little things of great importance. The chemist speaks of atoms and molecules and diagrams their structure in his study of chemical reactions. The physicist, too, deals with extremely minute forms of matter in the form of electrons, protons, and those strange particles he calls neutrons, in the exciting new field of atomic physics. The biologist is not without his study of extremely small things in the form of bacteria and viruses. Strangely enough, all of these tiny objects of scientific study constitute fields of the most important scientific research today.

The science, microbiology, began with the invention of the microscope. But the study of bacteria, the smallest of microorganisms, required a highly perfected microscope, capable of great magnification. Hence, most of our knowledge of bacteria has been acquired since 1860 and is linked with the modern microscope. But while *bacteriology,* as the study of bacteria is called, is one of the youngest biological sciences, its contribution to the progress of mankind has been immeasurable.

The discovery of bacteria provided scientific explanations for many strange phenomena which have always been perplexing problems for the human race. Man looks to the bacteriologist for new developments and discoveries which may lead to the control of dread diseases.

This chapter will acquaint you with the structure and activity of the smallest of fungus plants, the bacteria. With a knowledge of their form and structure, the manner in which they reproduce, and some of their important life activities, the study of disease as well as the beneficial activities of these important plants will mean much more to you.

What are bacteria? When bacteria were first discovered, they were thought to be extremely small animals. Later, however, they were found to be plants, belonging to the group called fungi. Bacteria are as simple as life can be. A single organism consists of one tiny cell, composed of a thin cell wall enclosing a mass of living protoplasm.

Bacteria range in size from about one ten-thousandth to one fifty-thousandth of an inch in diameter. They are visible under the high-power magnification of a standard microscope, although special microscopes providing a magnification of at least one thousand diameters are necessary for the study of most bacteria. Biologists are still trying to discover the nature of one group of organisms, the *filterable viruses* [*vy'russ sez*] which resemble bacteria in some respects, but are invisible under all microscopes except the new electron microscope with which some viruses have been photographed. These forms of life, if they are living organisms, are so minute that they pass through fine clay filters used to separate bacteria from solutions in which they grow — hence, the name, filterable virus.

Where are bacteria found? This question can be answered rather simply. Bacteria are found almost everywhere. They live in the air, in water, in food, in the soil, and in the bodies of plants and animals. They are by far the most widespread form of life. It is fortunate that most of the bacteria are harmless, for we would have little chance to escape them.

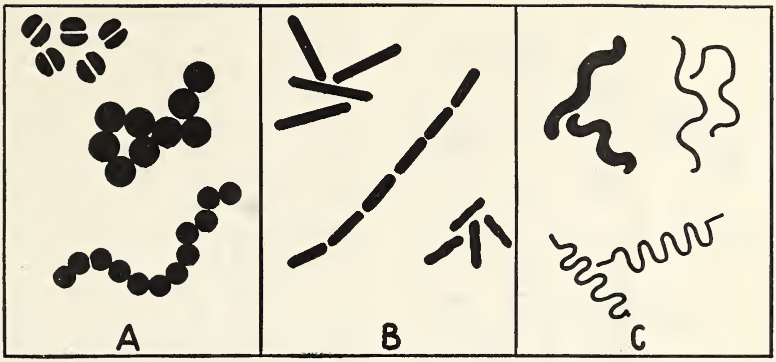
The importance of bacteria. We have heard so much about disease-producing bacteria that we are inclined to think of all of them as being harmful organisms. Fortunately, however, this is not the case. In fact, many kinds of bacteria are absolutely necessary to our lives. According to their importance, bacteria may be classified into three general groups as follows:

1. Harmless bacteria
2. Beneficial bacteria
3. Bacteria which produce disease

The harmless bacteria compose by far the largest group. They live in the air, in water, and even within our bodies and yet do no particular damage. The second group, the *beneficial bacteria,* likewise live all about us, and carry on activities which are of a definite benefit and, in some cases, a necessity to our lives. Only a small number of organisms are classified as *disease-producing* or *pathogenic* [*path oh jen'ick*]. These organisms invade the bodies of plants and animals with damaging effects. Their activities cause disease and, in many cases, death.

All bacteria live as dependent organisms, associated with a host. Parasitic forms invade a living host, where they may or may not cause disease. The human mouth, for example, supports numerous parasitic bacteria which do no apparent damage. Other kinds of bacteria live in the intestinal tract and are necessary for the proper functioning of the digestive organs. These bacteria are parasites upon man, yet in no way harm the body.

Many bacteria live as saprophytes upon nonliving organic matter. They may be beneficial or harmful, depending upon the kind of host on which they live, and the nature of their activities.



BACTERIA. A. Coccus types. B. Bacillus types. C. Spirillum types.

Forms of bacteria. We stated that bacteria are one-celled organisms, consisting of a minute mass of protoplasm surrounded by a wall. While they vary considerably in size, the thousands of forms known to science may be classified into three relatively simple groups, based entirely upon the individual shapes of the cells as follows:

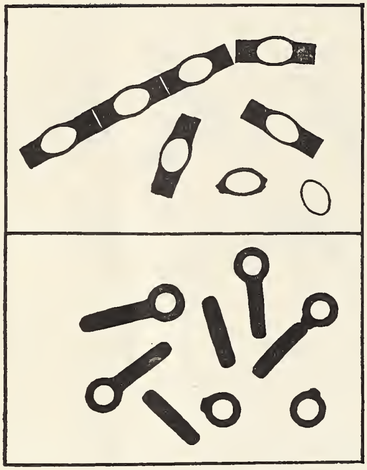
1. Coccus forms — round
2. Bacillus forms — oblong or rod-shaped
3. Spirillum forms — spiral-shaped and curved

Many *coccus* and *bacillus* forms develop groups or colonies of cells which are as characteristic as the shape of the individual cells. For example, many coccus bacteria live in pairs. The bacteriologist looks for this characteristic in determining the presence of pneumonia organisms in sputum. Other coccus bacteria form clusters or chains resembling a string of beads. Bacillus, or rod-shaped bacteria, likewise, may exist in colonies. The most common bacillus grouping is in chains, resembling a string of sausages. These groups of bacteria may be classified as follows:

1. Diplococcus [*Dip'lo cock us*] — pairs of round cells
2. Staphylococcus [*Staff'ee lo cock us*] — clusters of round cells
3. Streptococcus [*Strep'to cock us*] — strings or chains of round cells
4. Streptobacillus [*Strep to bass sill' us*] — strings or chains of rod-shaped cells

The shape and microscopic arrangement of cells help to classify bacteria, although one may readily understand why shape alone will not identify any particular kind of organism. Streptococcus, for example, is a form of round-celled bacteria with the cells attached in chains. To many people, the term "*streptococcus*" refers to blood poisoning or to a severe throat infection. True, both of these diseases are caused by a streptococcus form. But other organisms of the streptococcus type cause milk to sour and eggs to rot. Similarly, a rod form may cause typhoid, another may produce diphtheria, while others live in the soil and are essential to soil fertility. By examining harmless cultures of bacteria, all shapes and cell groupings may be found.

Multiplication of bacteria. Bacteria multiply by dividing. This apparent mathematical impossibility is accomplished through the simple method of



Spore-Forming Bacteria

cell division. When a cell reaches maturity, it merely separates into two cells by forming a wall through the middle. Since a complete organism consists only of one cell, the division of a cell into two parts results in two organisms. Neither cell would be considered the parent cell. Both are young, small, and capable of further enlargement.

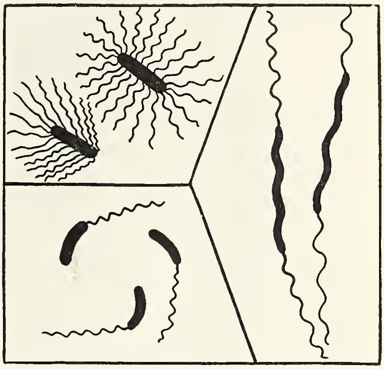
One of the most amazing things about bacterial reproduction is the rate at which it may occur. Under ideal conditions, a cell may reach maturity and divide every twenty minutes. This may not seem alarming until you calculate the results of such a rate of multiplication. But when you consider that a single bacterium, under these ideal growth conditions, would form a mass weighing 7,000 tons in three days, bacterial multiplication becomes much more significant. To get some idea of how numbers increase during bacterial growth, start with a single cell and double the number every thirty minutes for only twelve hours.

This rapid increase accounts for the fact that an invisible bacterium growing upon a host can produce a large, visible colony within a day or two. A portion of the colony examined under the microscope will reveal literally billions of bacteria. Fortunately, this rapid rate of division of bacterial cells continues for only a limited time. As the mass of cells becomes larger and larger, the bacteria themselves begin to interfere with each other. Poisonous waste products accumulate in the mass, and food supplies often fail to reach many cells in the mass. As a result, cell division ceases and the bacteria become inactive. Over a three-day period, growth is extremely rapid during the first day, much reduced during the second day, and usually ceases during the third day.

Spore formation. Many kinds of bacteria, especially the bacillus or rod-shaped types, carry on another method of reproduction during unfavorable periods. Each cell may draw its content into a spherical mass which becomes surrounded with a thick, protective wall. This special body is called a spore. Since a single cell produces only one spore, the total number of bacteria is not increased. Spore formation cannot be considered a method of multiplication.

Bacteria spores are capable of enduring almost unbelievable conditions. They may dry out completely and remain in a dormant condition for years. During the spore stage they may be carried far and wide by various means. Some of these spores are even resistant to boiling water. But when they are subjected to steam under pressure, they invariably die. Steam sterilizers are, therefore, the most effective way of getting rid of them.

When a spore falls on a suitable host, the resting period ends, and a new cell develops. By rapid division, the new host may soon be supporting tremendous numbers of bacteria, all having come from the single spore. Spore-forming bacteria are especially dangerous in a hospital. Tetanus, more commonly known as lockjaw, is caused by a spore-forming bacillus organism. The spores are not destroyed by ordinary methods of disinfection. Spores of this and other organisms may lurk in the operating room of a hospital unless extreme means of disinfection and sterilization are used. Needless to say, all modern hospitals use ample means of destroying the spores of these dangerous organisms.

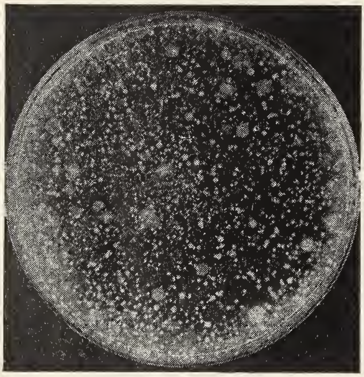


Motile Bacteria

Conditions for growth. Bacteria, like all other fungi, require a host for nourishment. In addition, they require certain other environmental factors. *Warmth* is essential to their activity although coldness does not destroy them. It merely causes the cells to cease activity and enter a dormant period. While bacteria vary in their heat requirements, most forms grow best at a temperature of 98.6° F. (37° C.), or ordinary body temperature. *Moisture* is a second growth requirement for bacteria. Prolonged dryness will not kill most bacteria, but, like low temperatures, results in a period of dormancy. *Darkness* is an extremely critical factor in the growth of bacteria. Exposure to light retards growth considerably and sunlight kills many forms, although it does not injure spores. Ultra-violet rays especially are death dealing to bacteria. This factor is made use of today in special sterilizing lamps which give off concentrated ultra-violet rays. Familiar examples of the effects of low temperatures and dryness are the preservation of foods by cold storage and by packaging in dehydrated (water removed) form.

Bacteria in relation to air. Oxygen is another important factor controlling the growth and activity of bacteria. Some forms require oxygen from the atmosphere for their activity and cannot grow in airtight places. Bacteria of this type are called *aerobic* [*air robe'ick*]. Other forms are just the opposite and cannot grow in free oxygen. These *anaerobic* [*an air robe'ick*] bacteria obtain oxygen as a result of certain chemical reactions they produce upon the host. Many types of anaerobic bacteria are killed by free oxygen, and live in the air only as spores. While less numerous than aerobic forms, anaerobic bacteria are found abundantly in the soil and in decaying organic matter. They occasionally become active in food products which have been packed in airtight containers without sufficient sterilization during processing. The tetanus organism is an outstanding example of an anaerobe which causes human disease.

Movement of bacteria. Many types of bacteria are equipped with whip-like flagella which protrude from their cells and serve as a means of locomotion. Such *motile* [*moh'till*] bacteria propel themselves rapidly through the liquids in which they live. Bacteria vary in the number as well as the location of the



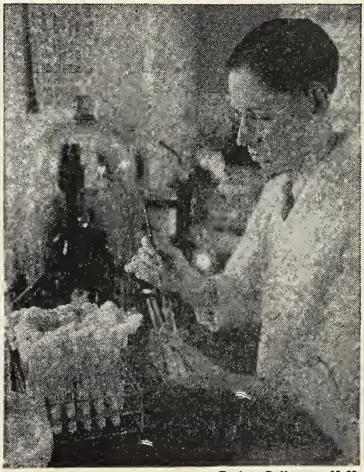
Petri Dish Culture of Bacteria

flagella. Some forms possess a single flagellum located at the end of the cell, while others have numerous flagella which protrude at numerous points over the cell wall. During certain stages, the typhoid organism develops numerous flagella with which it propels itself rapidly through water, blood, and other fluids. Motile bacteria may be obtained readily in stagnant water. They may be observed under the microscope by placing a small drop on a clean glass slide and examining with the high power lens.

Laboratory culture of bacteria. While bacteria exist nearly everywhere, they are not collected in nature as one would gather other plants for study. They are grown in the laboratory under carefully controlled conditions. Hence, laboratory culture of bacteria is one of the most important phases of the work of the bacteriologist.

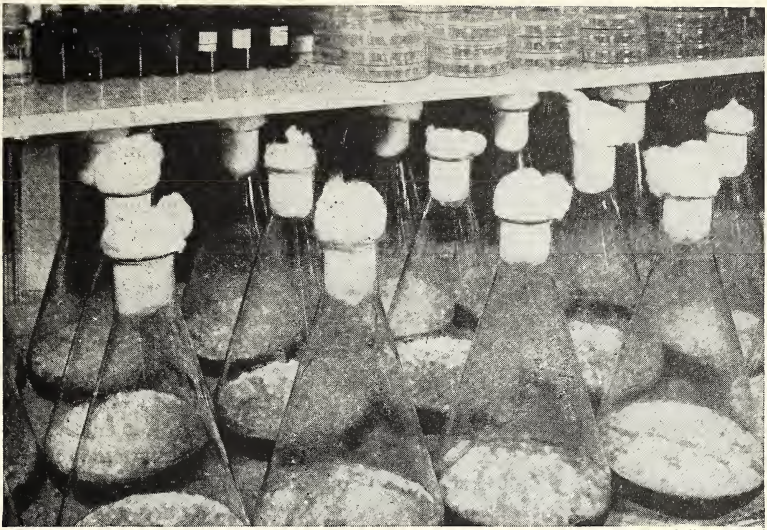
Growth of bacteria in artificially prepared cultures is essential not only to provide organisms for study, but also as a means of identifying them. Size, shape, and other structural characteristics are not sufficient to classify a form of bacterium. While these characteristics are useful, the bacteriologist must grow the organism in question in various kinds of cultures and observe its effect upon the cultures before he can make a positive identification. Bacteria cultures are necessary, also, in the production of numerous biological products used in the treatment and prevention of disease. The procedures used in culturing bacteria include several very important steps. Needless to say, these procedures require extreme care.

In preparing a culture of a specific kind of organism, the bacteriologist must first select an appropriate *culture medium* for the bacteria he wishes to grow. Culture media provide the host substance from which the organisms obtain nourishment. They may be gelatinous materials such as agar-agar or gelatin to which protein, sugars, and other nutrients have been added. Broths and sugar solutions, or solid substances of various sorts are also used. Certain disease bacteria require the addition of blood to the medium. Since many bac-



Ewing Galloway, N.Y.

Bacteriologist Making Inoculations



BACTERIOLOGICAL INCUBATOR. Only one shelf of a large incubator is shown in this picture.

teria are very critical in their requirements, media must be selected carefully.

Cultures are frequently prepared in shallow glass dishes called *Petri* [*pee' tree*] *dishes* or in culture tubes plugged with cotton. After the medium has been added to the container, it must be *sterilized* to destroy any bacteria which may have gained entrance during preparation. While many methods of sterilization are used, live steam under fifteen pounds of pressure for a period of fifteen or twenty minutes is the most common laboratory procedure. After sterilization, the cultures must be handled with care to prevent exposure of the sterile media to outside sources of bacteria. The next step in the culturing process is called *inoculation* [*in nock ku lay' shun*], and consists of the addition of bacteria from a known source to the sterile media. Bacteria may be added by touching an object to the medium, adding a small quantity of liquid containing bacteria, or by transferring organisms from another source to the culture by means of a sterile inoculating needle.

After inoculation, the bacteria which have been added are invisible in the culture. But after two or three days of *incubation,* during which the organisms are provided with warmth, moisture, and darkness, the individual cells have multiplied to form millions. The bacteria are now visible in the form of masses called *colonies*. The shape, size, and color of a colony varies with the kind of organism forming it. The bacteriologist notes very carefully the appearance of the colonies in each kind of culture he uses as an important factor in the identification of bacteria. From the colonies, *smears* may be prepared by spreading a thin film of bacteria upon a clean glass slide and, after thorough drying and flaming to kill the organisms, adding stain to make the bacteria more visible under the microscope. If an examination of living cells is necessary, they may be added to a small drop of sterile water.

Beneficial activities of bacteria. Bacteria, like some other forms of life, have received so much unfavorable publicity that the entire group is often associated only with destructive activity. But when one considers the beneficial activities of some bacteria, one quickly changes one's impression of at least a few of these organisms. Certain kinds of bacteria are absolutely essential to the maintenance of life. Others have been employed by man in numerous processes which are important to modern civilization. While the study of these beneficial forms is very extensive, some of their more useful activities may be classified as follows:

1. Bacteria in the food industry
2. Bacteria in other industries
3. Bacteria in the soil
4. Bacteria of special significance

Bacteria in the food industry. We may or may not consider the souring of milk as a beneficial activity. But this process is essential to the dairy industry in making butter and cheese. In the case of cheese making, bacteria are necessary in acid formation and in the coagulation of milk protein from which the cheese is made. Certain kinds of aged or ripened cheeses such as Swiss, Limburger, and Liederkranz owe their distinctive flavors to bacterial action during the ripening period. Milk sours as a result of the activity of several kinds of organisms which digest the milk sugar (lactose) and form lactic acid.

Another group of souring or fermenting bacteria lives in fruit juices, where they occur associated with yeasts. Yeast cells break down the sugar in the fruit juice and form alcohol, after which acetic acid bacteria convert the alcohol into vinegar. Colonies of these beneficial bacteria grow in vinegar jars, where they are called "mother of vinegar."

The fermentation activities of bacteria are further utilized in the making of sauerkraut. Cabbage leaves are finely chopped and placed into a container between alternate layers of salt. The salt extracts the juice containing sugar from the leaves. Bacteria then convert the sugar to acid, thus giving the cabbage the familiar sour flavor of sauerkraut.

Bacteria in other industries. The finest grades of linen fibers are obtained from flax plants which have undergone bacterial *retting* (rotting). Retting may be accomplished in two ways, both depending upon bacterial action. In one process, the flax plants are tied in bundles and submerged in water. Bacteria enter the stems and begin the destruction of the stem tissues. This action, called retting, loosens the bast fibers from the other tissues of the stem, after which they may be removed and used in the production of linen thread. A similar process, called *dew retting,* is used in the moist fields of Ireland, France, and other countries with a cool, moist climate. Dew retting is similar to water retting except that other kinds of organisms are involved.

The tobacco industry makes use of bacterial action in the curing process. Stalks and leaves of the tobacco plant are harvested and hung in special curing barns where sweating occurs at cool temperatures. Bacteria invade the moist leaves and cause fermentation, resulting in special flavors.

The tanning industry, likewise, makes use of bacteria in the processing of leather and animal hides. Tanning involves several processes, some purely mechanical and others bacterial. Hides are soaked in large tanks containing tan bark. It is during this process that bacteria attack the hides and make them pliable.

In the dairy industry, bacteria are used

Philip D. Gendreau, N.Y.

A Silo. Corn stalks fermented in a silo make excellent feed for cattle.

in the production of *ensilage* [*en'sill age*] for dairy cattle. A special structure called a *silo* [*sy'lo*] is filled with shredded corn stalks and leaves which are fermented by souring bacteria. Fermenting not only preserves the ensilage but adds acid which is of value in the diet of dairy cattle.

Bacteria in the soil. Several kinds of bacteria which live in the soil should really be classed as essential rather than merely beneficial. Without them higher plants could not obtain their necessary soil elements. They form a vital link in the constructive and destructive processes which constitute the chemical cycles of living things. You learned that plants remove mineral compounds containing nitrogen, phosphorus, potassium, and sulphur from the soil and use them in the formation of complex organic compounds. Thus, these essential soil materials are temporarily "lost" from the soil, but will be replaced upon the death of the organism. Before these elements can be used again, the complex compounds composing the organism must be returned to simpler forms. Undecomposed plant and animal remains are unfit for use by other plants. At this point in the cycle, bacteria enter, and render one of their most valuable services. During *decay,* certain kinds of bacteria attack the complex organic compounds composing the plant and animal substance and convert it to simpler compounds. The odors characteristic of decaying organic matter are such simplified compounds in the form of gases. One of the most important of these gases is ammonia, a form in which nitrogen is released from protein substances.

With the production of ammonia, a second group of soil bacteria enter into the important nitrogen cycle. During a process called *nitrification* [*nit re fi kay'shun*], bacteria act upon the ammonia and convert it into mineral compounds called *nitrates.* While ammonia is a form in which nitrogen cannot be

Nitrogen-Fixing Bacteria. Nodules of nitrogen-fixing bacteria on the roots of clover.

obtained by plant life, nitrates are readily absorbed as nitrogen-yielding compounds. Thus, soil fertility is related directly to the activity of decay and nitrifying bacteria.

Still another group of bacteria, the *nitrogen-fixing organisms,* is essential in the formation of nitrates but in a manner quite different from the nitrifying bacteria. Nitrogen fixers live in swellings or nodules on the roots of clover, alfalfa, soybeans, and other plants of the legume (bean and pea) family. They do the host plant no harm and, in turn, add greatly to soil fertility by forming nitrates from the gaseous nitrogen of the atmosphere. These organisms are unique in carrying on this activity because no other plants can use this readily available source of nitrogen. Nitrogen fixation does not require organic matter as a source of nitrogen. Hence, it is an ideal method of restoring nitrates to the soil. Farmers make use of the activity of these organisms in the practice of crop rotation. After growing crops of corn, wheat, or other cereals for several years, the soil usually becomes deficient in nitrates. Accordingly, clover, alfalfa, or some other legume crop is grown to introduce nitrogen-fixing bacteria into the soil. During a single season these organisms may produce enough nitrates to supply other crops for several years. The clover or alfalfa is usually plowed under and increases the supply of available nitrates.

Not all soil bacteria carry on beneficial activities. One such group of organisms, called *denitrifying* [*dee nit′ri fying*] bacteria, reduces nitrates in the soil to ammonia, thus losing the soil fertility. Denitrifying bacteria are anaerobic and do not thrive in cultivated soil. When soil becomes waterlogged, however, denitrifying bacteria become active, which explains why flooded fields lose their fertility so rapidly.

Bacteria of special significance. A discovery rivaling that of penicillin in its importance to medicine provided a new drug to the series with which we are now able to control many dreaded infectious diseases. This latest germ killer, called *streptomycin* [*strep to my′sin*], is effective in the treatment of certain diseases, although it is still in the experimental stage. It is an effective " team mate " with penicillin in the war against disease. Strange as it may seem, streptomycin is a product of soil bacteria. The organism which produces it is a filamentous kind of bacterium somewhat resembling a mold. Bacteriologists classify it as one of the *Actinomyces* [*Ack ti no my′sees*], a name given to this group of organisms. The use of streptomycin is an excellent example of the manner in which science can use bacteria to fight bacteria.

Harmful bacteria. One of the most destructive activities of bacteria is the spoilage of food. Decay and fermentation may be extremely harmful when it occurs in our food supply. Certain bacteria produce poisonous substances during the breakdown of foods which may cause illness or death if consumed by man. In other cases, the food may be simply rendered unfit for use.

Various processes such as sealing food in airtight containers, drying, freezing, and cold storage are used to prevent bacterial action. Milk may be freed of most dangerous bacteria by *pasteurization* [*pass tur iz ay'shun*], which means heating to a temperature of from 140 to 150° F. for a period of thirty minutes, and then cooling quickly. Pasteurization does not completely sterilize milk. It merely destroys the majority of bacteria present, including those capable of causing disease. While pasteurization delays souring, the milk must be kept closed and cool to prevent the entrance of souring organisms from the air and the multiplication of those already present.

Pathogenic bacteria. The name *pathogenic* is reserved for the most destructive of all bacteria, the forms which cause disease. The study of disease requires a knowledge both of the organisms which cause infection and of the organisms attacked. One cannot understand infectious diseases of man without a knowledge of the human body. For this reason, the study of disease will be reserved for a later unit, following the study of human biology.

Summary

Bacteria are the smallest and simplest of the fungus plants. They average from about one ten-thousandth to one fifty-thousandth of an inch in diameter. They live almost everywhere and are the most widely distributed forms of life. Bacteria are dependent plants and, like other fungi, must live in association with a host. They may endure for long periods in a dormant condition.

Bacteria multiply at a very rapid rate under ideal conditions by cell division. Actively growing cells require food, warmth, moisture and darkness, although the spores of certain bacteria may endure extreme heat and cold.

Most bacteria are neither beneficial nor harmful to man. Certain kinds of bacteria are extremely beneficial, however, and are used in food processing and in other industrial processes. Decay, nitrifying, and nitrogen-fixing bacteria are vital in maintaining soil fertility. A most striking use of bacteria is in the production of streptomycin, a powerful new weapon against disease.

Bacteria cause great harm in the spoilage of food and as causative agents of disease. Bacteria which produce disease are given the special name, pathogenic. They are the most destructive because they endanger man's health.

Using Your Knowledge

1. What characteristic of bacteria classes them with the other fungus plants?
2. Where are bacteria found?
3. Into what three general groups may bacteria be classified on the basis of their importance and the nature of their various activities?
4. Into what three groups may they be divided according to form?
5. Describe various ways in which bacteria are joined together to form colonies.
6. How do you explain the apparent mathematical impossibility, "bacteria multiply by dividing."

7. Explain why spore formation in bacteria is not a method of multiplication.

8. Enumerate the three conditions which are necessary for the growth of most bacteria.

9. Distinguish between aerobic and anaerobic bacteria.

10. Discuss the use of culture media in the laboratory growth of bacteria.

11. Name four general ways in which bacteria are beneficial to man.

12. With what chemical element are the more common forms of soil bacteria especially concerned?

13. Mention three ways in which bacteria may be harmful to man.

Expressing Your Knowledge

bacteriology	Streptobacillus	smear
filterable virus	spirillum	retting
harmless bacteria	ultra-violet	ensilage
beneficial bacteria	aerobic	decay
pathogenic bacteria	anaerobic	nitrification
coccus	culture medium	nitrogen fixing
Diplococcus	Petri dish	denitrification
Staphylococcus	sterilize	streptomycin
Streptococcus	inoculate	Actinomyces
bacillus	incubate	pasteurization

Applying Your Knowledge

1. Make a series of drawings to illustrate the form of coccus, bacillus, and spirillum bacteria and the various colonial forms of coccus and bacillus.

2. Calculate the number of bacteria a single cell can produce over a twelve-hour period if all cells multiply every thirty minutes. Continue your calculations to include a twenty-four-hour period.

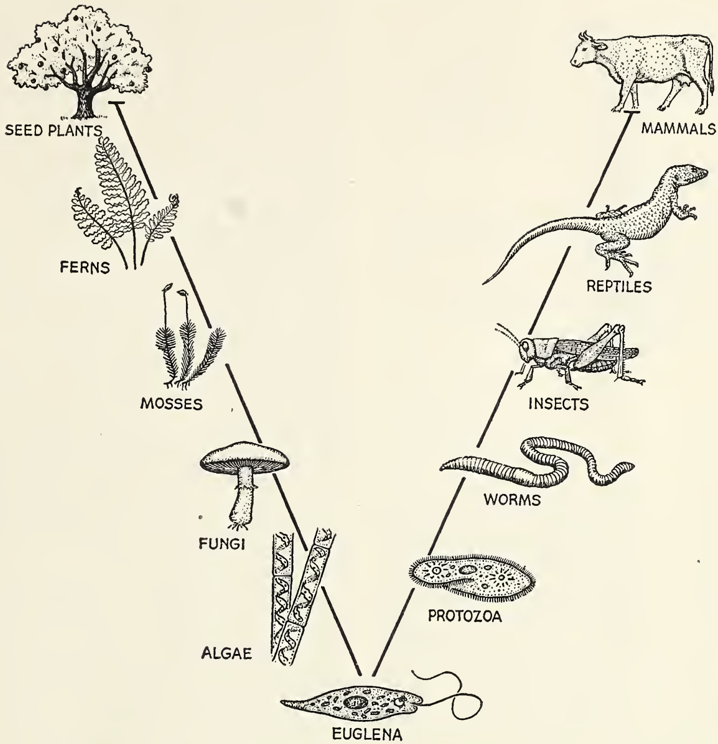
3. Place a small drop of water containing decayed or fermented organic matter (black in color) under the high power of a microscope. See if you can observe motile forms of bacteria.

4. Prepare a report on the relation of bacteria to one of the many food or industrial processes with which they are concerned.

Chapter 24

Microscopic Animal Life

Having become acquainted with some of the Thallophyte plants which compose the vegetation of the microscopic world, we now turn our attention to the animal life of this strange society of minute living things. Your first glimpse of these tiny creatures will be even more impressive than a trip through a zoological garden. You will discover animals totally different from the inhabitants of

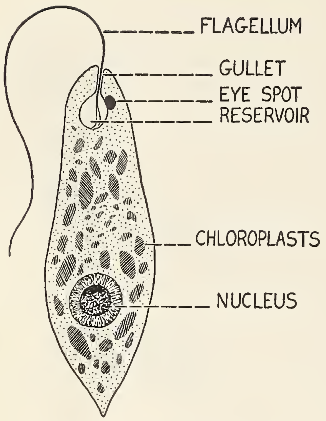


PLANT AND ANIMAL LIFE. Plant life is represented on the left side of the "V"; animal life on the other.

the forest and field. Thallophyte jungles abound with creatures which look like tiny slippers or curious bells with stalks, which propel themselves through the tangled filaments of vegetation in search of prey. Now and then, a shapeless mass of animal matter may be seen moving slowly across the jungle floor, consuming smaller creatures which lie in its path. Strange indeed are the animal inhabitants of a drop of pond water.

These tiny creatures are the simplest of all animals. Their bodies consist of a single animal cell, living a solitary existence, yet capable of performing all of the processes of life. Protoplasm becomes even more striking when we see one of these tiny one-celled creatures moving about, taking in food, throwing off waste products, and reproducing at regular intervals without any specialized organs with which we usually associate these processes. Biologists call these one-celled organisms *Protozoa* [*Pro to zo′a*], which means, literally, "first animals." They are well named, for they are truly the beginning of all animal life — animal life in its most primitive form, as we shall see in this chapter.

Plants, animals, and basic forms of life. You know that plant life and animal life are basically similar because



EUGLENA, PLANT OR ANIMAL?

plants and animals are composed of a universal substance called protoplasm. This may have been hard to understand, because we think of plants as trees and shrubs and animals as dogs, cats, and horses. But in the realm of microscopic life, this similarity is much more evident. Let us visualize all life as a " V," with plant life representing one side of the " V " and animal life the other. At the top of the plant side we find the seed plants, with complex tissues and specialized organs such as leaves, stems and roots. As we follow the line downward, plants become more and more simple, until we arrive at the primitive algae and fungi at the base of the line. The complex animals, like horses, cattle and man are found at the top of the other side of the " V." These organisms, like higher plants, are extremely specialized and possess complex animal organs such as muscles, hearts, and brains. They are quite unlike the higher plants and are widely separated from them at the top of the " V." But farther down the animal kingdom one finds the simpler creatures, tending to have much more in common with plant life. At the bottom of the animal kingdom are the one-celled animals, or Protozoa. At the base of the " V," the two kingdoms unite, and an organism called *Euglena* is found. We shall consider this tiny creature which possesses characteristics of plant and animal life.

Euglena, plant or animal? This tiny creature is quite unaware of the confusion it has created among scientists in trying to decide whether it should be considered a plant or an animal.

Euglena [*you glee'nah*] is found abundantly in fresh-water ponds and streams where it is often so abundant that the water appears a brilliant green. One who watches for this condition in the pond or stream will be rewarded with a nearly pure culture of the organism for laboratory study.

Under the microscope, *Euglena* appears as a spindle or pear-shaped cell which swims about freely in a spiral or twisting path. The front or anterior end of the organism is rounded, while the rear or posterior end is usually pointed. Locomotion is accomplished in two characteristic ways. The creature swims by means of a long whip or flagellum which is attached to the anterior end and is nearly as long as its one-celled body. As the flagellum lashes from side to side, the organism is pulled rapidly through the water. Another type of locomotion is accomplished by a gradual change in shape of the entire cell. The posterior portion of the body is drawn forward, causing the cell to assume a rounded form, after which the anterior portion is extended, thus pushing the cell forward. This type of movement is so characteristic of *Euglena* that it is termed " *euglenoid movement*." Both types of locomotion may be observed readily under the microscope.

The internal structures of *Euglena* show an interesting combination of plant and animal characteristics. The outer covering is a thin, flexible membrane, resembling the membranes of typical animal cells. At the anterior end of the cell is a *gullet* opening which leads to an enlarged *reservoir.* While the gullet and reservoir are not used to admit food, they closely resemble similar structures found in distinctly animal relatives of *Euglena.* Near the gullet is a very noticeable red *eyespot.* This tiny bit of specialized protoplasm is especially sensitive to light and serves to direct the organisms to bright areas in its habitat. Near the center of the mass of cytoplasm which fills the cell is a large nucleus.

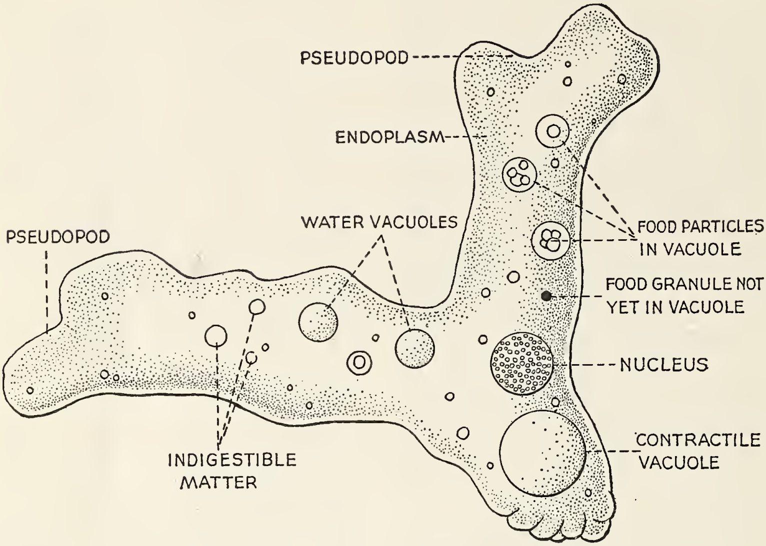
Perhaps the most striking plant characteristic of *Euglena* is the presence of numerous oval *chloroplasts* which are scattered through the cytoplasm. These bodies contain *chlorophyll.* Consequently, *Euglena* carries on photosynthesis and lives independently of any outside source of food. Certain kinds of *Euglena* exhibit a means of obtaining food when grown in the dark. The cells lose their chlorophyll and, consequently, their ability to carry on photosynthesis. They begin the absorption of soluble organic matter from the water in which they live. Food materials pass through the cell membrane in a manner characteristic of animal cells. Thus, these organisms live as green plants in the presence of light, but assume a form of animal nutrition when light is not available.

Euglena multiplies rapidly under ideal conditions by the process of cell division. A mature organism splits lengthwise, forming two new cells. Thus, a few *Euglena* may give rise to teeming millions within a few days, if conditions for growth are favorable.

Amoeba, a living mass of jelly. Living or animated jelly is the best description of this organism, the most primitive of true animals. One who has never watched one of these lowly creatures flow across the field of a microscope has a new thrill in store. At first you may overlook *Amoeba* [*Am ee'bah*] as a particle of nonliving matter, for it bears little resemblence to other members of the animal kingdom. But the fact that this tiny mass of grayish jelly moves of its own accord, consumes food, and grows in size places it immediately in the realm of animal life.

Amoeba is barely visible to the naked eye when it is mounted on a microscope slide or confined in a small glass dish. When collecting the organisms in their native haunts, however, one merely takes samples of the slime at the bottom of streams and ponds and from the surface of the leaves of aquatic plants and examines them in the laboratory for the presence of *Amoeba* cells. When the cells are located, they may be cultured in the laboratory in covered dishes containing the water in which they were collected or distilled water containing the slime in which they normally live.

Under the microscope, the *Amoeba* appears as an irregular mass of jellylike protoplasm surrounded by a thin membrane. When the animal is active, its cytoplasm exhibits a constant flowing motion. This moving cytoplasm presses against the thin cell membrane resulting in numerous projections called false feet or *pseudopodia* [*soo doh pod'ia*], characteristic of the organism. The cytoplasm is of two types, an outer, thin layer of watery *ectoplasm* [*eck'toh plazm*], and an inner area of *endoplasm* [*end'oh plazm*] which resembles gray jelly with pepper sprinkled through it. The *nucleus* is a large, spherical mass of

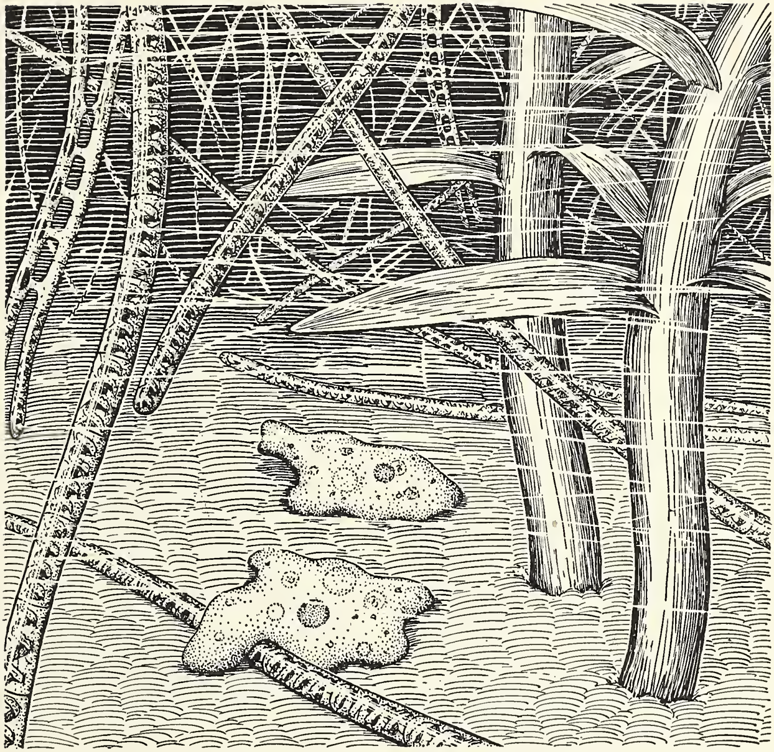


STRUCTURE OF AMOEBA

protoplasm, somewhat bronze colored, and changing its position continually with the flowing cytoplasm. Scattered through the cytoplasm are numerous food particles, contained in tiny cavities or *vacuoles*. Additional vacuoles, appearing as clear bubbles in the cytoplasm, contain water. Another vacuole may be seen to expand slowly, forming a large, clear bubble and then contract suddenly forcing out its contents and disappearing. This is the *contractile vacuole* which collects water from the cytoplasm and discharges it through the outer membrane.

Amoeba obtains food by extending pseudopods and actually flowing around each particle. As a food particle enters the cytoplasm, it is surrounded by a thin membrane and is thus enclosed in a vacuole. Digestion is accomplished by means of secretions formed by the cytoplasm which pass into the vacuole and act upon the food substances. Digested food enters the cytoplasm, where it may be oxidized to release energy or assimilated to form additional protoplasm. Undigested particles remain in the vacuole and pass out of the cell at any point in the membrane. Oxygen is absorbed directly from the water and enters the protoplasm through the entire surface of the membrane. Thus, with the exception of the nucleus which is specialized for reproduction, the entire mass of protoplasm is directly concerned with the performance of all of the life processes and lacks the specialization of the cells of more complex organisms.

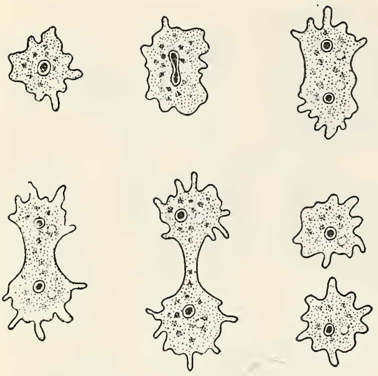
The response of *Amoeba* to conditions around it is an ideal illustration of the sensitivity of protoplasm. It has no eyes, yet it is sensitive to light and seeks areas of darkness or dim light. It has no nerve endings such as we associ‹te with the sense of touch, but reacts ‹o jarring and moves away from obj‹ ‹s which it contacts in the water. The ‹ -



AMOEBAE AND ALGAE. Two amoebae are making their way amidst a group of algae across the bottom of the pool where they live.

sponse to food may be illustrated by placing small quantities of food materials in a culture. The fact that the organisms congregate in the food area indicates that a stimulus rather than mere chance directed the cells to the food supply. Unfavorable conditions, such as dryness and cold, cause an *Amoeba* to withdraw its substance into a rounded mass called a *cyst* [*sist*]. A hardened shell secreted by the protoplasm protects the organism from unfavorable conditions during this resting period. With the return of favorable conditions, the organism emerges from its protective cover and resumes active life.

Reproduction in Amoeba. In the presence of abundant food and ideal conditions for growth, *Amoeba* rapidly reaches maximum size. Reproduction occurs when the mass of protoplasm has become as great as the membrane surface can supply with food, oxygen, and waste-removing area. Accordingly, the mass must be reduced. This is accomplished by separation of the mature *Amoeba* into two smaller organisms. The nucleus divides first, forming two similar portions which move into opposite ends of the cell. The rest of the protoplasm then separates gradually, forming two separate masses, each with



Stages in the Reproduction of Amoeba

a nucleus and capable of independent life and growth.

Amoeba-like organisms. There are nearly a thousand kinds of Protozoa which resemble *Amoeba*. Some of these forms live as parasites in man and other animals where they may produce disease. Other curious relatives of *Amoeba* secrete layers of flint or limy material in the form of a shell. These shelled protozoans are so abundant in the tropical seas that they tinge the water white. Their shells falling to the bottom make deposits of limestone, such as the chalk cliffs of England. Some of the pyramids of Egypt are made of stone formed from such protozoan deposits.

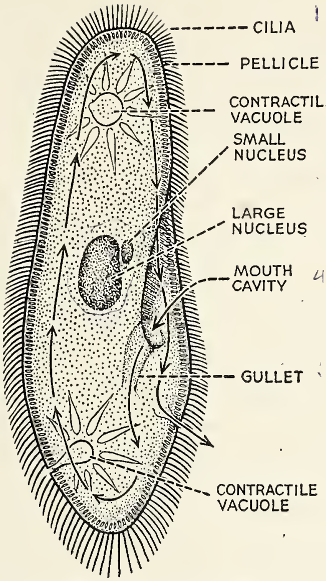
The Paramecium, a complex protozoan. *Amoeba* illustrates the ability of a simple mass of protoplasm to perform the life processes without the aid of specialized structures. *Paramecium* [*para mee' cium*], another protozoan, shows how specialized the protoplasm of a single cell may become.

Paramecia live abundantly in stagnant water, where they often form a milky scum on the surface. They may be cultivated in the laboratory by making a *hay infusion*. Place some dry hay or leaves in distilled water and add a portion of pond water containing paramecia or the contents of a commercially prepared *Paramecium* culture. Place the infusion in a warm area of the laboratory for several days. The liquid will soon be swarming with various kinds of Protozoa (if pond water is used) many of which will be paramecia. The paramecia have multiplied enormously, using the hay or leaves as food. Contrary to common opinion, the organisms do not come from the hay or leaves, as paramecia do not form cysts and cannot survive in such dry surroundings. In the absence of water they die.

Paramecium is called the " slipper animalcule " because of its shape, which resembles the sole of a shoe. Its definite shape is in contrast to the ever-changing form of *Amoeba*. But *Paramecium* is in no sense rigid and can bend around an object which it chances to meet in swimming. The form of the cell is due to a thickened membrane called a *pellicle* [*pell'ickle*] which surrounds the protoplasm.

Perhaps the most striking characteristics of this one-celled animal is its rapid movement. When placed on a microscope slide for examination, it swims rapidly through the thin film of water between the slide and cover glass. A few strands of cotton or filaments of algae serve as effective barricades in preparing a slide for examination of these fast-moving organisms. Movement is accomplished by tiny hairlike *cilia* [*sill' iah*] which project through minute openings in the cell membrane. These cilia are arranged in rows and are lashed through the water like tiny oars. While they cover the entire cell, they are most easily seen along the edges of the organism.

Another striking feature of *Parame-*

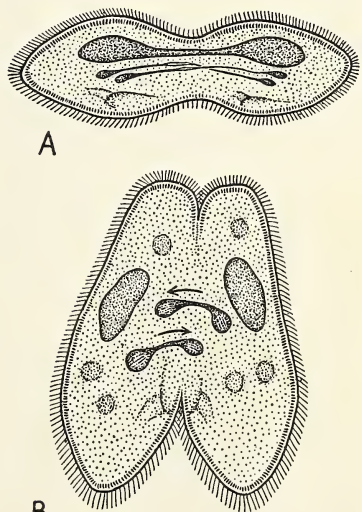


Structure of Paramecium

cium is a deep *oral groove* or cavity along one side of the cell. This hollow area causes the animal to turn over in the water in propeller-like fashion as it is pushed forward by the action of its cilia. *Paramecium* has a definite anterior end which is rounded, and a pointed posterior end — a perfect design in streamlining. The oral groove runs from the anterior end toward the posterior end. At its lower end, the oral groove forms a narrow gullet which leads into the cell protoplasm. The top of the gullet is called the *mouth cavity,* and marks the point at which food enters the gullet. The oral groove is lined with cilia which lash inward toward the gullet. The action of the cilia and the forward movement of the organism forces food particles into the gullet, from which they enter the cell protoplasm in the form of food vacuoles.

The internal structure of the cell illustrates a high degree of specialization of protoplasm. Like *Amoeba,* the cytoplasm of *Paramecium* is in a constant state of motion. In *Paramecium,* however, the flow is confined by the outer membrane and follows a circular course around the cell. Food vacuoles circulate with the cytoplasm, digestion occurring in the vacuoles during the process. Undigested food passes to a special opening through the cuticle called the *anal* [*ay' nal*] *spot.* This tiny opening, quite difficult to detect, is located near the posterior end of the cell.

The *contractile vacuoles* are always two in number and have a definite location, one in either end of the cell. Surrounding each vacuole are numerous canals which radiate from the central cavity into the cytoplasm. The canals enlarge as they fill with water, after which their content is passed to the central vacuole and discharged at the surface.



Paramecium. A. Dividing cell. B. Conjugating pair of cells.

Reproduction in Paramecium. The high degree of specialization of *Paramecium* is illustrated further in its reproductive processes. The organism possesses two different nuclei which are located near the center of the cell. A *large nucleus*, or *macronucleus*, seems to regulate the normal activity of the cell. Near the large nucleus is a *small nucleus* or *micronucleus* which functions during reproduction. Just why *Paramecium* should have two nuclei is not clearly understood. Apparently, the functions of the nucleus, which are the regulation of normal cell activities and the control of reproduction, are divided between two specialized bodies.

Reproduction involves two distinct processes, *fission* and *conjugation*. Fission involves the separation of a cell into two parts in a manner similar to the reproduction of *Amoeba*. Both nuclei elongate and pull apart, half of each migrating to either end of the cell. Following division of the nuclei, a constriction forms through the center of the cell, cutting it into two portions of approximately equal size. The lower portion of the oral groove and the gullet remain with the lower daughter cell. These parts are soon reformed by the upper daughter cell during a remarkable process termed *regeneration*. Fission may occur several times a day under ideal conditions, but usually after a limited number of divisions, the process of conjugation occurs.

During conjugation, two paramecia cells unite by joining the region near the mouth cavity, and their cell membranes become thin at the point of union. Complicated divisions occur in the nuclei, resulting in the formation of numerous particles of nuclear material. An exchange of particles then takes place, resulting in a mixture of the nuclear content of the two cells. Each cell contains, therefore, part of its original nucleus and part of the nuclear material of the other cell. Following conjugation, the nuclei reorganize and the cells separate and go their separate ways.

Conjugation is not a method of multiplication as no new individuals are formed. Rather, it results in rejuvenation of the cells, increasing their vitality and enabling them to continue reproduction by fission. It bears some resemblance to conjugation in *Spirogyra* but differs essentially in that no zygospore is formed.

Sensitivity in Paramecium. The reactions of paramecia cells to conditions around them is remarkable, considering that this animal, like Amoeba, possesses no specialized sense organs. Except when feeding, the cells swim constantly, bumping into objects, reversing, and moving around them in a trial and error fashion. How a tiny mass of protoplasm may sense the location of an object, reverse its cilia and continue in a new direction is beyond explanation except in terms of the properties of this wonderful living substance. Excessive heat and cold, chemicals, and food substances cause definite reactions in *Paramecium*. One of the most striking sensitivity reactions occurs when the organism is molested by enemies and at certain times when it is feeding upon smaller organisms. Special protoplasmic threads called *trichocysts* [*trick′oh sists*], which normally appear as minute lines just within the outer membrane are exploded into the water through tiny pores. The trichocysts are quite long and, when exploded, give the organism a bristly appearance. Perhaps this sudden outburst is intended to impress another organism about to attack *Paramecium*. Actually it is one of many automatic responses of protoplasm to its surroundings.

Paramecium is one of a great number of similar Protozoa called *ciliates,* because of the numerous hair-like cilia which cover their cell surfaces. Other members of this large group are found abundantly in samples of pond water. One can hardly collect specimens of *Paramecium* without finding numerous species of these other ciliates in the culture.

Specialization of protoplasm in the Protozoa. *Euglena, Amoeba,* and *Paramecium* were selected as typical examples of Protozoa. Biologists have found more than 15,000 different species of Protozoa, all one-celled animals, ranging from simple creatures like *Amoeba* to complex ciliates like *Paramecium.* The progression through these organisms from simple to complex forms illustrates the increasing specialization of protoplasm. Different degrees of specialization are especially well illustrated in a comparison of the structure and activity of *Amoeba* and *Paramecium.*

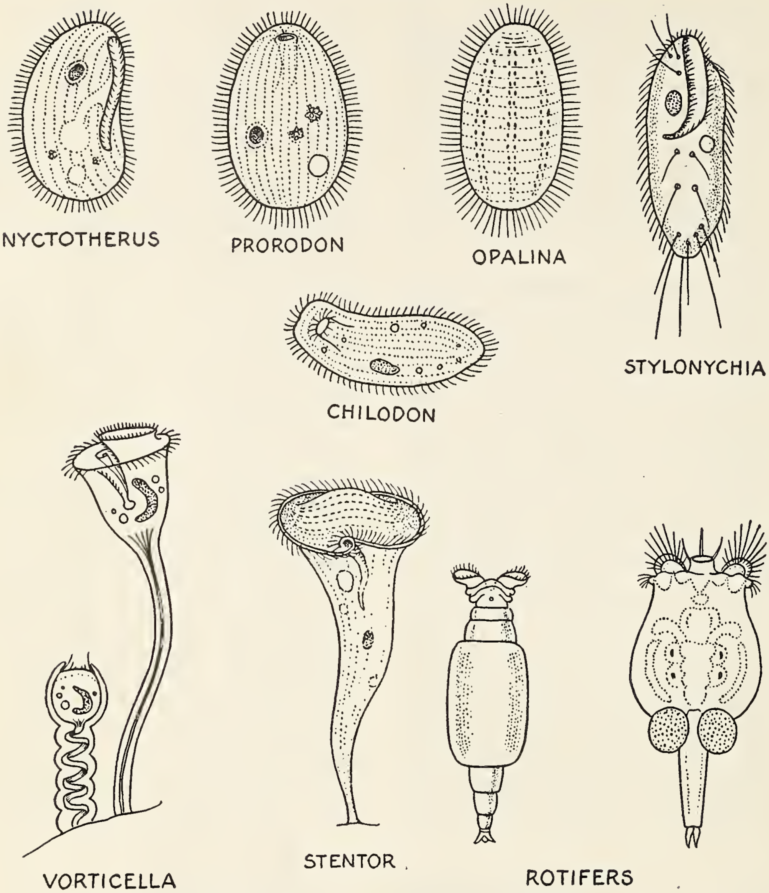
Economic importance of the Protozoa. Most of the Protozoa lead a rather unimportant existence in the fresh-water ponds and streams. Certain of their number, however, are of great economic importance to man because of the nature of their activities.

Some protozoans are parasitic, attacking man and other animals and producing disease, much as bacteria do. They are often classified with the latter as "disease germs." If we realize that these terms include both one-celled parasitic plants (bacteria) and one-celled parasitic animals (Protozoa), then their use is correct. One of the earliest protozoans to be studied was a parasite which caused enormous losses among the silkworms in southern France. Louis Pasteur, the famous French scientist, isolated the microorganism causing the disease and saved the silk industry.

A certain kind of *Amoeba* may grow in the alimentary canal of man, producing a highly infectious disease called *amoebic dysentery.* While amoebic dysentery is very widespread and not uncommon in America, it is most highly prevalent in the tropics. Another type of *Amoeba* is fatal to turkeys. One of the most dreaded diseases of the tropics is *sleeping sickness,* caused by a protozoan called *Trypanosoma* [*try pan oh so'ma*], is spread by the *tsetse* [*tet'see*] fly, an African insect. A group of spiral-shaped

Comparison of "Amoeba" and "Paramecium"

	Amoeba	*Paramecium*
Form	Variable	Constant
Outer wall	None	Present
Locomotion	Flowing lobes, variable	Cilia, definite
Speed	Slow	Rapid
Food taken in	At any point	At definite region
Reproduction	Fission	Fission; conjugation
Food getting	Flowing lobes	Cilia
Oxidation	Contact with dissolved air	Same
Excretion	Vacuole, variable	Two vacuoles, definite
Sensation	Responds to heat, light, contact, moisture, etc.	Same



TYPICAL PROTOZOA FOUND IN STAGNANT WATER

organisms resembling both bacteria and protozoans in many respects and called *spirochetes* [*spy'ro keets*] cause diseases both in man and in other animals. The widespread human disease, syphilis, is caused by such an organism, as is "yaws," a disease of animals.

One of the most famous protozoan diseases, malaria, is caused by a protozoan of a type called a *Sporozoan* [*spor oh zo'an*]. The name, Sporozoan, refers to the spore-forming characteristic of this group of organisms. Malaria organisms enter the human blood stream through the bite of an infected *Anopheles* [*an off'fell eeze*] mosquito, an insect prevalent in warm regions of the earth. Malaria was an uncommon disease in North America until World War II when millions of soldiers were sent into the malaria-infested regions of the tropics. In spite of medical precautions, many of these men returned to the States as victims of this disease.

During the war years, scientists conducted extensive research in the field of protozoan diseases. The knowledge gained will unquestionably throw much more light upon the interesting group of parasitic protozoans.

Observing protozoans. The world of protozoans is sealed completely against your vision unless you have the help of a compound microscope. This means that probings into this realm of microorganisms may have all of the thrills of exploring an unknown country. Of the 15,000 known species, probably several hundred kinds are available in bodies of fresh water close to your home. An inexpensive microscope and a few sample bottles is all you need to become an amateur protozoologist. You will find a thrill in collecting various species, establishing your own cultures, and examining them regularly to detect changes in their animal population.

Summary

Protozoa, the simplest forms of animal life, are one-celled animals which function as complete organisms. They are especially interesting to the biologist because they illustrate the manner in which a single unit of protoplasm can perform all of the life processes without the aid of any specialized organs.

Euglena is a connecting link between the plant and animal kingdoms, since it has certain characteristics of both groups. This curious border line organism carries on photosynthesis in true plant fashion in the presence of light. Many kinds of *Euglena* assume an entirely different type of nutrition when confined in dark places and absorb organic food material through their outer membranes in the manner of an animal cell.

Amoeba represents the simplest forms of animal life. This shapeless mass of living protoplasm lacks the specialization of other protozoan cells, yet, in its primitive way, performs all of the processes of life. *Paramecium*, on the other hand, illustrates a high degree of specialization and lives a much more efficient existence than its lowly relative, *Amoeba*.

The greatest economic significance of the protozoans is found in those forms which live as parasites within the bodies of man and other animals, and which cause disease.

Using Your Knowledge

1. Why do the plant and animal kingdoms form an imaginary " V " rather than two parallel lines?

2. List the characteristics of *Euglena* which tend to make it animal and those which tend to make it plant.

3. Why is *Amoeba* considered to be even more primitive than *Euglena* and other Protozoa?

4. Describe the manner in which *Amoeba* obtains its food. What is this process called?

5. Describe motion in *Amoeba*.

6. Enumerate the specialized structures which are present in *Paramecium* which were not found in *Amoeba*.

7. Can you give any reasons why *Paramecium* needs two contractile vacuoles rather than one, as in *Amoeba*?

8. Describe conjugation in *Paramecium*, including the manner in which it occurs, changes within the cells during the process, and the result of the process.

9. Explain how paramecia multiply.

10. Describe various manners in which *Paramecium* demonstrates sensitivity.

11. Mention several ways in which protozoans are of economic importance to man.

Expressing Your Knowledge

Protozoa	ectoplasm	macronucleus
Euglena	endoplasm	micronucleus
euglenoid movement	food vacuole	trichocyst
reservoir	contractile vacuole	regeneration
gullet	*Paramecium*	ciliate
eyespot	cilia	microbe
Amoeba	pellicle	amoebic dysentery
animated jelly	mouth cavity	sleeping sickness
pseudopod	oral groove	spirochete

Applying Your Knowledge

1. Collect samples of water from several sources, including a stagnant pool, back waters of a stream, or a fish pond. See how many different kinds of protozoans you can find.

2. Prepare a hay infusion by placing hay, dry grass, or dry leaves into a container of distilled water and adding a sample of stagnant water from a pond. Paramecia may be added, also, by inoculating from a culture purchased from a supply house.

3. Make a chart of protozoan diseases, including the name of each disease, the organism afflicted, the nature of the disease, and the protozoan which causes it.

Increasing Your Knowledge of This Unit

ALLEN, P. W. *Story of Microbes*. 2d. Edition. John S. Swift Co., St. Louis, Missouri. 1938

ALLEN, P. W. *Microbes which Help or Destroy Us*. The C. V. Mosby Co., St. Louis, Missouri. 1942

BAYNE-JONES, STANHOPE. *Man and Microbes*. The Williams and Wilkins Co., Baltimore. 1932

BUCHANAN, ESTELLE D. and BUCHANAN, ROBERT EARLE. *Bacteriology*. The Macmillan Co., New York. 1938

BUCHSBAUM, RALPH. *Animals Without Backbones*. The University of Chicago Press, Chicago. 1938

CALKINS, GARY N. *The Smallest Living Things; Life as Revealed by the Microscope*. The University Society, New York. 1935

CHRISTENSEN, CLYDE M. *Common Edible Mushrooms*. The University of Minnesota Press, Minneapolis. 1943

COHN, F. J. *Bacteria: The Smallest of Living Organisms*. Johns Hopkins Press, Homewood, Baltimore. 1939

CONN, HAROLD J. *Bacteria, Yeasts and Molds in the Home*. 3rd Revised Edition. Ginn and Co., Chicago. 1932

COULTER, MERLE C. *The Story of the Plant Kingdom*. The University of Chicago Press, Chicago. 1935

DEKRUIF, PAUL. *Microbe Hunters*. Harcourt, Brace and Co., New York. 1939

DISRAELI, ROBERT. *Seeing the Unseen*. The John Day Co., New York. 1939

EPSTEIN, SAMUEL and WILLIAMS, BERYL. *Miracles from Microbes: The Road to Streptomycin*. Rutgers University Press, New Brunswick, New Jersey. 1946

FULLER, HARRY J. *The Plant World*. Henry Holt and Co., New York. 1941

HEGNER, ROBERT. *Big Fleas Have Little Fleas* or *Who's Who among the Protozoa*. The Williams and Wilkins Co., Baltimore. 1938

HEGNER, ROBERT. *Parade of the Animal Kingdom*. The Macmillan Co., New York. 1935

MORGAN, ANN HAVEN. *Fieldbook of Ponds and Streams*. G. P. Putnam's Sons, New York. 1930

RAHN, OTTO. *Microbes of Merit*. Jaques

Cattrell Press, Lancaster, Pennsylvania. 1945

Ratcliff, J. D. *Modern Miracle Men.* Dodd Mead and Co., New York. 1939

Rice, Thurman B. *Applied Bacteriology.* The Macmillan Co., New York. 1932

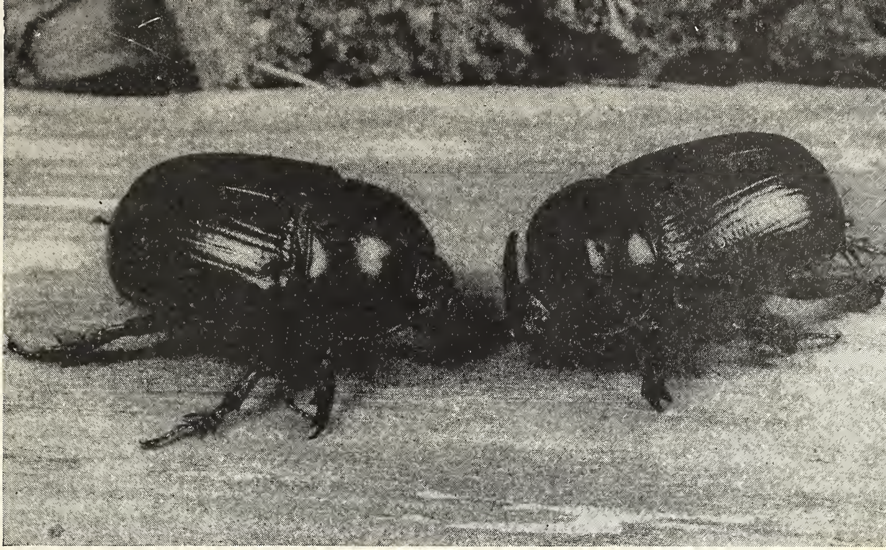
Smith, Gilbert M. *Freshwater Algae of the United States.* McGraw-Hill Book Co., New York. 1933

Taylor, F. Sherwood. *The Conquest of Bacteria, from Salvarsan to Sulphopyridine.* Philosophical Library, New York. 1942

Tiffany, Lewis H. *Algae, the Grass of Many Waters.* Charles C. Thomas, Publisher, Springfield, Illinois. 1938

Tressler, Donald K. *The Wealth of the Sea.* The Century Co., New York. 1927

Watson-Baker, W. *World Beneath the Microscope.* The Studio Publications, New York. 1935



Monkmeyer Press Photo Service

Unit 6 —

Simpler Forms of Animal Life

Animals are divided into two big groups: those having a backbone or spine — the vertebrates, and those lacking a backbone — the invertebrates. Biologists often refer to the invertebrates as simpler animals because their bodies lack much of the specialization and high degree of functional efficiency which are characteristic of vertebrates like the frog, bird, horse, dog, and man.

The spineless animals far outnumber the vertebrates, both as to kinds and actual number of individuals. They range in complexity from the one-celled protozoans you studied in Chapter 24 to more complicated forms like the mollusk, crayfish, and insect. Invertebrates live both on land and in the water, although the majority of them, especially the lower forms, require a strict water environment.

In your study of invertebrates, you will discover many kinds of animals which you had no idea were in existence. Strange, indeed, are many of these creatures.

Chapter 25

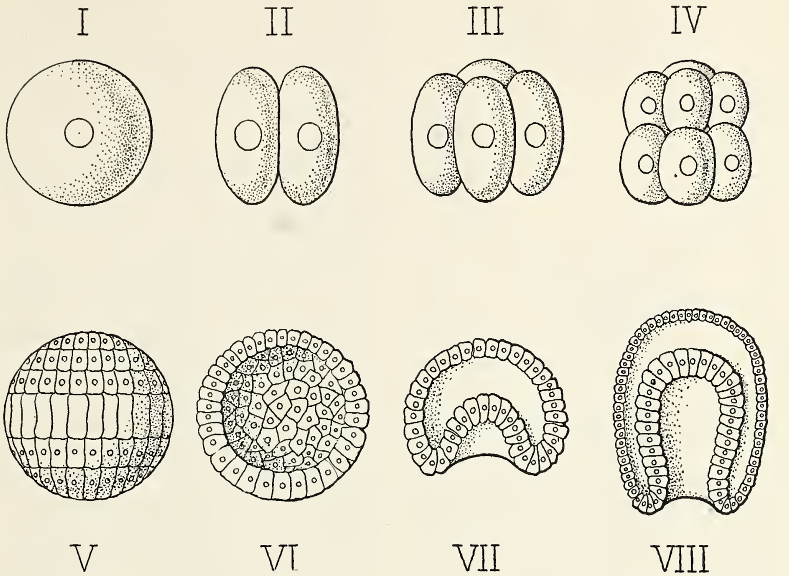
Animals with Many Cells—the Metazoa

Among the Protozoa, *Paramecium* is supreme, for it represents one of the most highly specialized of these one-celled organisms. But compared with fish or frogs or even the lowly worms, this one-celled creature is indeed primitive, in spite of its specialized cilia and gullet and contractile vacuoles.

The structure of a protozoan is limited to a single cell or a group of cells existing in a small colony. Since the size which a cell may reach is definitely limited, the size which the one-celled organism may attain is likewise limited. The one-celled organism is limited further in the degree to which its functions may become specialized. A single unit of protoplasm which must cope with all of the life problems of an organism cannot possibly become a specialist in the performance of any single activity. It is only when organisms consist of many cells, all working in close harmony, that protoplasm may reach the high degree of specialization which results in the marvelous activities of the higher forms of animal life.

In the study of the Metazoa you will deal with all of the forms of animal life with the exception of the Protozoa. All of the forms you will study are composed of many cells which function as a unit. Some will be rather simple in structure — others extremely complex. Activities of this extensive group of organisms will range from the automatic performance of the life processes to the wonderful degree of sensation you possess in being able to read and comprehend this printed page.

Development of the Metazoa. Changes occur slowly in living things. The high degree of mental efficiency you possess as a human organism is not the result of sudden changes. You have reached your present mental plane as a result of a gradual process of learning which began in infancy. So it is with the physical development of an organism. No matter how complicated a higher plant or a metazoan animal may eventually become, it begins life in a primitive one-celled condition. The life of a metazoan starts as a fertilized egg, resulting from the union of two specialized germ cells, the egg and the sperm. During this beginning stage, the most complicated organism does not exceed the protozoan either in size or in functional specialization. But where the protozoan is destined to remain in this primitive condition, the metazoan rapidly becomes more complex. The single egg cell soon divides to form first two, then four, eight, sixteen, and, within a short time, a mass of cells, arranged in a hollow ball. At this point, certain cells along the surface move inward and form an oval structure with both an inner and an outer layer. From this point on, the development of the organism becomes extremely complicated and should be left to the specialized study of biology called *embryology*. We may summarize these complicated changes in stating, merely, that cells become specialized and per-



Early Stages of Metazoan Development. I. Single cell. II. Two cell stage. III. Four cell stage. IV. Eight cell stage. V–VIII. Development of a mass of cells arranged in a hollow ball.

form certain activities. In more complicated animals, certain cells become a heart, while others develop into a brain, nerves, digestive organs, skeleton, and muscles. Each hour of change results in more specialized development. Cells become as members of a highly organized society—each fitted for the performance of a particular kind of activity and depending, in turn, upon other cells of the organism which are more highly efficient in performing other activities.

Division of labor. Robinson Crusoe on his island had to perform all the processes needed to supply his wants. He had to catch and prepare his food, make his clothes and shoes, build his house, and defend himself against enemies. Even though he became somewhat skilled at all these duties he could never hope to excel in any. He was, in fact, in the position of the protozoan, where all the life functions are performed by one cell. Even though that cell is as highly developed as in *Paramecium,* still its limit of advance is soon reached.

Now, if there had been ten men shipwrecked with Crusoe, it would have been possible for one to get food, another to prepare it, others to build houses, and so on. The increase in numbers permits *division of labor.* This is precisely the case with all higher types of organisms. The fact that there are a number of cells makes possible a separation of life functions, which is actually division of labor among cells.

If one man continued making shoes or another did all the building, each would soon acquire skill and perform his duty better; he would become a specialist in his line. Cells also are able to perform their functions better and better by constant use. In other words, they

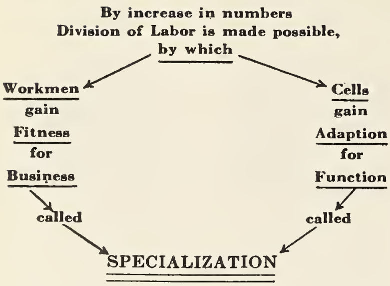


Chart Showing Development of Specialization

become specialists in a small way just as men do.

Finally, both cells and men would acquire special fitness for their tasks. This special fitness is called *adaptation* and is the permanent result of specialization. The more perfectly a plant or animal is adapted to its environment, the better is its chance to survive; hence this matter of development, division of labor, specialization, and adaptation is of the utmost importance.

Interdependence. There is, however, another phase of this matter of specialization which cannot be overlooked. The man who devotes himself solely to the making of shoes is liable to lose the ability to do many other important things. Similarly, cells and tissues which become adapted for special functions are dependent upon other specialized cells for equally important services.

So it is evident that the more highly specialized a plant or animal becomes, the more each part depends upon all the others, and the more difficult it is to replace or to live with a damaged tissue or organ. For instance, the muscle cells of the hand or foot require oxygen for the process of oxidation of food or protoplasm, to release energy for physical activity. They are too far away from the surface of the body to get oxygen directly from the air, as protozoans do through their cell membranes. Moreover, the skin of higher animals is relatively thick, and seals the muscles so well that little or no gas can be taken in through it.

To a lesser degree this is true of parts of plants distant from the leaves which require oxygen for cell activity.

Somewhere, therefore, there must be cells whose moist walls are thin enough to absorb oxygen, or the muscle cells are doomed. In animals that live on the earth or in the air such cells cannot be on the surface for there they would be exposed to the drying effect of the atmosphere. But in aquatic animals such oxygen-absorbing cells are frequently found on or close to the surface, i.e., in gills of fishes, tadpoles, salamanders, etc.

The cells concerned in obtaining oxygen *inside* of the body are in the form of lungs, where they can easily be kept moist and indefinitely continue to pass on oxygen to the blood to be carried to the muscle cells of the whole body by the red blood cells.

To a lesser degree the same sort of interdependence of cells operates in all metazoans.

Plants have the same fundamental functions as animals. Yet even in a specialized plant like a geranium where there is some division of labor between different structures, there is not the same need for co-ordination. This is partly due to the lack of activity in plants and the corresponding absence of muscles and appendages for locomotion. Then, too, the cell activities in plants function at a very slow rate compared with those of animals. Several dependent functions of plants are performed at the same time, yet with no brain or nervous system to assist in producing the resulting harmonious action.

COMPARISON OF PROTOZOA AND METAZOA

Protozoa	Metazoa
Minute size	Much larger size
One-celled	Many-celled
No true " body wall "	Body wall
No specialization in simplest forms except the nucleus	Specialized tissues and organs
Some have cell membranes, cilia, " mouth," etc. but no regular system of organs	Digestive, respiratory, nervous, and other systems
Excretion by vacuoles	Excretion by kidneys or analogous organs, such as skin, gills, or lungs
Reproduction by fission	Reproduction by budding and other asexual methods in lower forms; by eggs and sperms in higher forms
No embryonic development	Embryonic development

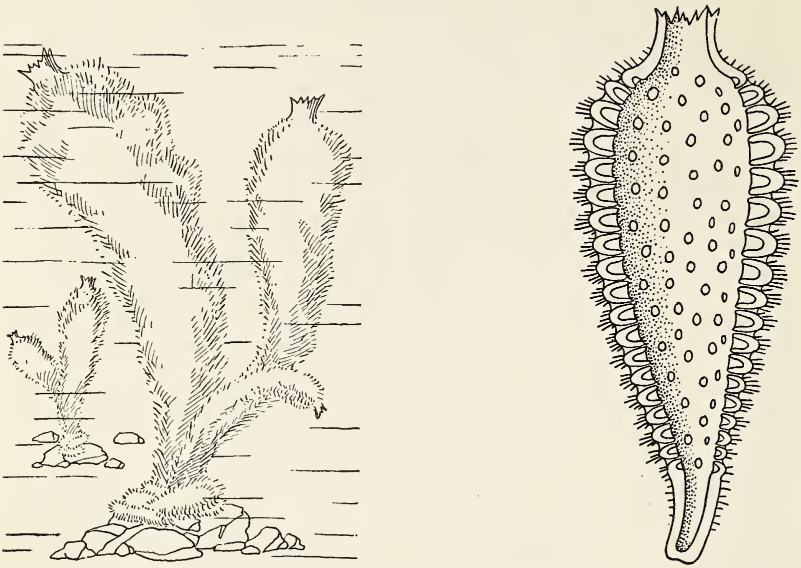
DEVELOPMENT OF TYPICAL METAZOA

Groups of Metazoans	Degree of Specialization	Representative
1. Sponges	Cells adapted for food-getting, digestion, reproduction, etc.	Bath sponge
2. Coelenterates	Tissues for the above processes and for locomotion	Hydra Jellyfish
3. Echinoderms	Some organs, true nerves, and eyespot	Starfish
4. Worms	Organs well developed, nerves, blood vessels, muscles, etc.	Earthworm
5. Mollusks	Sense organs, gills, heart, etc. more complicated	Snail Clam
6. Arthropods	Great specialization, external skeleton, all senses, very active, nervous system, instinct	Insects Crayfish Spiders
7. Vertebrates	Great internal specialization, high special senses, brain, instinct and reason, varied locomotion, internal skeleton, limbs not more than four	Fish Amphibia Reptiles Birds Man

Metazoans Without Backbones — The Invertebrates

The animals most commonly seen, such as the dog, cat, horse, and bird, are similar in possessing a bony column along the back called the " backbone." Each part of the backbone is called a vertebra. Hence, the scientist calls backboned animals *vertebrates.*

There are hundreds of thousands of animals, such as sponges, worms, insects, spiders, mollusks, and the like,



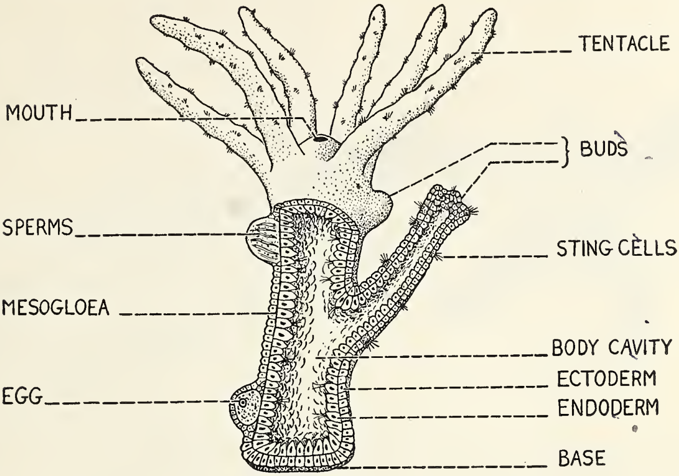
SPONGES. At left, the animals are shown growing under water where they are attached to rocks on the sea bottom. At right, one of these sponges sectioned to show the body cavity.

which never have a backbone and hence are called *invertebrates*. There are many more kinds of invertebrates than vertebrates, and the number of individuals is also much greater among the invertebrates.

Invertebrates are classified into groups according to the structure of their bodies. In the general survey of this portion of the animal kingdom, we shall consider certain of the more familiar groups of invertebrates and some of the individuals which compose them.

Sponges. Sponges are composed of groups of cells arranged in two layers, supported by a sort of primitive skeleton made up of *spicules* which are limy, silicious, or horny. A live sponge is usually a smooth brown mass provided with many holes for the passage of water, and having about the consistency of beef liver. The inner cells are ciliated and produce currents of water, bringing in food and carrying out wastes. The "sponge" of commerce is really the horny skeleton of the sponge animal, from which the jellylike flesh has been removed. Sponges grow attached to the sea bottom in various warm regions, such as the Mediterranean and Red seas and in the waters around the West Indies. Living sponges are collected by divers or by dragging hooks, and piled on shore until the flesh rots off. They are then washed, dried, sorted, and sometimes bleached.

To meet the depletion of the sponge supply, caused by its commercial use, sponge culture is now practiced. Living sponges are cut into small pieces which are "planted" on supports placed in selected regions in the sea. In about five years each segment has grown to marketable size. Sponges reproduce normally from eggs fertilized by sperms from the same individual or from an-



HYDRA

other sponge. Reproduction involving fertilization of eggs or other union of protoplasm is called *sexual;* when no eggs or union are involved, it is called *asexual.*

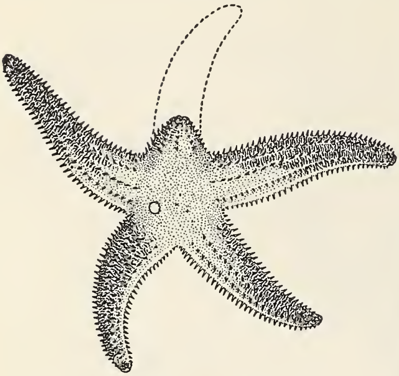
Coelenterates. Coelenterates are considered " higher " than sponges because they are structurally adapted for a more active life. They also have a distinct digestive cavity and sting cells. Most of them live in salt water and are called *marine,* such as corals, hydroids, sea fans, and jellyfish; many are brightly colored. The *Hydra* is a fresh-water form. Coral *polyps* are the only coelenterates of great importance to man, and their limy secretions form the extensive coral reefs north of Australia. Prehistoric coral reefs often form important limestone ledges such as those in New York. The red coral used for jewelry comes from the Mediterranean.

Hydroids are attached at the bottom or elsewhere in the ocean. They produce asexual buds which develop into free-swimming jellyfish. They, in turn, by sexual methods, produce new hydroids.

Echinoderms. These are spiny sea animals, the two most prominent representatives being the starfish and the sea urchin.

The starfish is common along the seacoast and is easily recognized by its five rays. In a groove on the lower side of each ray are double rows of tube feet.

The small opening in the middle of the lower side is the entrance to the stomach. The starfish has the ability to send its stomach outside of the body when it is attacking an object for food. It eats prodigious numbers of oysters and clams by arching itself over the shell and attaching its tube feet to the valves. Slowly it exerts more and more pull until it tires out the muscles of the oyster or clam and the valves open a little. Now the stomach of the starfish comes out and goes *to* the food instead of having the food brought to it. Gradually the folds of the stomach penetrate the interior and then actually digest and absorb the body of the oyster or clam.



STARFISH

Oyster fishermen used to tear starfish to pieces when they caught them, thinking that this killed them; but they found that each ray developed into a complete starfish by asexual reproduction. They had only assisted in multiplying their troubles. With modern biological knowledge, the fishermen now drag for starfish and then throw them on the beach out of water in the sun, where they soon die. Starfish produce enormous numbers of eggs which are fertilized in the water.

The sea urchin looks like an animated pincushion having long spines, among which are rows of tube feet like those of the starfish.

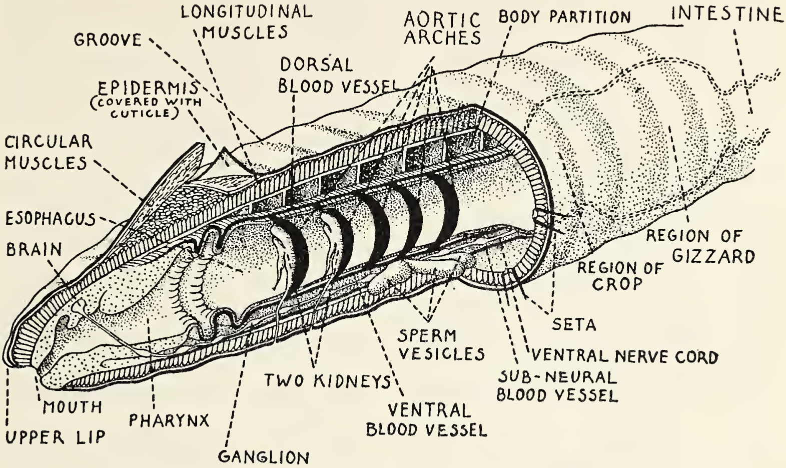
Worms. The word *worms* is used here to cover three forms: the true flatworms, such as the tapeworm, liver fluke, and *Planaria;* the roundworms, such as threadworms, pork worms, and hookworms; and the segmented worms, such as the earthworm, leech, and various marine worms. Most worms show a moderate degree of specialization. The earthworm is one of the most highly specialized.

Many animals called worms are not true worms at all but are merely an early stage in the life of some insect. Such are "apple worms," which hatch from the eggs of the codling moth, "wire worms," which actually are larvae of "click" beetles, and cabbage worms that develop into the common white butterfly.

The earthworm. If you examine an earthworm you will immediately note the rings or *segments.* The extremities seem to resemble each other, but the end which usually goes ahead, and is also darker, is the *anterior* end. There is no distinct head, nor can one find eyes or other sense organs. The somewhat crescent-shaped opening in the anterior end is the mouth opening. The vertical slit at the *posterior* end is the *anus* or the end of the intestine. Projecting from the lower side of each segment, except the first and the last, are four pairs of bristles or *setae* which are of definite assistance in locomotion and in clinging to the walls of the burrow. These setae are not visible without a hand lens.

The earthworm has no jaws or teeth. By means of its muscular *pharynx* or throat, however, it draws particles into its mouth and thus is able to bore into the ground, literally eating its way downward. Later it deposits on the surface of the ground, in the form of *casts,* parts of the soil not used by the body. This method of feeding loosens and enriches the soil, performing about the same function as the farmer's plow, more slowly but surely and to a much greater extent. Earthworms are found in all parts of the world in such numbers that Charles Darwin estimated that about 50,000 earthworms exist in the average acre of land, and that in certain localities an equivalent of eighteen huge wagonloads of soil per acre pass through their bodies every year.

The outside of the earthworm's body



Dissected Earthworm Showing Structure of Anterior End

is covered by a thin skin through which the animal breathes. This passage of oxygen and carbon dioxide will not take place, however, unless the skin is moist. Therefore, it is fatal for an earthworm to remain long enough in the sun for the skin to dry.

The earthworm, though it may appear to be simpler in structure than the echinoderm, really expresses division of labor among the organs of its body to a more marked degree, since it has special digestive, circulatory, and excretory systems of complicated structure and a true nervous system. There is no definite heart, but so-called "arches" pulsate and force the blood through the upper and lower blood vessels. In the skin the blood gathers oxygen and gives off carbon dioxide. From the walls of the intestine the blood absorbs digested food which with oxygen is carried to all cells of the body. In most of the segments there are two little tubes, corresponding to the kidneys of higher animals. A definite brain, a nerve collar around the pharynx, and a *ventral* cord with an enlargement, called a *ganglion,* in each segment, together with many branches from each ganglion, make up the nervous system. A skin which is very sensitive to touch takes the place of better sense organs.

A swollen region called the *girdle* secretes a case with eggs fertilized by the sperm of another worm, though each worm produces both eggs and sperm. These eggs hatch in the ground.

The leech or bloodsucker is a common segmented worm found in fresh-water ponds and streams. The sandworm, or *Nereis,* and many other marine worms, are found along the seashore.

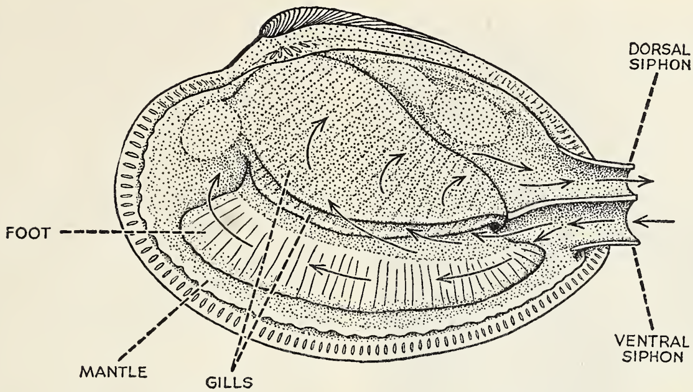
Among the common flatworms is the small ribbonlike *Planaria.* Though it usually reproduces sexually, if cut into pieces with scissors, each portion will grow into an entire animal. The *liver fluke* is another flatworm which, after living in the body of a snail, eventually reaches the liver of sheep and sometimes of human beings, causing great damage.

Parasitic worms. The humble earthworm is of great service to humanity. It has some relatives, however, which have degenerated into parasitic habits and do a great deal of harm. The parasitic worms well illustrate the degenerative effect of parasitic habits on animal structure. Among them are forms of pronounced economic detriment to man, such as the tapeworm, trichina, and hookworm. Almost all animals, from clams and insects to cattle and man, are subject to the attacks of parasitic worms.

Tapeworm. The tapeworm lives first within the body of pigs or cattle, its eggs being taken in with their food. It develops in the intestine, bores its way into the muscles and goes into a resting stage. If the flesh of such animals be eaten when not thoroughly cooked, the development continues in the intestine of man. The worm attaches itself by its head, living on digested food with which it is surrounded, and robbing its host of needed nourishment. It produces segment after segment till a length of thirty feet may be attained. These segments are practically sacs of eggs which break off from time to time allowing the eggs to escape, dry, and scatter where

Comparison of Life Histories of Three Dangerous Worms

Tapeworm	Trichina, pork worm	Hookworm
Adult segments pass off in intestinal waste These are really egg masses	Adults produce living young	Eggs pass off in waste
Eggs eaten by hogs or cattle	Hogs may get them from rats or from infected food	Eggs hatch into larvae in moist soil
Hooked larvae bore into muscle making "measly" pork or beef	Young bore into flesh and form cysts; cause disease in hog	Bore through skin of feet Many get in via food
Flesh not well cooked eaten by man	Flesh not well cooked eaten by man	Penetrate into blood vessels, thence to trachea, and are swallowed
Larvae developed into adult in intestine and attach to wall by hooked head Absorb digested food and produce eggs	Cyst dissolved; worms mate and produce young; larvae bore into the muscle, causing disease If patient survives, they form cysts and are inactive	Attach to upper intestinal wall and suck blood Produce more eggs
Usually one large worm in the intestine	Numerous small worms in the muscles and organs	Numerous small worms in the intestine
Robs body of food Interferes with digestion Lowers vitality	Causes acute painful and often fatal disease	Produces anemia and lowers vitality
Remedies: meat inspection and thorough cooking	Remedies: meat inspection and thorough cooking	Remedies: proper disposal of body wastes Cleanliness and wearing shoes Easily cured by simple treatment



A Bivalve Mollusk Showing Structure. The path of water is indicated by the arrows.

hogs or other animals may eat them and start the cycle over again.

Trichina. Another group includes roundworms and other parasites. The " vinegar eel " and the intestinal pinworms are comparatively harmless forms. The pork worm (*trichina*) of this same class may cause serious illness or death. These worms pass their first stage in the pig, dog, cat, or rat, where they bore into muscles, surround themselves with a coating (*cyst*), and remain alive but inactive. If man eats infected pork insufficiently cooked, the cyst is dissolved, the worms develop and mate in the human intestine, and the young embryos thus produced bore through the tissues. This produces the painful and often fatal disease known as *trichinosis*. The tapeworm is large; usually only one is present; and it does its chief harm to man by absorbing food needed to nourish the body. *Trichina,* on the other hand, is microscopic in size, vastly numerous, and produces acute disease by penetration of the tissues. Careful cooking of meats cannot be too strongly emphasized.

Hookworm. The hookworm of the southern states is a parasite which attacks man most often by way of the feet. Thence, by means of the veins, lungs, and throat, it penetrates to the intestines where it absorbs food and causes loss of blood. It is also introduced into the body through food that has been in contact with infected soil. It lowers the victim's strength and produces characteristic laziness. In spite of the wonderful remedial work accomplished by the Rockefeller Foundation, the hookworm still costs the country about twenty million dollars per year in loss of labor due to its effect on health.

The " horsehair snake," which you frequently find in ponds and streams, is not a northern hookworm, has nothing to do with horsehairs, nor is it a snake. It is one of the roundworms (related to the " vinegar eel," which is not an eel) and is parasitic on beetles and other insects, thus doing considerable good.

Mollusks. These animals were formerly called shellfish because the edible forms were found in the same waters with fish and most of them possessed shells. The name *mollusk* is derived from the Latin *mollis* meaning " soft," and refers to the unsegmented and usually soft body (as distinguished from the

Ewing Galloway, N.Y.

GEODUCKS. These giant clams (pronounced "gooeyducks") live two to three feet below the sandy bottoms of shallow waters along the Pacific Coast. They are highly prized as food delicacies.

shell) which generally includes a *mantle* and a muscular *"foot."* Primitive man, before he knew the use of fire, depended upon raw mollusks for much of his food, as the enormous shell heaps remaining to this day testify. Even yet we look upon oysters, clams, mussels, and scallops as useful foods — or luxuries — depending on how far we live from the seacoasts where they are obtained. In the case of scallops we eat only the white muscle which holds the shells together; of others we eat the entire body. Many Orientals eat the squid.

Bivalve mollusks. These mollusks all have two valves or shells, opening with a common hinge. Clams are found along the Atlantic Coast and to some extent, where transplanted, on the Pacific Coast. Oysters are abundant south of Cape Cod, with Chesapeake Bay as the center of the industry. To aid in the propagation of fresh-water mussels, whose shells are extensively used for buttons, the United States Bureau of Fisheries has built a biological station at Fairport, Iowa.

Economic products. In addition to buttons, ornaments, and crushed shell for chicken feeding, many bivalves and other mollusks provide "mother-of-pearl" and pearls. Pearls are found chiefly in pearl oysters (not the edible species) and are caused by the entrance into the shell of a grain or sand or other irritating substance such as a tiny worm. This causes the mantle of the oyster to secrete layer after layer of the substance normally deposited to form the pearly lining of the shells, to cover the offending particle, much as the hand grows a callous layer to protect it from irritation. The most valuable pearls are found in the Persian Gulf and off the coasts of Ceylon. Fresh-water clams too may produce pearls but they are darker colored. Irregular pearly deposits called "baroque" pearls are found largely in the Mississippi and its branches.

Monkmeyer Press Photo Service

A LAND SNAIL

Univalve mollusks. As the name implies, these mollusks have only one shell, a *calcareous* house which the soft-bodied tenant builds for itself on a spiral plan. In the cases of the slugs the shell has degenerated and is either very small or absent. Most of the *univalves* will be found to be snails, though the term properly should be applied to the common fresh-water and land forms rather than to the large univalves of the sea. The land snails of the tropics have very beautiful shells.

Ewing Galloway, N.Y.

An Octopus

Pond snails, like fresh-water mussels, make interesting inhabitants of an aquarium and render service as scavengers. The muscular waves of their flat "foot," by means of which they glide over the surface, can be observed through the glass. Of all the adaptations of snails the strangest is the location of the eyes on the tips of two collapsible tentacles. Touch the eyespot, and it will be drawn in, disappearing by *introversion* — as the toe of a stocking vanishes within if the stocking is being turned wrongside out. Left alone, the animal will soon reverse the operation.

Valveless mollusks. A third group of mollusks includes the squid, cuttlefish, octopus, and nautilus. The name *cephalopod,* by which they are called, comes from two Greek words: "Kephalos" meaning "head," and "pod" meaning "foot," and is applied to these animals because projecting from their heads are many tentacles which might be regarded as modified legs.

The nautilus has a shell whose beautiful spiral structure amazes us. How can a soft creature with no hands for measurements, no eyes to make comparisons, no instruments to produce constantly increasing curvatures, with no apparent intelligence, and without visible pattern, slowly deposit shell material in the dark depths of the sea and produce such an exquisite form?

The other three forms also possess shells, but they are modified structures and are internal. The "cuttlebone," familiar in the canary cage, is the internal shell of the cuttlefish. Man also obtains from the cuttlefish the true "sepia," a brown, inklike pigment, the base for "India ink," which the animal squirts out into the water to hide itself when attacked. Squid are used for fish bait and are eaten with great relish by the people of certain races.

Summary

Metazoans differ from protozoans in possessing a body composed of many cells. These cells are usually of many types, specialized to perform specific functions. This specialization, termed division of labor, is only slightly developed in the lower forms of Metazoa like the sponge and jellyfish and increases through the various groups of metazoans to reach its greatest degree in complex organisms like the horse, cat, and man.

The Metazoa are divided into two great groups — those without backbones, called invertebrates, and the vertebrates which possess a backbone composed of separate bones called vertebrae. The invertebrates are the largest group of Metazoa. They live abundantly in the seas as well as on land. One group, the worms, contains many examples which live within the bodies of other animals as parasites. The tapeworm, *trichina*, and hookworm are better known parasites upon man, where they invade the digestive tract.

Certain invertebrates, including the mollusks, sponges, and certain kinds of worms, have a distinct economic value, while others, like the jellyfish and sea urchin are of much less direct importance.

The most important group of invertebrates, the insects and their relatives, will be discussed fully in the following chapters.

Using Your Knowledge

1. What is the outstanding difference between the Protozoa and the Metazoa?

2. Describe the manner in which a single cell undergoes a series of divisions and begins to form the body of a metazoan.

3. How does increase in the number of cells in a metazoan permit division of labor? Explain.

4. Explain interdependence of the cells of a metazoan.

5. Distinguish between vertebrates and invertebrates.

6. Explain why the sponge is considered the most primitive form of metazoan life.

7. What is the usual habitat of the coelenterates? Name an exception to the rule.

8. Why are the various worms classified into three groups?

9. Name three worms which are parasitic in both man and animals.

10. Distinguish univalve, bivalve, and valveless mollusks. Give an example of each type.

Expressing Your Knowledge

Metazoa	spicule	girdle
embryology	coelenterate	ventral cord
division of labor	polyp	parasitic worm
adaptation	segmented worm	mollusk
interdependence	roundworm	bivalve
specialization	flatworm	univalve
vertebrate	setae	valveless
invertebrate	pharynx	calcareous
sponge	ganglion	cephalopod
echinoderm	sand worm	liver fluke

Applying Your Knowledge

1. Try making models of typical early stages in the development of a metazoan (one-celled, two-celled, four-celled, etc.). Use plaster of Paris (carve when wet) or papier-mâché (thoroughly soaked newspaper). Paint when dry.

2. Prepare a list of different individuals or concerns whose products have made " di-

vision of labor " possible during one day of your life.

3. Start a collection of shells, including bivalves and univalves from fresh water and salt water environments. You will find books to aid you in identification of shells available in the library.

4. Arrange a " nightcrawler " hunt some night during a warm, moist period of the spring or fall. Use a strong flashlight and see if you can surprise the large earthworms as they lie in the grass, extended from their burrows. The specimens you obtain may be valuable in your biology course.

5. Investigate the mounds of earth, called *casts,* excreted by earthworms. Are they really finer in texture than the surrounding soil? What does their texture imply? How deep does the earthworm's burrow extend?

6. Visit a veterinarian and see if you can obtain specimens of parasitic worms which have been removed from the digestive system of animals.

Chapter 26

Animals with Jointed Feet—the Arthropods

The Arthropods [*Ar'throw pods*] outnumber all other kinds of animal life. Like knights of old, these creatures wear a suit of protective armor, completely encasing their softer body parts within.

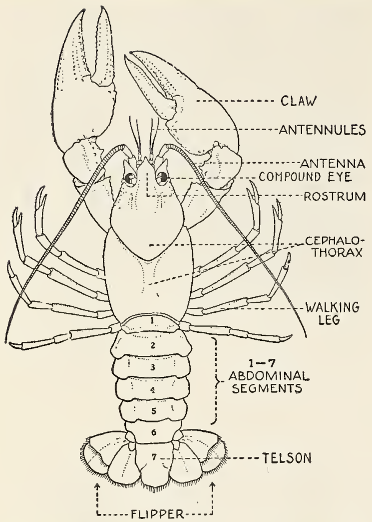
The hard outer covering or *exoskeleton* is one of their most striking characteristics although their name refers to the jointed feet (*Arthros,* jointed; *poda,* feet) which they likewise possess.

Arthropods in their widely varied forms thrive in nearly all of the environments around us. Few living things are more widely distributed than the insects, the largest group of Arthropods. Their numbers include, also, such familiar animals as spiders, centipedes, crayfish, crabs, and lobsters.

This animal group is of such great importance that several chapters will be devoted to the study of its members. Your study will acquaint you with the body structure, life activities, adaptations, and economic importance of familiar examples of these " animals with jointed feet."

Characteristics of Arthropods. To the casual observer, the graceful butterfly has little in common with the crayfish lurking under a rock in a stream. But careful study of these widely varied animals will reveal that they have much in common. The characteristics which make the butterfly similar in structure to the crayfish also relate these creatures to spiders, scorpions, and centipedes. The biologist refers to these points of similarity as characteristics of Arthropods, and includes the following:

1. Jointed appendages, which include legs and other body outgrowths.
2. Exoskeleton, which gives form to the body externally rather than internally as in our bodies.
3. Segmented body, which refers to distinct sections or segments into which the exoskeleton is divided.
4. Heart dorsal, or located along the upper region of the body.
5. Nervous system ventral, the principal nerves running along the lower region of the body.



THE CRAYFISH, A TYPE OF CRUSTACEA

Classes of Arthropods. In the classification of Arthropods, such widely varied forms as butterflies and crayfish, spiders and centipedes, are segregated into separate groups called *classes.* The great group or *phylum* is commonly divided into four smaller groups of related Arthropods as follows:

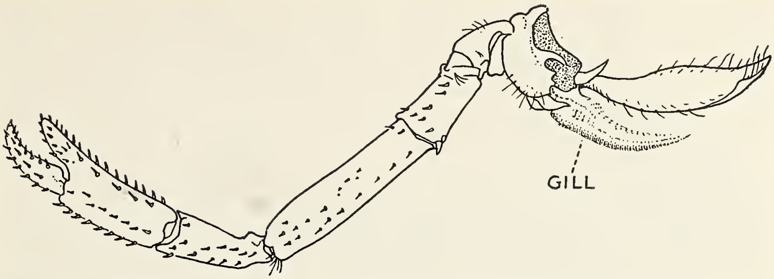
1. *Crustacea* [*Crus tay′she ah*], including crayfish, lobsters, crabs, shrimps, and many others.
2. *Arachnida* [*Ar ack′nid dah*], including spiders, scorpions, ticks, and mites.
3. *Insecta* [*In seck′tah*], including all insects.
4. *Myriapoda* [*Meer ree ap′o dah*], including centipedes and millipedes.

Each of these classes has all of the fundamental characteristics of Arthropods, and, in addition, certain characteristics of the class to which it belongs. For example, Crustacea have two pairs of antennae or " feelers " on the front of the body, two distinct body regions, five pairs of legs, a limy exoskeleton, and, in nearly all cases, have structures called gills for respiration. The Insecta, on the other hand, have one pair of antennae, a body composed of three parts, three pairs of legs, an exoskeleton composed of a material called *chitin,* and carry on respiration by means of special air tubes called *trachea.* These, and other structures, will be explained more fully in the discussion of the different kinds of Arthropods.

The Arthropods show a great advance over the other animals we have studied. Worms, especially the earthworm, showed a high degree of specialization of body parts and the presence of specialized internal organs. In the study of Crustacea as typical Arthropods, we deal with animals such as the crayfish, lobster, and crab, which are adapted for an active, aquatic life, in which division of labor among their various organs has been carried to an even higher point.

The crayfish, a typical Arthropod. Everyone is familiar with this common, aquatic Arthropod, although you may be accustomed to calling it a crawfish or crawdad. The crayfish is an ideal Arthropod to use as a type study because it is large, easy to observe, characteristic in its structure, and easily obtained in nearly all rivers, lakes, and streams.

The body is covered with a dark-colored, limy exoskeleton divided into two regions. The first of these regions is called the *cephalothorax* [*sef al o thor′ ax*] and includes the head and a second region, separate in many Arthropods, called the *thorax.* The cephalothorax is covered by a hard plate or shell called the *carapace* [*kar′ah pace*]. Attached to the rear of the cephalothorax is a second body region, the *abdomen* which is composed of seven movable segments. This is the first animal we have studied



SECOND WALKING LEG OF LOBSTER. Note the gill which is attached at the base. Six more or less movable segments and claw are shown.

which has a skeleton, and it may seem strange to find it on the outside of the body. Whether internal or external, however, skeletons serve the same purpose, namely, to give the body form, to protect the delicate internal organs, and to aid in motion by serving as attachments for muscles.

The Crustacea, with their armor-plated bodies, are among the best protected Arthropods. This protective cover extends even over the legs, which may be bent only at special hinges or joints. The heavy carapace, covering the head and thorax, gives special protection to these vital regions of the body. It is like a plate of armor, but is even more efficient, for it is a shield far lighter than a warrior ever carried. Not only is their exoskeleton strong, light, and flexible, but its color blends with that of the surroundings so that it escapes the notice of enemies (protective coloration). The front of the carapace extends forward into a protective beak, the *rostrum,* on either side of which are the eyes, set on movable stalks and composed of many lenses, because of which they are called *compound eyes.*

Head appendages. Beginning at the anterior (head) end, we come first to the small and large feelers (antennae) at whose base open the " ear sacs " and excretory organs respectively. Then come the *mandibles,* or true jaws, and two pairs of *maxillae,* or little jaws, which aid in chewing the food. The jaws work from side to side and not up and down, because they are merely leg-like appendages adapted for chewing and so continue to have a horizontal motion, as do the legs.

Thoracic appendages. The first appendages of the thorax are three pairs of *maxillipeds* (jaw-feet) whose function is to hold and chew food. Next come the large claws, obviously for defense and food getting, then two pairs of legs with tiny pincers at the tip, and two more pairs with a claw. These four pairs of legs are concerned mainly with walking. Attached to the maxillipeds, to the eight legs, and to the large claws are feathery gills which extend up under the carapace into the gill chambers.

Abdominal appendages. The appendages of the abdomen are called *swimmerets* and on the first five segments are small. They are used in the process of reproduction by the female as the attachment for her eggs. The sixth swimmeret is enormously developed into a wide fin or flipper, located at the extreme posterior (end farthest from head) part of the body. The appendage of the seventh segment is lacking and the segment itself reduced to a flat, triangular part called the *telson*. The sixth and seventh segments together form a powerful organ for backward locomotion, for they can be whipped forward by the strong muscles of the abdomen, making the animal shoot backward at high speed.

Adaptation. We have here the modification of *one* kind of organ for many uses. From a simple kind of appendage resembling the swimmeret, organs as widely different as the tail fin, the large claws, and the antennae appear to have been developed.

Homology. When we find organs (either in the same or different animals) which were developed from the same part — that is, whose origin and structure are similar, allowing for certain modifications — we call them *homologous* organs. The antennae and claws of the crayfish are homologous to the swimmerets, just as our arm is homologous to the foreleg of a horse, even though the functions are so different. *Analogous* means similar in function. We might say that the gills of the crayfish and the lungs of man are analogous, because both perform the function of respiration, but we cannot say that they are homologous, since the gills are developed from the legs, while the lungs are outgrowths of the throat and their structure is different.

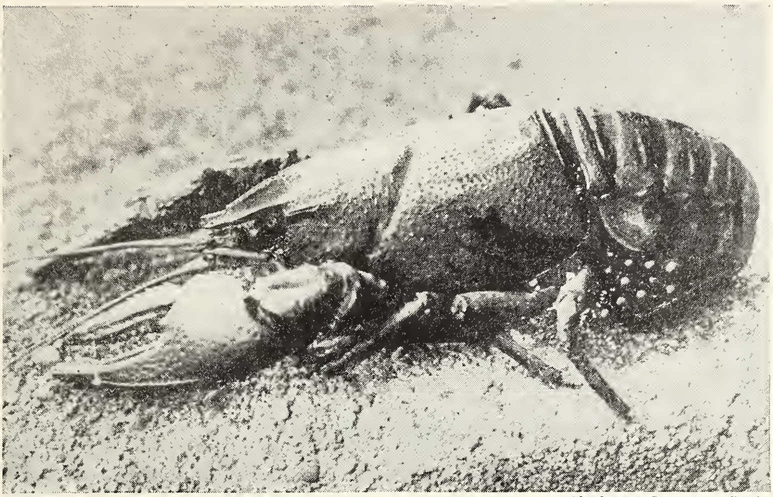
Internal structure. Internally, also, there is a considerable degree of specialization. The digestive system and its glands occupy a large part of the cephalothorax. There are three toothlike structures in the stomach, which complete the chewing of the food. A well-developed circulatory system and a muscular heart mark an advance along this line. The excretory and reproductive organs are present, fairly well developed. The nervous system, though similar to that in the worms, is much more specialized. The senses of touch and smell, located in the antennae, are acute. The eyes are on movable stalks and are compound, each consisting of numerous lenses, but the sight is probably not keen. Internal "ears" are located at the base of the antennules and probably aid in balancing. Neither hearing nor taste seems to be especially developed.

While these sense organs do not seem very efficient, yet enormous advance can be seen when comparison is made with the earthworm. The worm probably feels only touch and vibration sensations through the body wall, with a possibility of taste and heat or light sensations in the region of the head. Since the degree in which an animal can get in touch with its environment marks the stage of its advancement, the Crustacea far excel the worms in development.

Locomotion. This function is provided for by the tail flipper which drives the crayfish swiftly backward, and by the four pairs of walking legs which can travel backwards, forwards, and sideways. All are operated by powerful muscles, assisted by the exoskeleton. You can see why the slang expression "to crawfish" means to back out of any agreement.

Protection. The crayfish's adaptations for protection are the exoskeleton with its color and spines, the powerful jaws and claws for attack, speed for escape, fairly keen senses, and a nervous system to guide its actions.

Respiration. Respiration in Protozoa is accomplished by contact of the cell with dissolved oxygen in the water; in the worm by contact of the body wall with oxygen in the air. In the crayfish, as in most Crustacea, we find organs



Monkmeyer Press Photo Service

FEMALE CRAYFISH WITH EGGS

called gills, especially developed for carrying on the exchange of oxygen and carbon dioxide. These gills are thin-walled to allow the passage of gases, feathery to expose much surface, provided with many blood vessels to receive oxygen and to liberate carbon dioxide, and arranged to insure a constant flow of fresh water over them. They move in the water, with every motion of a leg or maxilliped. The gills are protected by the carapace, which extends over them and forms a chamber which will hold moisture for some time, thus keeping the animal alive when removed from the water. Notice the importance of the fact that oxygen is soluble in water; if it were not, aquatic animals could not exist, since it is oxygen dissolved from the air, and not the oxygen of the water (H_2O) itself which all water animals use.

Food. The crayfish eats so many different kinds of food that it is sometimes called *omnivorous*. It prefers animal food, however, and does not seem to object if the animal has been dead a long time!

Life history. Frequently, crayfish are found during the spring months with curious berry-like structures attached to the swimmerets on the lower side of the abdomen. Such crayfish are females, and the curious berry-like structures are eggs. The eggs are usually laid in April and number around one hundred. They are fertilized at the time they are laid by sperms which have been stored in small sacs in the lower side of the female's body since mating which occurred the previous fall. The eggs usually hatch in about six to eight weeks, depending upon the temperature and other conditions of the water. During the interval between laying and hatching, they remain securely fastened to the swimmerets. After hatching, the young remain attached to the swimmerets usually for about one week. When first hatched they are not entirely like the adult in structure. During a series of changes called *molts,* however, they become more like their parents in form.

Molting. During their life at the bottom, *molting* occurs at longer intervals until adult size is reached (at the age of five years in the case of the lobster), after which they do not usually molt oftener than once in one or two years.

This molting, or shedding of the exoskeleton, is a direct result of having the hard parts on the outside. They cannot grow larger except by shedding their armor. With the internal skeleton of the higher animals growth may be continuous. When the crayfish is ready to molt, the lime is partly absorbed from the skeleton, the carapace splits across the back, water is withdrawn from the tissues, which makes them smaller, and the animal literally humps itself out of its former skeleton, also leaving behind the lining of its stomach and its teeth. Immediately water is absorbed and growth proceeds very rapidly. The lime is replaced in the new and larger armor and " Richard is himself again." Usually the later molts take place in hidden locations and with haste, as the animal is totally helpless and a prey to all sorts of enemies when growing its new suit.

Reproduction of lost parts. In molting or in battle with enemies, it often happens that appendages are lost or injured. In the latter case the limb is voluntarily shed between its second and third segments. A double membrane prevents much loss of blood, and a whole new appendage is developed to replace the injured member. This accounts for the common sight of crayfish or lobster with one claw temporarily much smaller than its mate.

This reproduction (called *regeneration*) of lost parts seems to depend somewhat upon the degree of complexity of the part. The earthworm may regrow the whole posterior part of its body, while a starfish can develop all its organs if one ray and its base be left. The Hydra and coral normally reproduce by budding off new individuals, and the Protozoa, simplest of all, regularly reproduce the whole animal by division in two parts. On the other hand, higher forms, such as man, have tissues so highly specialized that he cannot grow even a new finger. The best he can do is to develop scar tissue to fill a wound, or grow new hair, nails, skin, and (once only) teeth. This is one penalty for a high degree of specialization.

Crustacea at home. Every country boy has, at one time or another, had the experience of being pinched by a crayfish, though he may call it a " crawfish " or a " crab." He has also doubtless more than once pulled up a crayfish determinedly attached to the bait on his fish line. It is one of the most common inhabitants of many streams and may be seen at nearly any time of day or night, searching for food. Since it eagerly consumes dead organisms in any condition, it may be considered of benefit as a scavenger. If one is kept in an aquarium, it will thrive best in very shallow water. In certain parts of the country, especially in the Mississippi River basin, crayfish cause extensive damage by making holes in earthen dams and by burrowing in fields, thus destroying cotton and corn crops. The area thus affected is said to be about one thousand square miles.

Another crustacean is the little pill bug which is always to be found under stones and logs and in moist places. When sufficiently alarmed it will roll into a little ball, thinly armored by gray, overlapping plates.

There are many other crustaceans such as the lobster, crab, prawn, shrimp, and the strange barnacle which betrays its relationship to the other crustaceans only when young.

Economic importance of the Crustacea. Included among the Crustacea are many examples of great economic importance to man. The *lobster,* the big brother of the crayfish, inhabits the cool waters of the Atlantic Coast from the Carolinas to Labrador. Lobster fishing is an important industry in many of the New England states, especially along the coast of Maine. In summer, the lobsters come into the shallow water close to the shore, where they live among submerged rocks. Lobster fishermen bait large traps or " pots " similar to rat traps with pieces of fish or other flesh. The traps are examined regularly and specimens exceeding the size limit are removed and brought to shore. They are packed in ice and shipped to markets in tubs or barrels. The inland resident hardly knows the lobster in its living condition but looks forward to the opportunity to see the bright red cooked lobster served on a dinner plate.

Another kind of lobster, the spiny lobster, lives in warmer regions of the ocean along the coasts of Florida, California, and the West Indies. This species lacks the large pincers of its northern cousin. The extremely long antennae are characteristic of the spiny lobster, as are the prominent spines which cover the front part of the body.

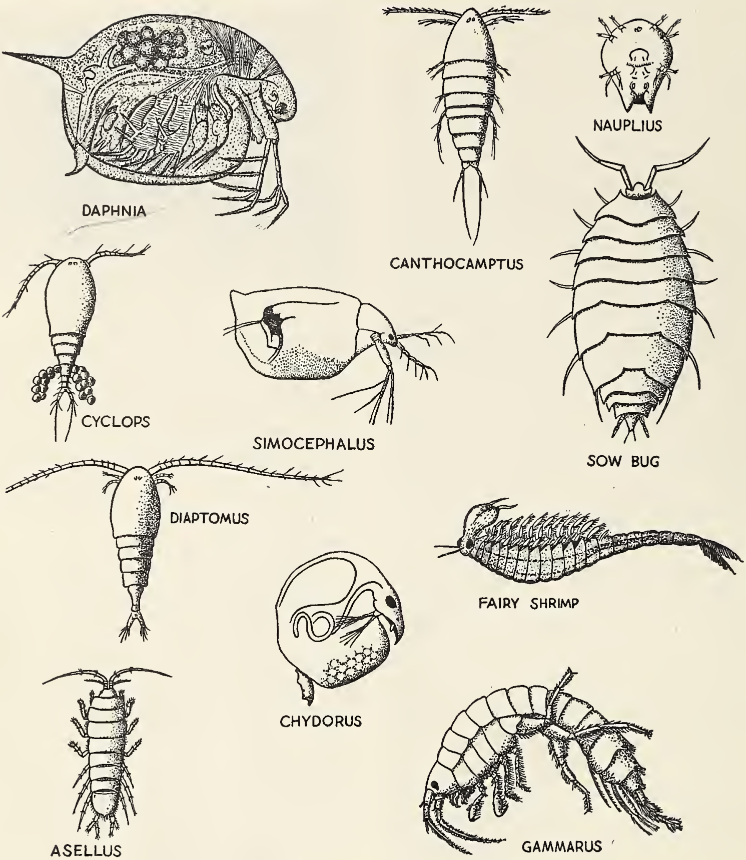
The *blue or edible crab* ranks next to the lobster as a table delicacy. They inhabit the shallow, grassy ocean bays, where they move about in search of decaying matter or any kind of animal they may be able to catch. The body of the crab differs from the lobster in being short and broad rather than elongated. The abdomen is much reduced in size and folds under the broad cephalothorax. Large pincers serve as organs of defense and food getting. " Soft-shelled " are merely edible crabs which are captured immediately following a molt. Within a few days, these table delicacies form a hard shell again. The name " blue crab " comes from the fact that the feet are blue in color.

Edible Crab

A discussion of Crustacea as items of food would be incomplete without mention of the *edible shrimp.* These creatures resemble other Crustacea in general form, but are distinct in having five pairs of walking legs and a much enlarged abdomen. They are very agile swimmers, moving rapidly with jerking movements and moving backward in true crustacean fashion. When alarmed, they bury themselves in the sand along the bottom and thrust out their eyes and antennae to keep in touch with their surroundings.

The shrimp industry is very important along the Gulf Coast. Louisiana and California supply most of the shrimp for inland markets, where they are considered a table delicacy.

Numerous forms of minute Crustacea abound in the waters of inland ponds and lakes. The minuteness of many of these forms brings them into contact with the microscopic Protozoa of these communities. The strange-appearing *Cyclops,* with its large, single eye, the

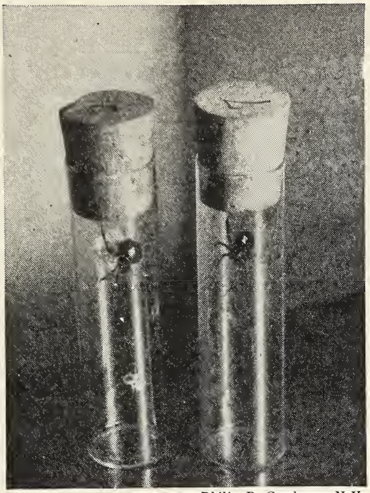


SMALL CRUSTACEA. These forms are common in ponds and streams. Many are microscopic, but all serve as important foods for fish.

Daphnia or water flea, and the peculiar "back-swimming" Fairy shrimp appear in swarms in certain bodies of fresh water during rather unpredictable periods. They serve as food delicacies for small fish and are a much sought item by owners of aquariums.

Spiders and other Arachnids. Unfortunately, the *spiders* are one of several groups of valuable animals whose reputations have been spoiled by a few undesirable members. With a few exceptions, spiders are extremely valuable because of their destruction of insects.

Some kinds of spiders, called orb weavers, spin elaborate webs of tiny silken threads which are an engineering feat to behold. The web serves as a trap to capture flying insects. When a victim becomes entangled in the sticky threads of the web, the spider races out of its place of concealment along the margin and binds its prey securely in a case of threads spun around the victim as the



Philip D. Gendreau, N.Y.

BLACK WIDOW SPIDERS

Monkmeyer Press Photo Service

WOOD TICK WITH EGGS

spider turns it over and over. Other spiders do not spin webs but live as solitary individuals stalking their prey as they roam about.

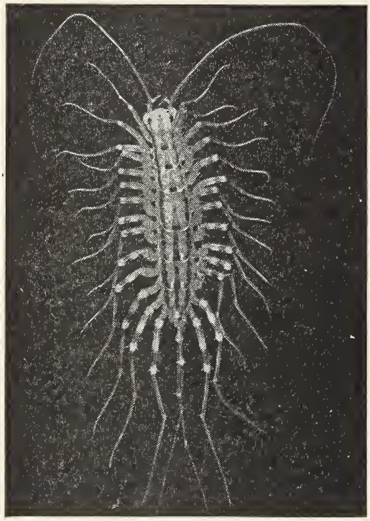
The spider resembles an insect somewhat, but differs in several important respects. The legs are eight in number and the head and thorax are joined to form a cephalothorax as in the Crustacea. A pair of greatly enlarged mandibles serve as poison fangs. The fangs are hollow and have small openings in the tip through which poison may be injected into the prey. On the tip of the abdomen of many spiders are several *spinnerets,* through which tiny strands of silk pass from the silk glands within the abdomen.

Among the most famous spiders are the *tarantula,* or banana spider, the *black widow,* famous for its very poisonous bite, and the *trap door spider* of the western desert regions. Other species of spiders are extremely numerous and may serve as a fascinating field of study for the interested biologist.

With spiders are grouped many other forms of related animal life. *Scorpions,* found in southern and southwestern United States and in all tropical countries, are provided with a long, segmented abdomen terminating in a venomous "stinger." The sting of a scorpion, while very painful, is seldom fatal to man. Scorpions live solitary lives except when mating, after which the female often turns upon her mate and devours him. The young are brought forth alive and spend the early part of their existence riding on the mother's back.

The *harvestman* or "daddy longlegs" is one of the most useful of the Arachnids since it feeds almost entirely on plant lice. They lead a strictly solitary existence, traveling through the fields in search of their prey. Their abundance during harvest season accounts for one of their names, while the extremely long legs, bent in the middle, and supporting a small, sac-like body, accounts for the other.

Mites and *ticks* are among the more



CENTIPEDE

notorious Arachnids, causing considerable damage to man and other animals. They live mostly as parasites on the surface of the bodies of chickens, dogs, cattle, man, and other hosts where they exist by sucking blood. Some forms like the Rocky Mountain tick carry diseases. The Texas-fever tick causes an annual loss often totaling more than $50,000,000 to cattle raisers.

Harvest mites or *chiggers* are immature stages of mites which attach themselves to the surface of the skin and insert a beak through which they withdraw blood. They are almost microscopic in size and give no warning of their presence until a swollen area causes great itching and discomfort. After a few days, the sore becomes covered with a scab and disappears.

Arthropods with numerous legs — the Myriapods. We have all wondered how a centipede or millepede can operate so many legs and not get them tangled in each other. These curious " worm-like " Arthropods are often seen racing away with a rippling sort of motion when their hiding place under a log, stone, or piece of rubbish has suddenly been disturbed. *Centipedes* have bodies composed of numerous segments each of which bears a pair of legs. The *millepedes* or " thousand leggers " have two legs fastened to each segment. Millepedes are frequently slow moving and are likely to roll into a ball when disturbed. Centipedes, on the other hand, are fast moving and difficult to capture. In tropical countries, centipedes several inches in length are common.

The fourth class of Arthropods, the insects, are so extensive and important that several chapters will be devoted entirely to them.

Summary

The Arthropods are the largest single group of animals, containing more different forms than all other animal groups combined. The phylum Arthropoda includes four classes of distinctly different individuals. The insects comprise by far the largest group of Arthropods, which include, in addition to insects, crustaceans, Arachnids, and Myriapods.

All of these classes are similar in possessing, among other characteristics, exoskeletons, jointed appendages, and segmented bodies. Class distinctions are made on a basis of other body characteristics.

Among the most important Arthropods economically are the crustaceans, which include the lobster, crab, shrimp, and numerous minute inhabitants of pond water. The most famous Arachnids are spiders which, for the most part, are extremely beneficial animals. Other

Arachnids are the harvestman, scorpions, chiggers, ticks, and mites.

The Myriapods, including the centipedes and millepedes are distinct from other Arthropods in having legs attached to all of the body segments.

Using Your Knowledge

1. Name three external characteristics of an Arthropod which distinguish it from other animals.

2. Name the four principal classes of Arthropods and give an example of each class.

3. Why is it especially important for an armored animal like the crayfish to have long antennae?

4. In which of the following localities do you think the crayfish would be likely to produce weaker exoskeletons: in waters flowing through limestone rock or in waters flowing through granite? Explain.

5. Discuss the advantages and disadvantages of an exoskeleton.

6. From your knowledge of the activity of the crayfish, explain the meaning of the expression, " crawfishing."

7. Explain how the antennae, claws, walking legs, and swimmerets of the crayfish illustrate homology.

8. In terms of molting of the crayfish, explain the common fisherman's terms, " soft craw," " peeler," and " hard craw."

9. Name three forms of crustaceans which are important to man because of food value.

10. Contrary to popular belief, most spiders are extremely beneficial animals. Explain why.

11. Spiders are often incorrectly referred to as " bugs " or insects. Name several characteristics of spiders which make them entirely different from insects.

12. What excuse or basis is there for the widespread fear of spiders?

Expressing Your Knowledge

Arthropod	carapace	lobster
exoskeleton	compound eye	shrimp
jointed foot	mandible	pill bug
segmented	maxilla	barnacle
dorsal heart	maxilliped	lobster " pot "
ventral nervous system	swimmeret	spider
Crustacea	homologous	orb weaver
Arachnida	analogous	spinneret
Insecta	omnivorous	harvestman
Myriapoda	molt	mite
crayfish	regeneration	tick
antenna	crab	centipede
cephalothorax	telson	millepede

Applying Your Knowledge

1. Collect several crayfish from a stream in your vicinity. Place them into an aquarium containing gravel and a few rocks and only a few inches of water unless an air pump is provided. Observe their habits and external structure carefully.

2. If you happen to live near the seashore, see how many different kinds of ocean crabs, shrimp, or lobsters you can obtain. Some forms may be found along the beach; others might be obtained from fishermen. Inland residents may see many of these forms in fish markets.

3. See if you can find a spider egg case

attached to a twig or stalk of a plant. Bring it into the laboratory and examine the contents with a lens or the low power lens of a microscope. Some of the egg cases will contain eggs; others, young spiders.

4. Take a hike through the woods and, if possible, locate a web of an orb-weaving spider. Catch a grasshopper or other small insect and toss it into the web. Notice carefully what happens.

5. Try to photograph a spider's web on a foggy morning by using the smallest aperture on your camera and an exposure of several seconds. If the camera cannot be focused, you should use a " portrait attachment " and place your camera exactly the prescribed distance from the web. You must use a tripod or have the camera on a stationary base, since you will be making a " time " exposure.

6. Report on the life history of the Texas-fever tick and the methods cattle owners use to rid their herds of the pest.

Chapter 27

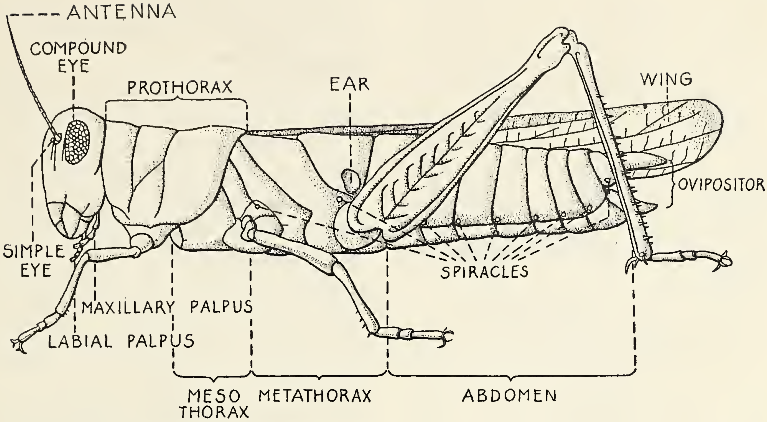
Insecta—a Type Study

Of all the Arthropods, insects are the most numerous and have the greatest economic importance. In order to understand the structure and ways of insects, we shall study in detail one kind of insect distributed over most of the world, the grasshopper. Like other living things, this insect has problems to meet and is adapted to solve most of them. While it has not the intelligence of the ant or bee, it has a long and venerable history. Even the Bible refers to grasshoppers, or " locusts " as they were called then. Though the grasshopper is not truly typical of every insect, in structure and function it is a good representative.

Insects. Most people speak of any small flying or crawling creature as a " bug." This is incorrect in two ways. A true bug is a member of only one division of insects. What we frequently call a bug may be some insect other than a bug, or even a spider or a centipede which are not insects at all. Do not speak contemptuously of " bugs," if you mean insects, for they are man's closest competitor for the food supplies of the world.

Insects include that division of the Arthropods which have three body regions: the head, thorax, and abdomen; one pair of antennae; three pairs of legs; usually two pairs of wings; and breathing tubes called *tracheae*. There are about twice as many kinds of insects as all the other living animals, more than 600,000 species of Insecta having already been recorded. Experts regard this as not more than one half of all insects in existence. Not only are there many kinds of insects, but each kind produces myriads of individuals, like the locusts and May flies, whose swarms darken the sky. Their struggle for existence is very severe and without manifold adaptations of structure they would not have survived.

High specialization. Highly specialized mouth parts for different kinds of



SIDE VIEW OF GRASSHOPPER SHOWING EXTERNAL PARTS

food, wonderful leg and wing development for swift locomotion, marvelous instincts and complicated internal structure are some of the lines along which insects have developed, producing survival qualities in the race against their countless competitors. Some are adapted for aquatic life, some take refuge by burrowing, some live in colonies like bees and ants, others fight their battles alone; some have become swift in running, leaping, or flying, while others have no adaptations and are dying out.

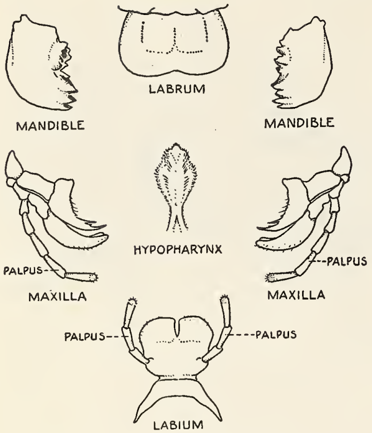
Classification. We cannot study even one species thoroughly. Of the twenty-two different orders, the following table will show the names and representatives of eight which will be taken up in more or less detail.

The grasshopper. The grasshopper will be studied as a type of all the insects. It belongs to the order Orthoptera, which means " straight-winged " and refers to the narrow folded wings, held straight along the body when not in flight.

As in all Arthropods, the skeleton is external, but differs from the crayfish in that it contains no lime. It consists entirely of a light, tough, horny substance called *chitin* which is usually protectively colored. The head, with its sense organs and mouth parts, the thorax with its legs and wings, and the abdomen, with the spiracles, anus and reproductive organs, can all be distinguished.

Sense organs. The *antennae* are the most anterior appendages, are many-jointed and devoted to the senses of

ORDER	REPRESENTATIVE
1. Orthoptera [*Orth op'ter ah*]	grasshopper, cricket
2. Lepidoptera [*Lep pid op'ter ah*]	moths, butterflies
3. Hymenoptera [*Hy men op'ter ah*]	bees, ants, wasps
4. Odonata [*O don ah'tah*]	dragonflies
5. Coleoptera [*Co lee op'ter ah*]	beetles
6. Hemiptera [*Hem ip'ter ah*]	squash bugs and other true bugs
7. Homoptera [*Hom op'ter ah*]	lice, scale insects
8. Diptera [*Dip'ter ah*]	flies, mosquitoes, gnats



Mouth Parts of Grasshopper

touch and smell. There are two kinds of eyes. Three *simple* eyes are located respectively at the base of each antenna and on the ridge between them. The large *compound* eyes project from the sides of the head and are composed of hundreds of six-sided lenses. The shape, location, and number of lenses in the eye seem to adapt the insect for sight in several directions at once, but the image formed cannot be very sharp.

Most insects are considered to be nearsighted, yet they can undoubtedly distinguish colors. It is well known that night-flying moths seek white flowers, while flies and some other insects are attracted by red and blue. Some insects, like carrion beetles and certain flies, are influenced by odors of decay.

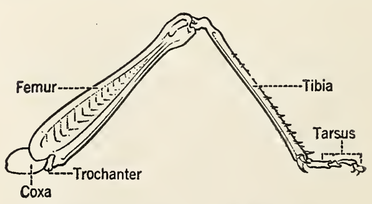
Mouth parts. The mouth parts of the grasshopper are fitted for biting and chewing plant material such as leaves and stems. Named in order from the anterior, they consist of *labrum* [*lay' brum*], *mandibles, maxillae,* and *labium* [*lay'bee um*]. Though the mouth parts of insects are greatly modified to suit different kinds of food, still these four sets of organs are usually present, so we must become familiar with their names and appearance.

The *labrum* is the two-lobed upper lip which fits over the strong, toothed, horizontal jaws, or mandibles. A pair of maxillae, or accessory jaws, are next behind the mandibles. They aid in cutting and holding food, and also have a sense organ, like a short antenna. This is called a *palpus*. Posterior to the maxillae comes the *labium* or lower lip, a deeply two-lobed organ, also provided with palpi, which aids in holding food between the jaws.

In insects like the butterflies and moths the maxillae join to make a hollow sucking tube. In the case of mosquitoes, the mouth parts are tiny lances placed around a sucking tube.

Thorax. The *thorax* consists of three segments, the prothorax, mesothorax, and metathorax. The *prothorax* is a large saddle-shaped segment to which the head is attached and bears the first pair of legs; the middle or *mesothorax* bears a pair of legs and the first pair of wings; the last segment, the *metathorax,* bears the leaping legs and the last pair of wings.

Legs. The typical insect has six legs, each of which consists of five parts or segments, connected by strong joints and adapted for locomotion by walking. In many insects the posterior pair is enormously developed for leaping also. The feet (*tarsi*) are provided with spines,



Posterior Leg of Grasshopper

hooks, and pads to give a firm grip when jumping or crawling. A joint near the body, almost like a "ball and socket," permits sufficient freedom of motion.

Wings. The anterior wings are long, narrow, and rather stiff. They protect the more delicate under wings and act as planes in aiding flight and leaping. The posterior wings are thin and membranous. They are supported by many veins and when not in use are refolded lengthwise, like a fan, beneath the narrower anterior wings.

There are many kinds of insects which are normally wingless, of which the walking stick and female tussock moth are examples. The cricket and cockroach possess wings, but seem to have lost their ability to fly.

Abdomen. The abdomen consists of ten segments, each composed of an upper and lower part, united by a membrane which allows the segment to expand and contract in the process of breathing. There are no jointed appendages as on the head and thorax. A pair of tiny openings called *spiracles* lead into the abdomen through eight of the segments. The segment next to the thorax bears the ears, which are large, membrane-covered cavities.

The extreme posterior segments in the female grasshopper bear two pairs of hard and sharp-pointed organs called *ovipositors* (egg placers) whose function is to dig a hole in the ground in which the eggs are laid. Males lack such organs, but the posterior of the abdomen is enlarged and rounded upward.

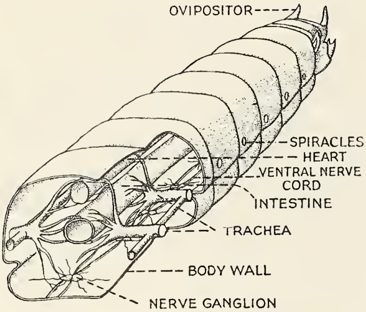
Some insects, like the saw fly and certain ichneumon [*ik nu'mon*] flies, have long, hairlike ovipositors with which they pierce wood and lay eggs deeply hidden. The sting of the bee and wasp is an example of an ovipositor modified for defensive purposes.

Active life. The activity of insects is well-known but little appreciated. They have, in proportion to their size, the most enduring and powerful muscles of any animal. Think of the long swift flight of bees, often extending for miles; think of the loads carried by ants and beetles; of the hard labor done by boring and burrowing insects; then compare their size and weight with our own and see how fast we could fly or run, how far we could jump, or how much we could carry, if, in proportion to our size and weight, we had their muscular ability. Their enormous activity requires a great deal of energy. This means that they must use a large amount of food, and this, in turn, implies a complete digestive apparatus. The digested food requires oxygen to oxidize it and liberate its energy, requiring a perfect system for breathing to supply the oxygen. To control such a powerful high-speed engine, a well-developed nervous system is also demanded.

The foregoing sounds like the "House that Jack Built," but is an outline of just what we find to be the case, not only in insects but in all higher forms. It is merely another instance of our order of study, "Structure, Function, Adaptation."

Internal structure. The internal structure is very complex, some insects having over twice as many separate muscles as we have in our whole body. The digestive system is well developed, there being salivary glands, a crop, stomach, digestive glands, intestine, and rectum.

Excretion is provided for by a large number of threadlike tubes at the junction of stomach and intestine. Circulation is controlled by a many-chambered, tubular heart on the dorsal (upper) side, from which the light-colored blood is forced toward the head and throughout



Dissected Abdomen of Grasshopper

the tissues, in contact with the air tubes. There are no blood vessels in insects other than a short tube leading forward from the heart.

Respiration. The respiratory system is highly developed. It consists of an extensive network of air tubes called *tracheae* [*tray' kee ay*] from which branches reach every tissue in the body.

These tracheae open by means of spiracles, eight pairs on the abdomen and two pairs on the thorax, each protected from dust by hairs. By alternate expansion and contraction of the segments, air is pumped in and out of these spiracles and circulates through the tracheae, where, by diffusion, the oxygen from the air and carbon dioxide from the internal tissues exchange places. A curious fact is that the veins of the wings were probably tracheae, adapted for the function of support rather than respiration. Note also the similarity between the spiracles of an insect and the stomates and lenticels of plants. Through which kind of openings do you think that gases would be able to enter and leave more rapidly?

Nervous system. The nervous system of insects reaches a higher degree of development than that of any invertebrate group except that of the cephalopods. A comparison of the types studied can well be made at this time.

The protozoan cell receives its impressions directly. It responds throughout to heat, light, contact, and possibly other stimuli, but vaguely and without the aid of any nervous tissue.

In animals like *Hydra,* certain cells seem more sensitive than others to external influences. These unconnected nerve cells are the simplest beginnings of a nervous system. In the starfish there is a well-developed radial nervous system.

In earthworms each segment has its nerve mass or ganglion, but all are connected by a nerve and each sends out many branches to various organs. There is a larger ganglion in the anterior end, above the mouth, which sends special nerves to the mouth parts and skin. Although there are no special organs of sensation, and the structure is very primitive, there is, nevertheless, an organ corresponding to a brain.

In Crustacea, the head ganglion, or brain, is located at the base of the rostrum. It is much larger than in worms and has nerves extending to the eyes, "ears," antennae, and mouth parts. This brain is connected with ganglia along the under side of the body but instead of having one for each segment, as in the worms, they are combined into eleven larger and more complicated nerve masses.

In insects this combination of ganglia has gone farther still. Including the brain there are two ganglia in the head, three in the thorax, and five in the abdomen, and the brain and sense organs are much more specialized in function.

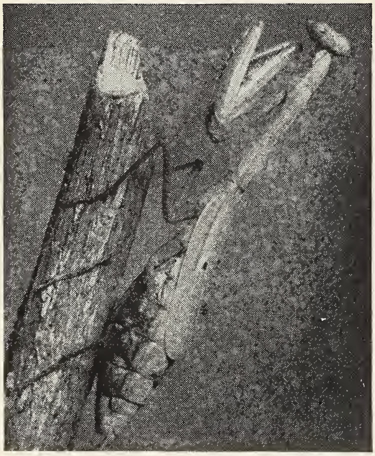
If we could study more kinds of animals we should observe this general tendency toward increasing the development of the head ganglia, of combining others and reducing their number while increasing their ability, and the develop-

Life History of the Grasshopper

ment of more efficient sense organs and greater motion control.

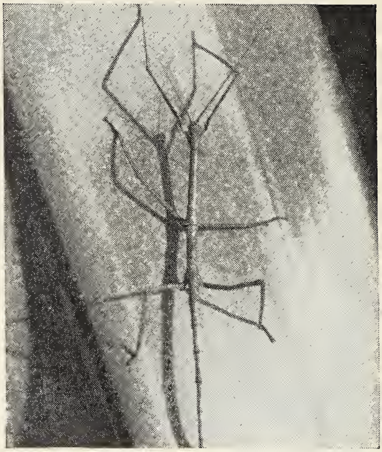
As soon as the simplest animal forms had developed far enough to have one end always go forward (anterior) in locomotion, that end naturally " ran into " contact with its environment. So, at the anterior end the sense organs would be most useful. This seems to be the reason for this headward tendency in development. As the complexity of animals increased, there was greater need of one controlling region so that all the body's numerous functions could operate in harmony. As a result the brain and a complex nervous system developed. The location of the brain was almost of necessity in the head or anterior end of the animal. The same necessity for a brain and the rest of the nervous system in order to co-ordinate the numerous activities of animals is not present in plants. They are not active; they do not have to be alert to seek food or to avoid enemies. Hence there is nothing in a plant corresponding to the head of an animal.

Life history. The eggs of the grasshopper are fertilized internally and are deposited in two masses, protected by a gumlike substance, in holes which the female digs in the earth with her ovipositor. One hundred or more eggs are thus deposited in the fall and hatch the following spring. This illustrates the twofold advantage of egg reproduction, for not only is the number of individuals increased, but embryos pass northern winters safely in a protected egg, while most of the adults are frozen to death. The young (*nymph*), though small and



Monkmeyer Press Photo Service

PRAYING MANTIS



Philip D. Gendreau, N.Y.

WALKING STICK

wingless, still resemble the adult in most respects, but as is often the case with the young, the head is disproportionately large. Like all Arthropods, they grow by molting, usually five times, and each time increase in size until they reach full growth. Molting, which takes about half an hour, is followed by rapid growth and formation of a new exoskeleton, the former having split along the thorax to allow the exit of the growing insect. It emerges head first but very weak, and often does not survive.

Insects do not usually deposit eggs in the ground. Some place them in water (dragonfly and mosquito), others protect them with a varnish (tent caterpillar) or with a frothy mass (tussock moth), but most lay their eggs on the leaves or stems of plants.

The larvae of many insects are so different from the adults that they have separate names, which confuse the relationship. Refer to the table below.

When we speak of " silk worms," or " apple worms," etc., we are really referring to larval forms of moths; " cabbage worms " are larvae of butterflies.

" Wire worms " are beetle larvae; the " moth " that eats woolens is the larva and not the moth itself; the " carpet bug " or " buffalo bug " is the larva of a beetle.

Metamorphosis. In many animals the development from egg to adult passes through more or less distinct stages instead of being a gradual increase in size. Such a life history is called a *metamorphosis* [*met ah mor'fo sis*].

Among insects these stages may be

The larva of the	beetle	is called a	grub
	fly		maggot
	bee		grub
	mosquito		wiggler
	butterfly		caterpillar or " worm "
	moth		caterpillar or " worm "

several in number and the differences between them slight, as in the grasshopper; or there may be four definite and distinct stages, the egg, larva, pupa, and adult, as found in the butterfly. The former type is called an *incomplete* metamorphosis, the latter a *complete* metamorphosis.

Relatives of the grasshopper. The meadow grasshopper and the katydid would be recognized by anyone as relatives of the grasshopper because of the general likenesses. The wings of the katydid so closely correspond to leaves, even to the veining, that they constitute a striking example of protective resemblance. Crickets, roaches, the wingless walking stick, and the mantis are other representatives of the Orthoptera.

Economic importance. The grasshopper and its relatives are, with one exception, harmful to man. Swarms of grasshoppers have plagued both the Old World and the New throughout recorded history. The second chapter of Joel in the Bible contains a vivid description of the destruction wrought by hordes of grasshoppers (then called locusts). Every few years the middle western sections of the United States have to fight armies of grasshoppers in order to save their grain and other crops. The only useful relative is the *mantis,* which is carnivorous and eats other insects, many of which are harmful. Egg cases of the mantis may now be purchased at seed stores. The eggs hatch in the spring and the insects remain in the garden, living on other insects which are injurious to flowers and vegetables. Although in appearance he is rather a fearful insect, actually the mantis is the most helpful.

Summary

The grasshopper, a typical insect, shows the characteristics of all Arthropods in having an exoskeleton, segmented body, and jointed appendages. Other characteristics of its body structure, including three body regions, three pairs of legs, one pair of antennae, and the presence of tracheae place the grasshopper in the largest class of Arthropods, the insects.

On the head of the grasshopper are two kinds of eyes, three simple eyes and two large compound eyes. A pair of segmented antennae serve as organs of touch and smell. The mouth parts are adapted for chewing the leaves and stems of plants.

The thorax, composed of three segments, bears the legs and wings. The legs are of two types, the first two pairs being modified for walking and clinging while the third pair is enormously enlarged for jumping. The wings, likewise, are of two kinds. The first pair is straight and leathery and quite useless for flight, although they serve effectively as protective coverings for the second pair of membranous wings which are used for flight. The abdomen consists of ten segments. On either side of eight of the segments is a tiny pore or spiracle which marks a tracheal opening. The ear is located on the first abdominal segment. The tip of the abdomen is modified for reproduction.

The internal structure of the grasshopper shows a high degree of specialization and the presence of internal organs. The life history of the grasshopper is called a metamorphosis and includes three distinct stages, egg, nymph, and adult. This type of metamorphosis, involving only a change in size, is referred to as incomplete.

Using Your Knowledge

1. Enumerate those characteristics of the grasshopper which make it similar to the crayfish.

2. Make a list of characteristics of the grasshopper which relate it to other insects and segregate insects as a group from the other Arthropods.

3. Explain what is meant by an order of insects.

4. Most animals have the sense organs located on the head. In what respect is the grasshopper an exception to this rule?

5. History tells of several great plagues of " locusts " or grasshoppers. What evidence did you find in the study of the mouth parts of the grasshopper which fit it ideally for the role of crop destroyer?

6. Insects are believed to have multiple vision. Explain why this is probably true.

7. From the structure of the wings of the grasshopper, how can you tell that much of its life is spent on land?

8. Explain how the grasshopper's legs illustrate adaptation.

9. Describe the life history of the grasshopper from the egg to the adult stage.

10. What protection is afforded the eggs of the grasshopper during the winter months?

11. The nervous system of insects is considered to be the highest of all of the invertebrates. What indications do you find that their actions and responses are correspondingly complex?

Expressing Your Knowledge

Orthoptera	palpus	ovipositor
chitin	thorax	salivary gland
simple eye	prothorax	stomach
compound eye	mesothorax	intestine
labrum	metathorax	trachea
mandible	tarsus	nymph
maxilla	spiracle	complete metamorphosis
labium	segment	incomplete metamorphosis

Applying Your Knowledge

1. Obtain a living grasshopper and observe its activities, such as walking, flying, chewing, and breathing. Make notes on the manner in which it performs each of these activities.

2. Make a careful study of the external structure of the grasshopper. See how many of its external parts you can locate.

3. Collect twenty-five common insects of your vicinity. Consult special insect books for collection methods, mounting methods, and classification into orders.

4. Prepare a report on grasshopper migrations and damage caused to crops during migrations.

Chapter 28

Some Interesting Insects and their Habits

No other group of animals shows a greater range of variation in its members than the insects. We studied the grasshopper as a typical insect and from this common member of the insect world learned about the body structure which is characteristic of all members of the group. But from this basic plan of structure, insects have become greatly modified not only in form but in life activities as well.

This chapter will deal with several common orders of insects which are quite different from the grasshoppers and their relatives. You will study the butterflies and moths, the most beautiful of all insects, the ants, bees, and wasps with their complex social orders, insects called bugs and hard-shelled warriors called beetles.

In the study of the life history of certain of these insects, you will learn about amazing transformations of unsightly "worms" into beautiful adults — a series of changes quite different from the nymph stages of a grasshopper.

Insects are so numerous that an entire book would be necessary to acquaint you with even the most common forms. But the typical examples selected in this chapter will show you some of the ways in which nature has modified this, her largest group of living organisms.

Butterflies and moths. To the order *Lepidoptera* belong the butterflies and moths, the most beautiful of all insects. The word *lepidoptera* comes from two Greek words, *lepidos,* meaning "scale," and *pteron*, meaning "wing." It seems incredible that the brilliant colors of the butterflies and moths are due to microscopic scales making a mosaic pattern. Under a magnifying glass, each scale is a thing of indescribable beauty. Living butterflies and moths, if handled, should be held by the thorax region, with light pressure. Touching the wings always removes scales, spoiling the specimen for collecting and maiming it for flight.

Comparison of butterfly and moth. Butterflies and moths are often confused, but can usually be distinguished by the comparisons at the bottom of this page.

Head. Unlike the grasshopper, the head of the butterfly and moth is hairy, frequently even shaggy. The compound eyes are very large and rounded, and the neck flexible. The mouth parts are very different from those of the Orthoptera, because they are adapted for sucking nectar from flowers. The labrum and mandibles are reduced to mere vestiges. The maxillae are enormously lengthened and locked together to form the coiled *proboscis* or "tongue" which, when extended, may equal in length all

Butterfly	Moth
Day flier	Night flier
Chrysalis, without cocoon	Pupa in cocoon
Wings vertical when at rest	Wings held horizontally
Antennae knobbed	Antennae feathery
Abdomen slender	Abdomen stout

L. W. Brownell

LUNA MOTH, FEMALE

the rest of the body. It is long enough to reach the nectar glands of the flowers that moths and butterflies visit. The labium is reduced in size, two feathery palpi being all that is left of it in most cases. In this set of mouth parts, we have an example of organs homologous to those of the grasshopper, but adapted for very different functions.

Thorax. The legs of the Lepidoptera are small and weak, but have the same general structure as in all insects. Obviously the butterfly spends much of its time in the air and uses its legs only for clinging to resting places. The wings are large, and the colored scales help the few veins in giving strength to the wing, and in some cases aid in color protection. The butterfly, though easily supported by its large wingspread, is not a swift flier.

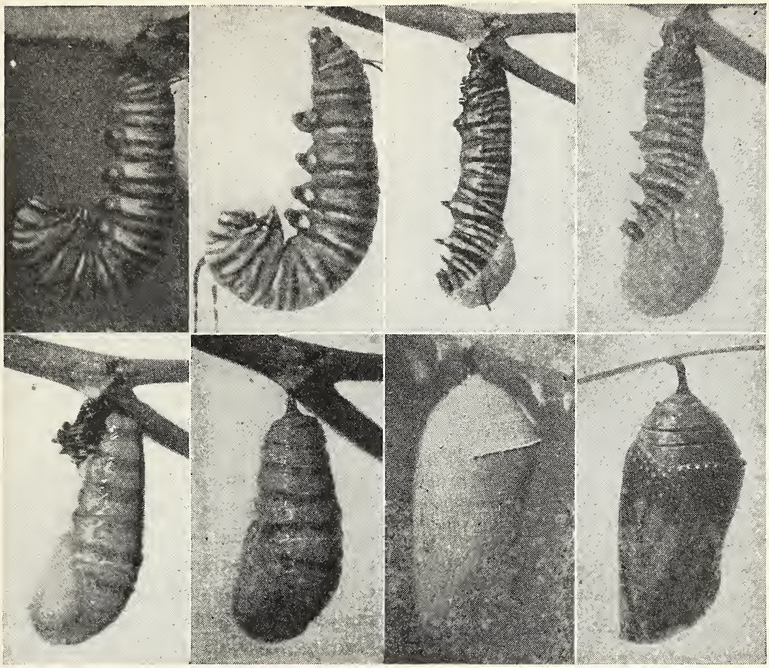
Abdomen. The abdomen resembles that of the grasshopper but has fewer visible segments and, as in all insects, is the least specialized body region.

Life history. The eggs of most Lepidoptera are deposited on or near the plant which is to be the food of the young. Some pass the winter in this stage but usually eggs are deposited in the spring and develop into caterpillars the following summer.

The egg does not hatch into a form at all resembling the adult, but instead there emerges a tiny wormlike form called the *larva*, or caterpillar, which differs entirely in structure, having no wings or compound eyes, but possessing several extra pairs of legs and biting mouth parts. In fact, these insect larvae are more often called "worms," because they resemble true worms in shape. They are actually a stage in the development of an insect, and are vastly more complex than the true worms. The caterpillar devotes its whole attention to eating, growing, and molting. After about five changes of clothing, it stops this gluttonous life in which it often does a great deal of harm to us, and goes into a resting stage called the *pupa*.

L. W. Brownell

MONARCH BUTTERFLY



METAMORPHOSIS. Eight stages in the transformation of the black and green caterpillar of the monarch butterfly into the jeweled pupa.

A silkworm, during its thirty-day period of growth, increases its weight 15,000 times. At this rate a seven-pound baby would weigh 3500 pounds when two days old and at one month, would reach the tremendous total of fifty tons. With such rates of growth, it is not strange that caterpillars need enormous quantities of food and so do great damage to crops.

In butterflies the pupa is called a *chrysalis,* the outer covering of which becomes a hardened case, usually brown in color. It is protected by this covering during its long pause. The larva usually seeks a protected spot before this change occurs. The moth larva, on the other hand, usually spins a strong case of silk, the *cocoon,* by which it protects and attaches its pupa for its period of retirement. This pupa stage in which the Lepidoptera usually pass the winter is not a period of entire rest. Marvelous changes take place which are not well understood, but at least this is known: whereas it was a wormlike larva, it emerges as the *adult* butterfly or moth, totally changed both in internal and external structure.

Whereas the function of the larva is simply to eat and grow, the adult eats only the nectar of flowers, and its life-work consists of producing or fertilizing the eggs for the next generation. Since the life development consists of distinct stages, it is an example of complete metamorphosis. Bees, beetles, and flies all pass through a similar series of changes

MIMICRY. Monarch butterfly (top) is avoided by birds because it seems to be bad tasting. Viceroy butterfly (bottom) has no such bad taste but birds avoid it because it resembles the monarch.

which can be tabulated as follows:

Egg	Deposited near source of food Period of increase in number
Larva	Period of eating and growth (often harmful to man) Worm, grub, or maggot stage
Pupa	Period of quiet; internal transformation Usually pass winter in this stage May have cocoon
Adult	Reproductive stage

Protective coloration. Color protection is especially evident among insects and their larvae. Many are green like the grass and leaves among which they live and on which they feed. This is often due to chlorophyll in their food showing through their delicate tissues. Others are colored like dead leaves, flowers, or bark — whichever may be their usual background. The brown grasshopper resembles the ground on which it alights. The walking-stick insect looks so much like the small twigs among which it lives that it can hardly be found.

Mimicry is color protection carried to such a degree that an animal resembles, not the background, but some other particular object. Butterflies afford the best examples of mimicry. The leaf butterfly bears a startling resemblance to a dead leaf; color, veins, shape, and position when at rest, all contribute to the similarity.

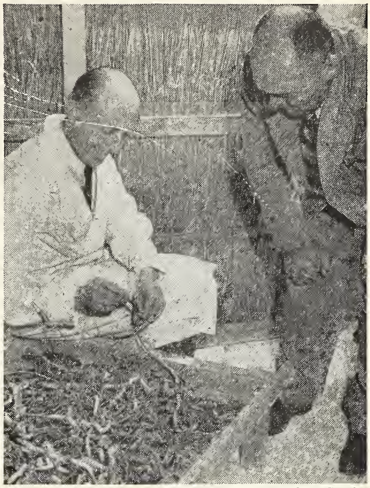
The viceroy butterfly much resembles the monarch species, which is protected by a bad taste so that birds do not eat it. Perhaps they leave the viceroy alone because they mistake him for the monarch.

Economic importance of Lepidoptera. The butterflies and moths pictured or discussed in this chapter are a few examples of the thousands of species included in this large order. In evaluating the economic importance of the butterflies and moths we must consider both the adult and larval stages. As adults, they furnish brilliant color to the landscape as they flit about from plant to plant. Accordingly, the larger and more brightly colored species are better known and serve as excellent material for the amateur insect collector, whether he specializes in Lepidoptera or not.

Many butterflies and moths visit flowers to obtain nectar, which they drink through their long, tube-like proboscis. In so doing, they aid in cross-pollination, carrying pollen from flower to flower on their hairy bodies. The greatest economic value of the Lepidoptera, however, is in the production of silk. The silkworm is the larva of a small moth which has been domesticated by man nearly four thousand years. Silkworms were first domesticated in China and from there were carried to Japan, where silk production became a major industry. During the sixth century, silkworms were introduced into Europe, although European silk production has never rivaled that of the Orient. Silkworms are now raised profitably in this country.

The female silk moth lays about 300 eggs on specially provided cloths. The caterpillars begin to feed immediately upon hatching upon mulberry, Osage orange, or lettuce, leaves which must be provided constantly during the larval period. After about six weeks of continual feeding, the larva spins an oval, silken cocoon from a thread as much as 1000 feet in length. Normally, the adult moth emerges from the cocoon in about two weeks. However, the adult spoils the threads of the cocoon by cutting a hole in one end in order to emerge. Consequently, the silk grower processes the cocoon to obtain the silk before the adult has come forth and in so doing necessarily kills the moth.

Among the Lepidoptera are numerous forms which are notorious for the damage they cause as larva. The apple "worm" alone may destroy over $12,000,000 worth of fruit. Millions of dollars are expended every year by the New England states in a losing fight against the gypsy and brown-tail moths. Cabbage "worms," tomato "worms," and corn ear "worms," all larva of Lepidoptera cause enormous damage to crops annually. Many of these damaging pests will be discussed in the next chapter, along with measures which are being used in our fight against them.

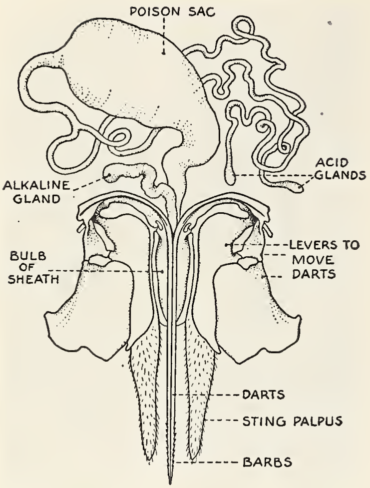


Monkmeyer Press Photo Service

SILKWORMS

The communal insects — Hymenoptera. For those who enjoy sitting quietly, many profitable hours may be spent watching the fascinating activities around a beehive or an anthill. No natural laws can account for the amazing communal life of the social ants, bees, and wasps. Here, the caste system operates to perfection, each member of the colony performing the tasks of his destiny without complaint or desire for advancement. Instinct alone accounts for the high degree of division of labor in the beehive, the wasp nest, and the ant colony. Contrary to common opinion, these insects probably are no more intelligent than any other forms. Yet, the marvelous efficiency with which they carry on their routine tasks could well be imagined to illustrate high intelligence. A complete account of the doings of some of the higher forms makes fairy tales seem credible. The famous biologist, Huxley, once said that an ant's brain was the most wonderful piece of protoplasm in the world.

Ants, bees, wasps, and related insects are grouped together in the order Hymenoptera. The order includes not only social forms which live in colonies and carry on division of labor, but numerous solitary forms as well. The members of the order show close relationship both in body structure and, in many cases, in the



THE COMPLICATED STRUCTURE OF THE BEE STING

manner in which they perform their life activities.

Honeybee. Typical of this order is the honeybee which we shall study in some detail as a remarkable example of adaptations of structure and function. The body regions are distinct, the head is attached to the thorax by a flexible neck, and the thorax to the abdomen by a slender waist. Each region is highly developed.

Head. The sensitive elbowed antennae, the enormous compound eyes, and three simple eyes are easily seen, but the mouth parts are complicated and are a set of tools by themselves. The labrum is small, but the mandibles are developed into an efficient lapping tongue. They are used in constructing the cells of honeycomb from beeswax.

Thorax. The thorax is large, strong, and provided with powerful muscles which operate the legs and wings.

Bees are swift and enduring fliers. Their wings, small but well proportioned, operate at high speed, producing the familiar hum. The anterior wings are much the larger and the posterior wings may be attached to them, for aid in flying, by tiny hooks. Honeybees sometimes wear out their wings.

Abdomen. The abdomen consists of six segments, with ovipositor or sting at the posterior end. Only in the queen is the ovipositor developed as a true egg-laying organ. The worker bees, which are undeveloped females, produce no eggs and have the ovipositor modified into the well-known "sting." This is a complicated organ consisting of two barbed darts operated by strong muscles and enclosed in a sheath. The darts are connected with a gland which secretes the poison and makes a bee sting so painful. On the four last abdominal segments of the workers are glands which secrete the wax used in comb making.

Life history. The life history of the honeybee is a fine example of communal life and mutual help. Each member of the colony works for the good of all, and this habit has resulted in great success as a whole, as well as remarkable development for each individual. There are three forms of bees in any colony, the queen, the drones, and workers.

The queen. The *queen* is almost twice as large as a worker, with a long pointed abdomen, but with no pollen basket nor comb. Her particular function is the production of eggs to continue the colony. She may produce in one day as many as three thousand eggs, twice her own weight. The queen develops from an ordinary egg, but the workers enlarge the wax cell in which it is to grow and feed the grublike larva with extra portions of nourishing food. This causes the development of a queen, or fertile female, instead of a worker, which is a female without the ability to lay eggs. After being thus fed for five days, the

Monkmeyer Press Photo Service

Worker Bee (left), Queen Bee (middle), Drone (right)

larva weaves a silken cocoon, changes to a pupa, and is sealed into her large waxen chamber by the workers. When the mature queen emerges from her cell, she seeks out other queen larvae in the colony and kills them, or if she finds another adult queen, they fight till one is killed. She never uses her sting except against another queen.

If the workers prevent her from destroying the other queens, she takes with her from two to twenty thousand bees and " swarms " out to seek a home elsewhere. In this way new colonies are formed and overcrowding is prevented.

After a few days she takes a wedding flight in the air where she mates with a drone or male bee, receiving several million sperm cells. Then she returns to the hive and begins her lifework of laying eggs. This is no small task as one queen may produce as many as one million eggs per year and often lives from five to ten years. Although we call her a " queen " she is in no sense the ruler of the hive but rather its common mother.

The drones. The *drone,* while larger than the worker, is smaller than the queen and has a thick, broad body, enormous eyes, and very powerful wings. He is not provided with pollen baskets, sting, or wax pockets. His tongue is not long enough to get nectar, so that he has to be fed by the workers. During the summer a few hundred drones are tolerated in the colony because one of them must function as a mate for the new queen. The rest are of no use in the hive. This easy life has its troubles, however, for with the coming of autumn, when honey runs low, the workers will no longer support the drones but sting them to death, and their bodies may be found around the hives in September.

The workers. The *workers* are by far the most numerous inhabitants of the hive; they are undeveloped females, smaller than drones, with the ovipositor modified into the sting, and with all the adaptations of legs, wings, and mouth parts, which have been described. Workers may number from 10,000 to 100,000 in a hive. With the exception of the process of reproduction, all the varied industries and products of the hive are their business. They perform, at different times, many different kinds of work as well as provide the three hive products — wax, honey, and propolis. In summer they literally work themselves to death in three or four weeks, but bees hatched in the fall may live five or six months.

Products of the hive. *Wax* is a secretion from the abdominal segments of workers, which comes after they have gorged themselves with honey, and have then suspended themselves by the feet in a sort of curtain. As the wax is produced, it is removed by certain workers, chewed to make it soft, and then carried to others by whom it is built into comb.

This *comb* is a wonderful structure, composed of six-sided cells in two layers, so arranged as to leave no waste space, and to afford the greatest storage capacity with the use of the least material. Not only is it used for storage of honey and "beebread" (a food substance made from pollen and saliva) but also for the rearing of young bees. The eggs are placed, one in a cell, by the queen and sealed up by the workers, making what is called "brood comb."

Honey is made from the nectar of flowers which is taken into the crop of the bee, its cane sugar changed to the more easily digested grape sugar, and then emptied into the comb cells, where it is left to ripen and thicken by evaporation before being sealed. Until the seventeenth century, people did not know how to make sugar and depended largely upon honey. The bee products in the United States are worth $22,000,000 per year.

The removal of honey by man does not harm the bees if about thirty pounds are left for their winter use; that is, enough to feed an average colony of 40,000 bees for an ordinary winter.

Propolis, or bee glue, is another important product of the hive. It is a brown substance gathered from the sticky leaf buds of some plants. Bees will even use fresh varnish if they can get at it. Propolis is used to make smooth the interior of the hive, to help attach the comb, to close up holes and cracks, and even to varnish the comb if it is left unused for a time. Traces of it may be seen on the inside of honey boxes.

Industries of the colony. Not only do the workers prepare the wax, honey, and propolis, as needed, but some attend and feed the queen or drones; some act as nurses to the hungry larvae, which they feed with partly digested food from their own stomachs; some clean the hive of dead bees or foreign matter; some fan with their wings to ventilate the hive; and all the time thousands of others are bringing in nectar, pollen, and propolis as needed for the use of the colony. Such a communal or colony life illustrates the highest development of division of labor found among the animals lower than man. It occurs among some ants and wasps as well as bees, though nowhere is it carried to a higher point than in the honeybee.

Other Hymenoptera. From the time of Solomon, whose advice regarding the ant was to "consider her ways and be wise," ants have been the center of much attention.

Like the bees, ants are social insects and the colony requires a queen. Unlike the bees, most ants are unable to sting, but they bite with jaws more powerful in proportion to their size than those of any other insect. Also they are unlike the bees in being wingless; but it is an interesting and generally unknown fact that during the early autumn the males and females acquire temporary wings and then start new colonies.

Wasps and ichneumon flies. Wasps, both solitary and social, and hornets are interesting to us, not only because of personal experiences we may have had with their stings, but because they are probably the original papermakers of the world. Their nests are made from a sort of pulp obtained from strips of wood chewed vigorously and mixed with secretions from the mouth. Probably no members of the Hymenoptera are more valuable to us than the tiny ichneumon flies which manage to lay their eggs under the skin of living caterpillars and thus kill them.

Odonata. The word *odonata* is derived from the Greek word meaning "tooth." It evidently refers to the powerful jaws possessed by dragonflies as adults, and in the larval stage when they are aquatic forms very inappropriately called *nymphs.* Perhaps the realization of their strong jaws has given rise to the prevalent superstitions that "dragonflies sew up your lips and fingers." They do no harm; on the contrary, like insect monoplanes they course back and forth over the water or above moist places, catching insects — chiefly mosquitoes.

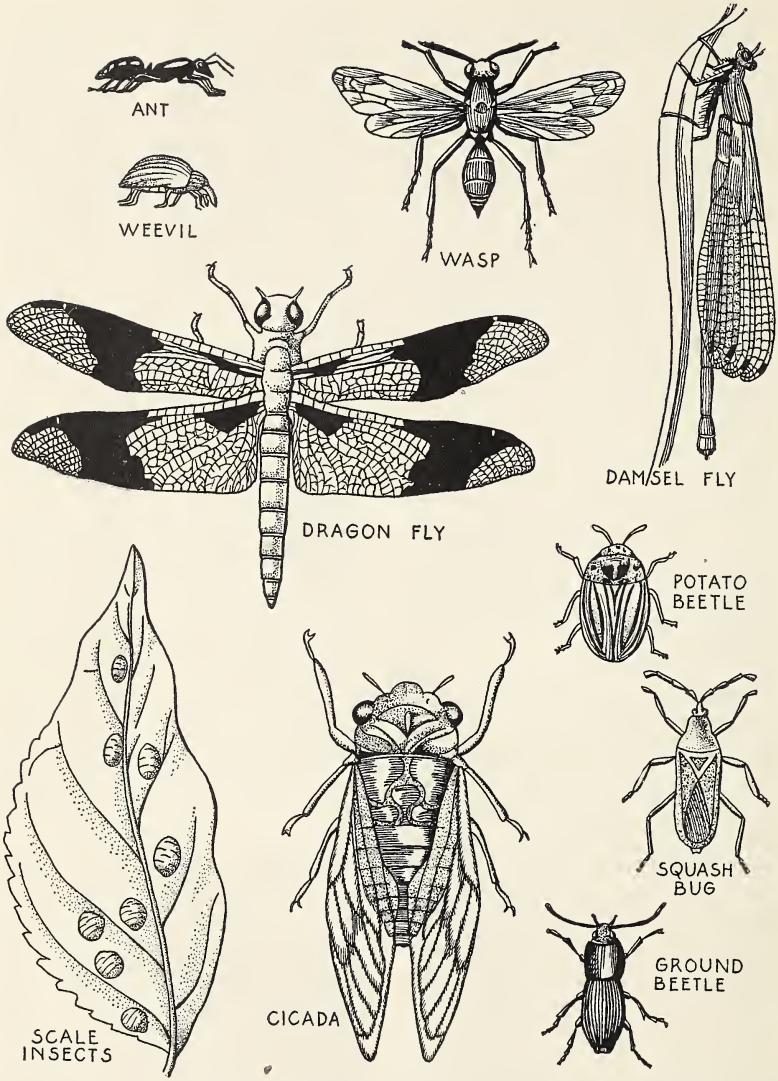
Coleoptera. The word *coleoptera* comes from two Greek words meaning "sheath" and "wing" and is most apt in its application to the hard exoskeleton of beetles. More than 15,000 species of beetles have been recorded, and most of them can be recognized as beetles by anyone because of their hard shells. They all have strong jaws and complete metamorphosis.

Wood-boring beetles cause extensive losses; buffalo "bugs" are destructive to carpets and skins; potato beetles ravage gardens; weevils damage grain and cotton. The state of Texas alone has paid out over $150,000,000 in the attempt to control the cotton boll weevil. The Japanese beetle, first discovered in this country in New Jersey in 1916, has already become a great menace to fruit trees. On the other hand, carrion beetles are scavengers, lady beetles eat scale insects and thus aid the fruit industry, and Calosoma beetles have been introduced into New England and elsewhere to aid in controlling detrimental insects.

Hemiptera. The "half-winged" insects, as the words *hemi* and *pteron* imply, have sucking mouth parts, and incomplete metamorphosis. One or two forms are wingless. The insects belonging to the *Hemiptera* are the only insects constituting the true *bugs.* Among them are many of our worst pests, such as the chinch bug, bedbug, squash bug, and stinkbug. Others, less harmful to us, include aquatic insects like water striders, back swimmers, water bugs, and water boatmen.

Homoptera. The word *homoptera* means "similar wings," though some of the members of this order are wingless. All have sucking mouth parts and incomplete metamorphosis. Plant lice, scale insects, mealy bugs, leaf hoppers, and others take a huge toll of our wild and cultivated plants. We are indebted, however, to the lac insect, which alone of the Homoptera is of economic benefit, because from it is obtained shellac which is used throughout the world.

The cicada is a common representative which lives underground from two years in the case of one species to seven-



Representatives of Several Insect Orders. Hymenoptera: ant, wasp. Odonata: dragon fly, damsel fly. Coleoptera: weevil, potato beetle, ground beetle. Hemiptera: squash bug. Homoptera: scale insects, cicada.

teen years in another species. They then tunnel to the surface, and spend a week or two as adults whose high-pitched and strident notes, coming from treetops, are so familiar on hot summer days.

The economic importance of insects. Probably only a minority of insects are distinctly detrimental to man. Yet these obnoxious forms are so prominent and well known that popular opinion is apt to condemn all insects thereby. Evidences of their ravages are always at hand; the necessity of constant warfare is continually being stressed, and the cost of combating insects has become obvious in the tax rate itself. To cope with animals so numerous and active as insects calls for accurate knowledge of the habits and life histories of these six-footed rivals of man.

As to their harmful activities, insects —

1. Destroy grain, vegetables, and fruit (numerous species)
2. Injure shade trees (tussock, gypsy, and leopard moths)
3. Convey many kinds of disease germs to animals and man (fleas, flies, mosquitoes)
4. Are agents in the transmission of plant diseases by carrying spores and infected material (hoppers and aphids)
5. Destroy buildings and wood (beetles, ants, white ants, etc.)
6. Annoy and injure man by bites and stings (wasps, mosquitoes, gnats)
7. Affect food (beetles, cockroaches)
8. Destroy clothing and fabrics (clothes moths, carpet beetles)
9. Are parasites on domestic animals and man (botflies, fleas, lice)

On the other hand, we owe to insects many useful processes and products such as:

1. Pollination of flowers (bees, butterflies, moths, certain types of flies)
2. Furnishing of silk (silk moth cocoon)
3. Furnishing of honey and wax (bees)
4. Furnishing of shellac (lac insect)
5. Furnishing of red dye (cochineal insect)
6. Furnishing of material for ink (gall insects)
7. Action as scavengers (maggots, beetles)
8. Killing of injurious insects (ladybugs, ichneumon flies)

Observing insects. Insects are so numerous, and there are so many kinds, that only days of deep winter could deprive an enthusiast from observing the ways of these six-footed creatures. In an amateur way, any boy or girl can be an *entomologist* (a person who studies insects). For instance, watch the antics of tumble bugs rolling their ball of eggs, or ant lions buried at the vortex of a funnel in the sand, with snapping jaws to catch luckless ants, or tent caterpillars leaving their webbed home in the morning or returning to it over silken paths at evening.

The life histories of insects offer endless possibilities for interesting observations. The kinds of eggs, where laid and how protected, the adaptations for larvae for food getting and concealment, the methods of pupating and emergence of the adults make a round of absorbing events. When you actually see all the stages in the final three- or four-day transition from the green jeweled pupa to the adult of the monarch butterfly, you will be breathless with the amazement at the miracle! Moths are easily reared from cocoons and even from eggs after you know how to care for the larvae. Another activity of insects worth watching is their visit to flowers when they are effecting cross-pollination.

Summary

The high degree of specialization found among the insects is well illustrated in the comparison of members of different orders. Butterflies and moths compose the order, Lepidoptera, which is readily distinguished from other orders by the brightly colored scales of the wings of its members. In the adult stage, butterflies and moths are the most beautiful of all insects. They are a decided contrast to the worm-like larvae from which they develop through stages of a complete metamorphosis. Some butterflies and moths render a valuable service in the cross-pollination of flowers, although the most famous service is rendered by the silk moth. Among the ranks of Lepidoptera are many exceedingly harmful members which do great damage in the larva stage to plants and fabrics of various kinds.

The order Hymenoptera includes bees, ants, and wasps, which are remarkable for the highly specialized societies in which they live. Three kinds of individuals, workers, queens, and drones, divide the labors of the beehive, most of the duties falling to the workers. The high degree of specialization of activities in the colony of social insects must be attributed to instinct rather than to intelligence. But even if these insects do not reason out their problems, they are none the less fascinating to study.

Other orders include dragon flies, beetles, true bugs, cicadas, and scale insects, all curiously adapted for different kinds of life activities.

Using Your Knowledge

1. From what source do silkworms obtain " silk " for cocoons?
2. How do you explain mimicry and protective coloration among insects?
3. Can you explain the fact that the sperm cells received in mating are able to exist alive for years inside the sperm receptacle of the queen bee?
4. How do insects communicate with each other?
5. Do any of the actions of ants imply intelligence or are they all to be classed as instinctive?
6. Dr. Beebe states that the army ant of the tropics is entirely blind. Can you name any other animals which lead successful lives in spite of the fact that they are missing one or more of the senses of higher animals?
7. Do you know the common representatives of each of the orders mentioned in this chapter?

Expressing Your Knowledge

larva	honey	Calosoma beetle
pupa	evaporation	chinch bug
chrysalis	beebread	bedbug
cocoon	pulp	squash bug
proboscis	shellac	stinkbug
protective coloration	entomologist	water strider
mimicry	moth	back swimmer
communal	butterfly	water bug
queen	monarch	water boatman
drone	viceroy	plant lice
worker	wasp	scale insect

sting	ichneumon fly	mealy bug
pollen basket	potato beetle	leaf hopper
wax	Japanese beetle	cicada
propolis	flea	weevil
gypsy moth	gnat	damsel fly
corn-ear worm	cabbage worm	tussock moth
comb	ladybug	apple worm

Applying Your Knowledge

1. Obtain some silkworms or silkworm eggs from a supply house and place them into a case in the laboratory. Keep the larvae well supplied with mulberry or Osage orange leaves. You should be able to observe all stages of the life cycle.

2. Make a collection of cocoons and chrysalises of moths and butterflies. Place them into a case in the laboratory and watch for each to hatch. This will occur much earlier indoors than out-of-doors. You will be able to secure fine specimens of adult moths and butterflies for your collection in this manner.

3. Make a collection of living water insects and display them in an aquarium in your classroom. They may be obtained by means of a dip net or a seine from a near-by pond.

4. Establish a demonstration ant colony in your schoolroom. The colony may be in a glass jar or in a special demonstration container. If a jar is used, wrap it in black paper until the ants have established runways along the glass. The ant colony may be obtained from nature or from a biological supply house.

5. Prepare a report on the importation of the ladybird beetle to fight the scale in the orange groves of California.

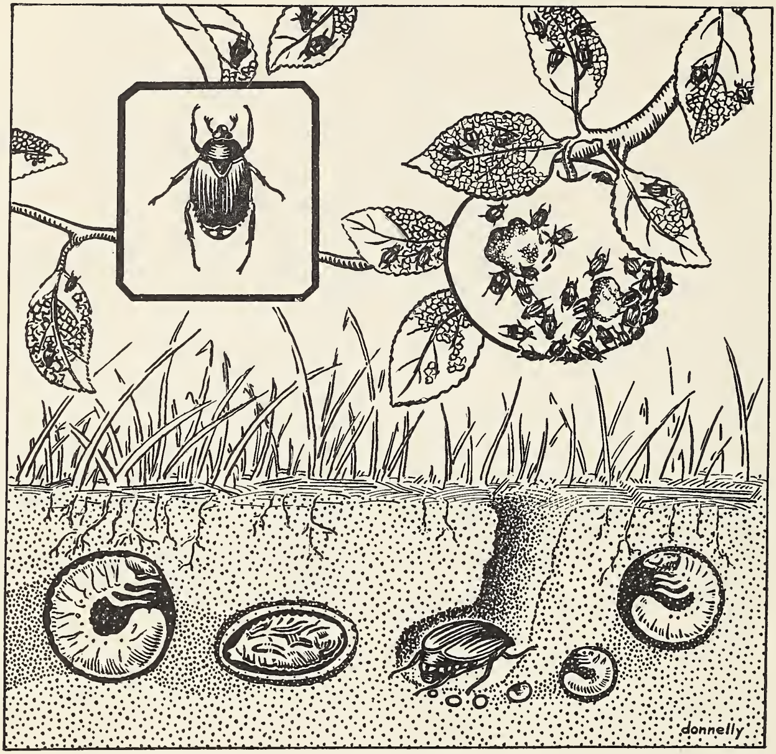
Chapter 29

The Control of Insect Pests

Some scientists have predicted that insects will finally contest with man for possession of the earth when the other living animals have perished. This startling prediction may seem somewhat exaggerated to you, but anyone who is thoroughly familiar with the insect problem will agree that it is at least a possibility.

A final struggle between man and the insect world can be avoided only by a constant program of insect control maintained through the close co-operation of the biologists of all nations. An effective program must receive the full co-operation of the entire population, farmers and city dwellers alike.

Biologists have established an international "rogues' gallery" of insects including the chief criminals. Methods of control have been formulated as a result of many hours of tedious research in the laboratories of colleges and universities, the Department of Agriculture and state agricultural institutes. Through these and other important agencies, the war against insects will continue. As new pests make their appearance, new



LIFE CYCLE OF THE JAPANESE BEETLE. Below the ground (left to right): mature grub (late spring); pupa; beetle laying eggs (summer); developing grubs (late summer and fall).

measures must be discovered to stop their destructive activities.

It remains for us, the general public, to take full advantage of the weapons now available and to take an active part in the war against insect pests. This chapter will acquaint you with some of the worst insect criminals and some of the control measures science has established to wage war against them.

Why are insects apt to become dangerous pests? Several characteristics of the insects account for the fact that they often become so abundant as to become serious pests. While most other forms of life have struggled to maintain their numbers with the spread of human civilization, insects have increased rapidly and have become the dominant form of animal life.

Small size is a distinct advantage to the insect. They are difficult to detect until the damage they have done has become noticeable. Shelter is no problem for them as hiding places need be no larger than a crevice in bark, the lower side of a leaf, or a tiny hole in the ground. Small size removes these organisms from the danger of starvation — a frequent problem to be faced by larger animals. Small amounts of food will maintain the insect, and if food becomes scarce in one locality the insect can easily travel to another.

Adaptability gives the insect another distinct advantage over most other forms of life. Many organisms are so critical in their environmental requirements that they cannot leave a specific environment. But not so with insects! They range far and wide over the land and seem equally at home in a great variety of conditions. They have invaded our land from Europe, Asia, and the Far East. Temperature changes, moisture variations, and other variable factors of environment seem to have little effect on most of them. Food, likewise, may be varied freely if the supply of any particular item becomes scarce. Any organism as freely adaptable as an insect could not help becoming a dominant form of life.

Rapid rate of reproduction. Over a period of time, birds or other larger animals may become so numerous in an area that they become destructive. Such a situation can be corrected by a little concentrated effort and will remain corrected for some time. But in the case of insects, epidemics may spring up suddenly. A campaign against them may correct the problem for a short time, but soon another situation, equally serious, may arise. This characteristic of insects is due to the extremely rapid rate at which they multiply. A single individual may lay from one hundred to several thousand eggs, most of which hatch. Thus, the population increases into almost staggering figures during a single season. The rate of reproduction is further increased by the short life cycle characteristic of many insects. The housefly, for example, may complete its life cycle within two weeks. That is, a fly may hatch from an egg, pass through the larva and pupa stages, and become an adult capable of further reproduction—all within the extremely short interval of two weeks. You will learn in the next chapter how many flies could be produced from a single female in one season, provided all of the offspring lived. The figure is indeed staggering. The short life cycle accounts for the fact that insects appear in swarms at certain times and, if destroyed, may reappear within a short time. Thus, insect control must be practiced continually.

Our weapons against the insect world. The war against insects is fought with four principal methods of attack. The struggle against them is effective only when all four of these methods are employed.

1. Quarantine
2. Conservation of natural enemies of insects
3. Environmental control
4. Chemical control

Quarantine as a control measure. At least seventy-five species of our harmful insects have been brought into this country unwittingly by colonists and importers in the form of eggs or larvae concealed on plants or in fresh fruits. To meet this danger Congress passed, in 1912, the Federal Plant Quarantine Act which checked the importation of insect-laden plants and fruits. In 1928 this work was reorganized under the Plant Quarantine and Control Administration whose inspectors have been placed in every port of entry by sea, land, or air. It is the duty of these inspectors to confiscate and destroy any plants or fruits coming into this country that are suspected of carrying harmful insects. Furthermore, the Control Administration is constantly on the watch to discover local areas in which insect pests exist within our own country in order that unaffected areas may be

PLANT QUARANTINE. At Nogales, Arizona, the customs inspector checks all purchases of tourists returning from across the border. The Federal Plant Quarantine Act prohibits the entry into the United States of any plant material which might bring in an alien insect pest or plant disease.

kept free. All roads and transportation lines leading out of the infected area are watched in the same way as at ports of entry. It is the duty of every one of us to co-operate with the inspectors who stop our automobiles for the purpose of preventing the spread of harmful insects into uninfected areas in this way. Had quarantines been in operation earlier in our history, we might not be struggling today with the European corn borer, the Mexican bean beetle, the Japanese beetle, the Oriental peach moth, the Mediterranean fruit fly, the gypsy moth, and many other foreign insect pests.

Conservation of natural enemies. Perhaps you have wondered how, if Japanese beetles are so terribly destructive, the Japanese are able to raise any plants at all. The answer concerns natural enemies of insects. Insects were present in America before our ancestors arrived from other lands. Yet, even without any control measures, these insects were held in check by natural enemies. The fact that our worst pests are imported species is explained, also, in terms of natural enemies. Introduced insects are free from those animals which held them in check in their native land. Consequently, they have multiplied here at a tremendous rate. Attempts have been made to import the natural enemies. Frequently, however, the natural enemies also become pests, thus creating a still greater problem. This situation should impress upon all of us the extreme need in preserving the balance of nature.

Birds are the most important natural enemies of insects. Much of our success in combating insects depends upon conservation of our bird life. We still have not learned this lesson completely, for we still needlessly destroy necessary nesting places and feeding grounds for our most important allies in the war on insects.

POTATO BEETLES. Both adult and larvae are shown.

Cotton Boll Weevil. The insect has its mouth inserted into a cotton boll.

Snakes, frogs, and toads are other valuable natural enemies of the insect world. But our attitude toward these creatures is far from enlightened. How many of you have felt that you have rendered a valuable service in killing a harmless garter snake which lives largely upon small rodents and insects?

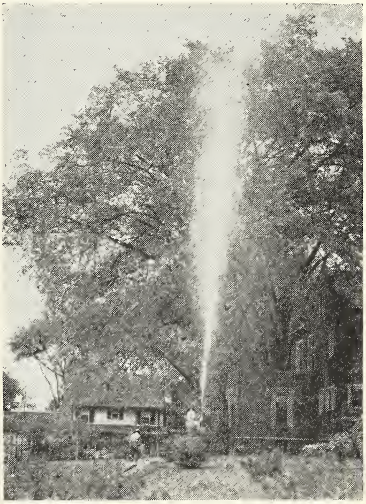
Environmental control. In some cases insects may be controlled by rotating the crops produced in a particular area. This method is totally ineffective against insects which migrate, but can be used against such pests as beetle grubs which are localized in a small region. Farmers often rotate crops in order to starve out root pests which attack a specific kind of plant.

Chemical control. When quarantines fail, and natural enemies are too infrequent to check a pest, we must resort to chemical means, which are expensive but usually very effective means of control.

There are four general classes of poisons or *insecticides* [*in seck'te sides*] which depend for their poisoning qualities on the different methods by which insects feed. *Stomach poisons* are used to combat chewing insects like caterpillars, beetles of all kinds, the potato bug, the brown-tail moth and the Oriental peach moth. These insects eat the foliage of those plants which they attack, and if they eat one of the poisons along with the green tissues, they are killed. The best stomach poisons are Paris green, arsenate of lead, and Bordeaux mixture.

Another group such as the scale insects, aphids, lice, and true bugs, get their food by sucking the plant juices. Stomach poisons are not effective against these insects because they do not eat the surfaces of the plants, but suck through these outer cells into the phloem and xylem cells. *Contact poisons* such as the various oil emulsions, lime-sulphur wash, whale oil soap, and nicotine solutions are effective against this group because they kill as they contact the insect's body. Formulae for making these solutions, and directions for their use may be procured from the Bureau of Entomology, United States Department of Agriculture, Washington, 25, D. C.

A third type of control employs gases like carbon disulphide or the very poisonous hydrocyanic acid. Peach borers,



Spraying Trees against Insect Pests

ANTI-LICE STATION. In Naples, Italy, DDT powder was used during World War II to kill lice. 70,000 persons were treated daily in this manner to help curb the spread of typhus fever.

the pink bollworm, and the common clothes moth may be controlled by using such *fumigants*. But they are effective only in a confined area and should be used by someone who knows them well and is an expert at handling them.

Sprays depend for their success on clogging or poisoning the trachea of insects. Pyrethrum, or certain thin oils chemically treated and prepared may be sprayed into the air of confined places and are very effective in the control of such insects as the tussock moth, cabbage worm, cotton boll weevil, and the codling moth.

Our new secret weapon. World War II was associated with several effective secret weapons, one of which was designed for use against the insect world. Many of us do not realize the tremendous problem faced by our armed forces in combating hordes of disease-carrying insects which hampered all operations. Along with new weapons to meet the challenge of the airplane, additional measures had to be devised to meet the insect problem. The result of the combined efforts of our chemists and biologists was the new weapon, DDT (an abbreviation for *dichloro-diphenyltrichloroethane*) which has been called the chemical "ack-ack."

DDT is not a recent discovery. In fact, it was produced by a German chemist named Othmar Zeidler in 1874. However, the first practical use of it was not made until 1940 when a Swiss company used it as a moth-proofing agent. During the early war years facilities were provided for large-scale production of DDT in America and the entire supply was hastened to the war theaters. In the Pacific theater it was a weapon as effective and necessary as those used against the enemy. Hospitals, barracks, tents, and bombing planes were rid of hordes of dangerous and obnoxious insects. In the European theater, too, it played an important part in winning the war. During the typhus epidemic in Italy, more than 2,000,000 people were dusted with DDT powder to rid them of disease-carrying lice.

DDT is now available to the public in the form of powder, sprays, and convenient "bombs." It is extremely potent against many species of insects which it kills by paralyzing the nervous system. Roaches, flies, mosquitoes, and bedbugs succumb quickly in air containing DDT mist. It is effective in the dairy barn against obnoxious flies. Important agricultural uses of DDT include spraying of orchards and garden crops. Unfortunately, DDT is as effective against bees as other insects. Hence, care must be used in its application to avoid the destruction of valuable insects.

DDT is effective against most of the insect pests of the household. Convenient Aerosol bombs are available for easy fumigation. It is a good plan to close the windows every few weeks and open the valve on the "bomb" for about thirty seconds in each room of the house. The air will be filled with a fine mist which will soon settle to the floor and kill all hidden insects. DDT is not poisonous to man but is somewhat irritating to the lungs. For this reason, it should not be inhaled. Fumigation can be carried on for an hour or two while the family is enjoying an outing. No precautions are necessary upon re-entering the house, although pets and goldfish should be removed before fumigation.

MATURE LARVA OF WEBBING CLOTHES MOTH

Summary

Insects, because of their small size, adaptability, and rapid reproduction are among the worst pests of man. Certain forms may suddenly appear in epidemic proportions, causing serious damage to shade trees, fruit trees, and crops. Among the most obnoxious forms are those which invade our homes.

Several control measures are employed in the fight against insect pests. These measures include quarantines, the conservation of natural enemies of insects, environmental control, and chemical control. The most rapid results are obtained by using chemical poisons called insecticides. Stomach poisons are used against chewing insects, while contact poisons are effective against sucking forms. Fumigants and sprays are very effective in confined areas.

One of the most striking discoveries for use against insects is the new weapon DDT. This substance was very effective during the war, and will continue its prominence in civilian use. DDT kills many kinds of insect pests by paralyzing their nervous systems. With weapons like DDT and the full co-operation of the public, man should win the war against the insects which threaten his existence. New insecticides make the battle much easier for him.

Using Your Knowledge

1. Why is a knowledge of the life history of insects necessary in order to cope with them?

2. Are "rogues' galleries" of insects of international importance?

3. If you were on the Control Administration, how would you develop public sentiment favorable to your work?

4. Describe the actual methods used by someone who, to your knowledge, is successful in preventing the ravages of insects.

5. What measures do you consider most effective against insects?

6. Are you able to recognize ten of the most important insect pests?

Expressing Your Knowledge

pest	Paris green	pyrethrum
quarantine	arsenate of lead	peach borer
extermination	oil emulsion	Oriental peach moth
conservation	lime-sulphur wash	Mediterranean fruit fly
insecticide	whale-oil soap	pink bollworm
rotation of crops	nicotine	corn borer
defoliating	carbon disulphide	cotton boll weevil
formulae	hydrocyanic acid	clothes moth
brown-tail moth	DDT	lice

Applying Your Knowledge

1. Write to the Commissioner of Parks in your city and try to arrange a conference with one of his experts to discuss methods of spraying trees and to see the process actually carried on.

2. Find out how some farmer or fruit grower uses insecticides.

3. If there are eggs of the tussock moth and tent caterpillar on the trees of your school ground, get several other volunteers and pick off the egg cases after the leaves have fallen in the autumn. Keep these over the winter and examine them the following spring. What has happened?

Chapter 30

Insects and Disease

Just how much human suffering and death can be attributed to certain insects which transmit disease is difficult to determine definitely, but sufficient evidence has been gathered to condemn several species as dangerous pests and enemies of mankind. No more important phase of the study of insects confronts the biologist than the investigation of insect-borne diseases and the control of the insect carriers.

Outstanding among these dangerous insects is the common housefly. The filthy habits of this creature all too frequently results in infection of those whose homes it inhabits with typhoid,

Wide World Photos, Inc.

HOUSEFLY

dysentery, or any of a number of other filth-borne diseases. Rivaling the housefly in notoriety are two species of mosquitoes, one which delayed the building of the Panama Canal with the scourge of yellow fever and another, the malaria mosquito, which only recently spread infection among large numbers of troops stationed in the Far East during World War II. The human louse, the rat flea, and the bedbug, likewise, deserve a prominent place in the insect rogues' gallery as dangerous carriers of disease.

The discovery of the strange and complicated life history of the malaria parasite, in which the *Anopheles* mosquito plays such an important part, reads like a fairy tale. The discovery of the relationship of the *Aëdes* mosquito to yellow fever was made by the medical officers and men of the United States Army.

In the study of flies and mosquitoes you will be introduced to a new order of insects, the *Diptera,* or two-winged flies. The discussion of the *Diptera* group will be limited to those members directly concerned with the transmission of disease.

Characteristics of the Diptera. These differ from other insects in having but one pair of wings, the posterior pair being replaced by flat or knob-shaped balancers, regarded as vestigial structures. The mouth parts are fitted for piercing, rasping, and sucking. Their metamorphosis is complete.

The housefly. The common housefly (*typhoid fly*) has large eyes, short fleshy antennae, and a club-shaped sucking tube. It never " bites " but the related stable fly, which closely resembles it, bites cattle and man fiercely. Its wings are well developed and operate at high speed by the powerful muscles of the thorax. The six legs are well developed and the feet are provided with claws and sticky hairs which aid in locomotion. Unless these hair tips are free from dust

Testing the Effectiveness of Fly Sprays. The technician is counting the number of flies killed by various different types of sprays.

they will not stick well and the fly cannot walk readily on smooth surfaces. You have probably noticed the care with which it cleans its feet by constantly rubbing them against each other and its body.

Our principal concern is with the life history and habits of the fly rather than with its structure, because it is in this connection that it affects vitally man's health.

The *eggs* are deposited in horse manure or in similar matter, from one to two hundred being laid by each female. They hatch in one day into the larval form which we call *maggots*, and in this stage do some good as scavengers. After eating and growing for five or six days, the larvae pass into the pupal condition, inside the last larval skin, which thus takes the place of a cocoon. From this the adults emerge in about a week. The whole development from egg to adult takes about two weeks. Breeding begins early in spring, and continues till cold weather. Flies multiply at a tremendous rate. Suppose that reproduction is unchecked and that all offspring survive (which fortunately is not the case;) then flies in the different generations of two weeks would each produce as follows:

1st		200	(half females)
2nd	(100 × 200)	20,000	(" ")
3d	(10,000 × 200)	2,000,000	
4th		200,000,000	
5th		20,000,000,000	
6th		2,000,000,000,000	
		2,020,202,020,200	in 12 weeks,

or the unthinkable number of over two million millions in half the breeding season.

Danger from flies. Flies have always been regarded as a nuisance, as they annoy mankind in various ways, but the real harm which they cause has only recently been realized. Biologists are now aware of the true menace of the fly.

They live in manure and filth, then come and crawl over our food and faces, or wash their feet in the milk pitcher. We can see that they are not only filthy but very harmful insects, and are to be

Wide World Photos, Inc.

Larvae of the Housefly

avoided and destroyed. Every day a fly eats its own weight of food, largely manure, sputum, and other filth, though it also samples our food at the table if it has a chance. Disease germs may pass through the fly's intestine unharmed and remain active in the " fly specks " which are desposited at intervals of five minutes. Thus the fly carries filth and disease germs not only externally on its feet and body but internally by way of its food and excreta.

Flies transmit germs of typhoid, cholera, summer complaint, dysentery, tuberculosis, and probably other diseases where the germs pass from the body in any form of excrement, pus, or sputum. The *tsetse fly* of Africa transmits the organisms causing the deadly "sleeping sickness." It has been proved that flies are responsible for the death of more people than all wild beasts and reptiles together. Anyone who enters the woods in early summer knows the annoyance of other Diptera such as midges, deer flies, and black flies. It is not thought that they carry disease germs, but they are unquestionably troublesome.

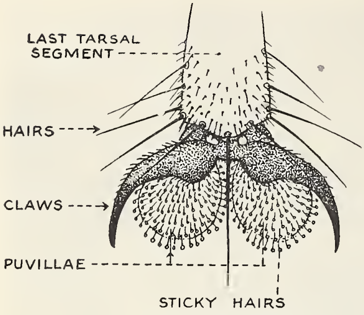
Fly control. The only time that " swatting " flies does much good is early in the spring when it is possible to kill the females that have survived the winter, and thus prevent their breeding. Fortunately there are more efficient ways of destroying this dangerous pest. Government bulletins fully describing all methods may be had for the asking, and general co-operation has much reduced the pest in many cities. The following are the most efficient methods of control:

1. Horse manure and other filth can be removed, screened, or chemically treated to kill the larvae.

2. Garbage and sewage can be properly covered and removed.

3. Houses can be screened.

4. Food, especially in stores, can be protected.



THE FOOT OF THE HOUSEFLY. Note the claws and sticky hairs which help in carrying disease germs.

5. Fly traps and wholesale poisons are helpful.

The mosquito. The mosquito is another member of the Diptera which demands mention because it, too, transmits disease germs to man, though it acts in a different way from the typhoid fly.

In the mosquito, the mouth parts — labrum, tongue, mandibles, and maxillae — are reduced to sharp, lance-like bristles, enclosed within the labium as a sheath, and are adapted for piercing and sucking. In order to dilute the blood so that they can withdraw it, they inject a little saliva, which causes the usual irritation and swelling known as "mosquito bite."

Transmission of disease germs. This would be bad enough, but it has been proved that if certain species of mosquitoes bite a person having either malaria or yellow fever, the organism which causes the disease is taken up with the blood, develops in the mosquito's body, and may be injected with the saliva into the blood of a well person. Not only has this been shown, but by means of experiments in which several men sacrificed their lives, it is also proved that this is the *only* way in which these, and probably other diseases, are transmitted. Men tended yellow fever patients, slept in their beds, wore their clothes, and though exposed in every way, did not contract the disease as long as screened from mosquitoes. Others who allowed themselves to be bitten by mosquitoes which had previously bitten yellow fever patients, invariably contracted the disease, which in some cases resulted in their death. From these sacrifices, methods of control have developed which have saved thousands of lives in all parts of the world.

Life history. As with the fly, a knowledge of its life history enables man to contend with the mosquito, and these campaigns are much more successful than those against the fly. The eggs are laid in stagnant water; ponds, rain barrels, and even tin cans furnish ideal breeding places. They are deposited in tiny rafts, consisting of many eggs covered with a waterproof coating, and when they hatch, the larvae emerge downwards into the water, and become the familiar "wigglers" seen in rain barrels. Though living in water the mosquito larva breathes air, which it obtains through a tube, projecting from the posterior of its abdomen. It may often be seen with this tube at the surface and the body hanging head downwards in the water. The pupa stage is also passed in the water and differs from most insect pupae in being an active "wiggler" like the larva. It differs from this larva in having a large head provided with two air tubes for breathing. The adult emerges from the pupa, whose shed skin acts as a raft. At this critical time the mosquito must not fall overboard or get its wings wet before they are expanded, else it will die.

Our most common northern mosquito (*Culex*) does not transmit disease germs and may be distinguished from *Anopheles* which carries malaria organisms, by the fact that the latter stands almost on its head when at rest, while *Culex* holds its body more nearly horizontal. Fortunately, *Aëdes*, which transmits yellow fever germs, is a tropical species of mosquito and does not usually invade the temperate regions.

Culex Mosquito Larvae and Pupae. Note the breathing tubes at the surface of the water.

Mosquito control. The following are successful methods:

1. Draining of swamps, covering or removing rain barrels, cisterns, cans, or any hollows where water may accumulate.
2. Spraying swamps and ponds with petroleum which covers the water with a film of oil so that neither larva nor pupa can breathe. (This also kills any adults which it strikes. However, oil treatment is injurious to plants and fishes in the water thus treated.)
3. Encouraging small fish and dragon flies which are natural enemies of mosquitoes.
4. Careful screening of houses, and in the tropics the wearing of protective clothing, especially in infected regions.
5. Quarantining of yellow fever and malarial patients in screened rooms.

By such methods both malaria and yellow fever have been stamped out in many regions where they were formerly very dangerous. The chief obstacle to the completion of the Panama Canal by the French was the awful death rate due to these diseases. Now, with proper sanitary measures, the Canal Zone has a lower death rate than New York City. Because of the modern knowledge of disease transmission and control as applied by Colonel W. C. Gorgas, the completed canal stands as a monument to American health science as well as to American engineering. In other notable plague spots the consequences of heroic experiment have been far-reaching. Central America, the West Indies, and the Philippines are now healthful regions. New Orleans, formerly scourged by epidemics of yellow fever, is now almost free from this dreadful malady.

A biological victory. One of the most brilliant chapters in the history of the war against disease recounts the work of four American army surgeons in the conquest of yellow fever.

In 1900, Doctors Reed, Carroll, Lazear, and Agramonte were sent to Cuba to study this disease. It had always been a scourge in the West Indian region and was now spreading among our soldiers. They suspected a mosquito (*Aëdes*) to be the carrier, but could not test their theory on animals, as only human beings take yellow fever. So they decided to try it on themselves, and allowed mosquitoes which had bitten yellow fever patients to bite them. Carroll was the first to be ill, but after a long and painful sickness, finally recovered. Lazear was the next to come down with the disease and he died. Still the experiments went on, despite the terrible risk, and there were many new volunteers. Two others were selected, a soldier, Kissinger, and a civilian, Moran. Both insisted that they receive no pay, as they willingly offered their lives for the benefit of humanity. Both men recovered after severe illness, but Kissinger was permanently disabled as the result of his heroism.

The work of this gallant band of soldiers of science proved that the mosquito is the *only* carrier of yellow fever germs, and means were proposed for its control. An active campaign was begun at once, lowering the number of deaths from the disease in Havana to eighteen in 1901 and none in 1902. The terrible curse of the tropics was wiped out.

Major Reed writes: "In my opinion this exhibition of moral courage has never been surpassed in the Army of the United States."

The history of medicine and sanitation is full of such examples of quiet heriosm, where men have offered themselves to suffering and death far worse than is incurred in battle and without the excitement of war or the encouragement of popular applause.

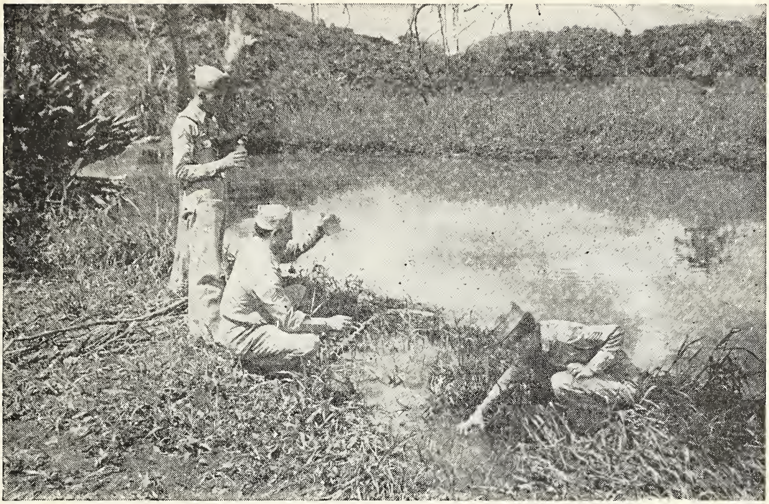
Conquest of malaria. The conquest of malaria was brought about in similar manner, by the careful research and courageous experiment of English and Italian doctors. As late as 1894, the Standard Dictionary of Medicine said that malaria was caused by "an earth-born poison generated in the soil," associated, as its name signifies, with bad air — especially night air.

The malaria germ had been seen by a French surgeon in 1880, but not associated with mosquitoes at all, though in 1884 an American, A. F. A. King, had urged this as possible. In 1897 two English physicians, Manson and Ross, traced the germ of bird malaria to the mosquito, and the following year two Italians, Grassi and Bignami, found the germ of human malaria in the body of *Anopheles* mosquitoes.

By experiments similar to those described for yellow fever, it was proved possible to live in health in the worst swamps of the Roman Campagna, if protected from mosquitoes. To prove their action in malaria transmission, Doctor Manson's son and another volunteer, both in England, allowed themselves to be inoculated with malaria germs from the bite of *Anopheles* mosquitoes brought from Italy. Both took the disease, but fortunately they were cured. It is to such work as this that science owes her victories and to it we owe also our greater safety from disease.

Treatment of malaria. Until recently, *quinine* was the only specific drug used in the treatment and prevention of malaria. Quinine is obtained from the bark of the Cinchona tree which grows in western South America and in certain islands of the East Indies, especially Java. The discovery of quinine was a triumph for medicine as it marked the only means of combating this dread disease.

The average American thought little about malaria until recently. It was rather rare in the United States and one who traveled into malaria infested regions could use quinine as a preventive measure. World War II brought a critical emergency, however. The quinine supply was largely cut off with the capture of the Dutch East Indies and the South American supply was far too meager to meet the needs of the large armies bound for the Pacific war theater. Accordingly, the American scientists began the search for a quinine substitute or a means of producing synthetic quinine. Synthetic quinine had long



Ewing Galloway, N.Y.

MALARIA CONTROL. In a quiet stream somewhere in the Panamanian jungle these workers are segregating mosquito larvae into specimen jars as they are strained from the still water. Research against malaria is still going on.

been a goal of chemists the world over, but with the opening of the war, the answer had not been found. The goal was attained in the research laboratories of America during the early years of the war in the form of a synthetic product called *atabrin*. This synthetic drug was used extensively in the armed forces and represents one of the great contributions of American science toward the winning of the war.

Relation of other insects to disease. World War II brought other problems in the control of insect borne diseases. Epidemics of deadly typhus fever broke out in Italy near the close of the war, causing high mortality among the troops and the civilian population. The disease is carried by the human body louse, so control of typhus depended upon destruction of the carriers. Utilizing the powerful insecticide DDT, the United States Army Medical Corps began the systematic "de-lousing" of all of the communities in which typhus had appeared. The control of the epidemic was a credit both to the Medical Corps and to the powerful new weapon which American scientists had placed in its hands.

The rat flea is another dangerous carrier of disease. It is known to carry typhus but is usually more closely associated with the transmission of bubonic plague. Ships from the Orient at one time carried many rats to American ports. Fleas present on the rats' bodies were a serious health menace. Today, rigid measures are used to prevent rats from gaining entrance to sea ports. While not associated with any particular disease, bedbugs may also carry infections which occur in the human blood stream. Among other diseases, a spread of relapsing fever has been traced directly to these insect carriers.

Summary

Probably the most direct damage insects cause to man is the spread of infectious diseases. Among the insects which carry disease, the common housefly is one of the most notorious. Flies breed in filth and sewage which may contain typhoid and other disease-producing organisms. Control of these harmful insects through sanitary measures and mechanical destruction can do much toward stamping out the filth-borne diseases.

The *Aëdes* mosquito, prevalent in Central America, the West Indies, and the Philippines, is the sole carrier of the yellow fever organism. The brilliant work of the United States Army at the close of the Spanish-American War resulted in control of this disease. Another species of mosquito, called *Anopheles,* is the sole carrier of the malaria parasite. Both yellow fever and malaria can be wiped out by eradicating their insect carriers.

Other insect carriers of disease include the body louse, the rat flea, and the bedbug. These insects create special problems for the biologist.

Using Your Knowledge

1. Why is prevention better than cure in the case of flies and mosquitoes?

2. Why is it incorrect to say that insects carry diseases?

3. Can yellow fever be eradicated or simply controlled? Explain.

4. Can you obtain statistics to show the relation between the rise in the death rate for certain diseases in the summer time and the prevalence of flies?

5. Can you list diseases other than those mentioned in the text which are associated with insect-carriers?

6. What institutions are studying the problem of the relation of insects to disease?

Expressing Your Knowledge

Diptera	Anopheles	atabrin
maggot	Aëdes	typhus
" fly speck "	malaria	bubonic plague
typhoid	yellow fever	louse
wiggler	Cinchona	flea
Culex	quinine	tsetse fly

Applying Your Knowledge

1. Make a survey of certain sections of your community to find: (a) possible breeding places for mosquitoes and (b) possible breeding places for flies. Indicate those places on a map. If possible, institute a campaign through the school and the Board of Health to have these places corrected.

2. Talk to a veteran of World War II and find out what measures were taken to prevent malaria, and what treatment was used in cases of the disease.

3. Try to get information on the campaign against the outbreak of the epidemic of typhus fever in northern Italy at the close of World War II. Control of this dangerous epidemic reflected great credit upon the United States Army Medical Corps.

4. Prepare a report on the conquest of yellow fever by Major Walter Reed and his associates at the turn of the century.

5. List the various ways in which the fly menace in the home can be reduced.

Increasing Your Knowledge of This Unit

Beebe, Charles William. *Beneath Tropic Seas*. G. P. Putnam's Sons, New York. 1928

Buchsbaum, Ralph. *Animals Without Backbones*. The University of Chicago Press, Chicago. 1938

Clark, Austin H. *Animals of Land and Sea*. 2d. Edition. D. Van Nostrand Co., New York. 1927

Clark, G. Glenwood. *Tiny Toilers and Their Works*. The Century Co., New York. 1921

Comstock, Anna Botsford. *Handbook of Nature Study*. Comstock Publishing Co., Ithaca, New York. 1911

Crowder, William. *Dwellers of the Sea and Shore*. The Macmillan Co., New York. 1923

DuPuy, William Atherton. *Our Insect Friends and Foes*. The John C. Winston Co., Chicago. 1925

Flint, Wesley Pillsbury and Metcalf, Clell Lee. *Insects, Man's Chief Competitor*. The Williams and Wilkins Co., Baltimore. 1932

Hegner, Robert. *Parade of the Animal Kingdom*. The Macmillan Co., New York. 1935

Hegner, Robert. *Practical Zoology*. Revised Edition. The Macmillan Co., New York. 1931

Holland, William Jacob. *The Butterfly Book*. (Nature Library) New Revised Edition. Doubleday Doran and Co., New York. 1931

Holland, William Jacob. *The Moth Book*. Doubleday Doran and Co., Garden City, New York. 1903

Howes, Paul Griswold. *Backyard Explorations*. Doubleday Doran and Co., New York. 1926

Howes, Paul Griswold. *Handbook for the Curious*. G. P. Putnam's Sons, New York. 1936

Lutz, Frank. *Fieldbook of Insects*. 3d Edition. G. P. Putnam's Sons, New York. 1935

Morgan, Ann Haven. *Fieldbook of Animals in Winter*. G. P. Putnam's Sons, New York. 1939

Morgan, Ann Haven. *Fieldbook of Ponds and Streams*. G. P. Putnam's Sons, New York. 1930

National Geographic Society. *Our Insect Friends and Foes and Spiders*. The Society, Washington, D. C. 1935

Reed, W. Maxwell and Bronson, Wilfrid S. *The Sea for Sam*. Harcourt, Brace and Co., New York. 1935

Robertson-Miller, Ellen. *Butterfly and Moth Book*. Charles Scribner's Sons, New York. 1912

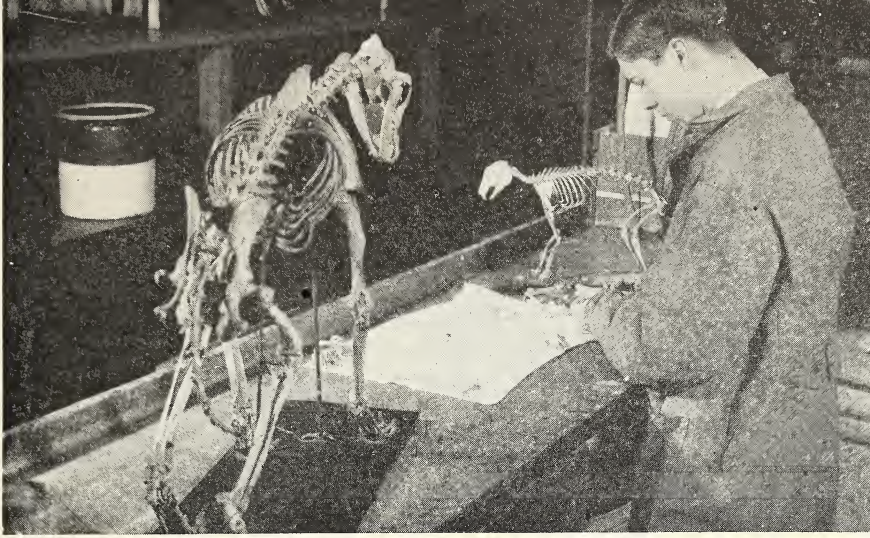
Roseneau, Milton J. *Preventive Medicine and Hygiene*. 6th Edition. D. Appleton-Century Co., New York. 1935

Teale, Edwin W. *Grassroot Jungles: A Book of Insects*. Dodd Mead and Co., New York. 1937

Verrill, A. Hyatt. *Strange Insects and Their Stories*. L. C. Page and Co., Boston. 1937

Verrill, A. Hyatt. *Strange Sea Shells and Their Stories*. L. C. Page and Co., Boston. 1937

Washburn, F. L. *Injurious Insects and Useful Birds*. J. B. Lippincott Co., Philadelphia. 1918



Unit 7 ~~

Animals With Backbones

You are about to study the most perfect group of animals in existence — a group which excels all others in body structure and functional efficiency. Scientists call them vertebrates because of a spinal column, composed of separate bones called vertebrae, which lies along the back or dorsal side. The spinal column encases a large nerve, called the spinal cord, which leads to a highly developed brain enclosed in a protective skull.

Man lives in close association with the other vertebrates. Fishes furnish an important part of the food supply and tempt many anglers to the waters in which they live. While not as important as the fishes, amphibians and reptiles affect our lives in many ways. Birds rule the air and often live close to man. Their value is tremendous in maintaining the balance of nature. The mammals, the group to which man, himself, belongs, are our closest associates. Many mammals serve man directly as food animals, beasts of burden, sources of pleasure, and as pets.

Chapter 31

Introduction to the Vertebrates

The term "animal," to most people, means a fish, frog, snake, dog, horse, deer, bear, or some other form of vertebrate. This is because these animals are closely associated with our lives. In your study of invertebrates, you probably found many animals you did not know existed. Many other invertebrate forms are known only to the biologist. In the study of vertebrates, however, you will be dealing with much more familiar organisms.

We live in the age of vertebrates. While less abundant in actual numbers than invertebrates, especially insects, vertebrates are far superior even to the most complicated invertebrate. It is among the vertebrates that we find life in its most highly specialized form. Complex systems composed of highly developed organs carry on the life processes in a manner far more efficient than in any other forms of life. It is among the vertebrates that we find the brain dominating all other organs and expressing itself through intelligent acts of the organism.

As vertebrates ourselves, we are naturally interested in those animals which are most like us in form and in behavior. To one who understands the fundamental structure of the human body, the anatomy of a fish, frog, or bird is not difficult. The study of the organs and systems of these lower vertebrates will, in turn, greatly simplify the study of the biology of man. The phases of vertebrate biology dealing with the habits and distribution of vertebrates will enrich the trips you take into their native haunts.

Before beginning the detailed study of any one group of vertebrates, a comparison should be made between the typical vertebrate and the typical invertebrate. This chapter will make such a comparison and will, in addition, show you the characteristics which all vertebrates have in common.

Invertebrate development. While it is certain that all living things are more or less related, still they have developed along very different lines and to very different extents.

The Protozoa seem to have carried the specialization of the *single cell* to its limit. This, while assuring their survival, could not raise them very high in the scale of development.

The sponges have obtained the utmost possible advantage from colonizing slightly specialized cells in slightly specialized bodies, and show a considerable advance over the Protozoa.

The *Hydra* and its relations have reached a much higher plane by development of tissues for special purposes.

The worms mark a very diverse class but some of them have well-developed systems of organs, digestive, circulatory, nervous, etc., which had never appeared in previous forms.

Between the worm type and the highest invertebrates it seems as if several schemes of development had been tried out, each carried to a point where it could no longer be much improved.

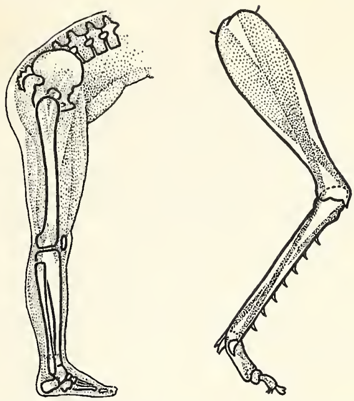
The mollusks represent the ultimate advantage to be gained from a protective shell and rather high internal development, coupled, in most cases, with an inactive life. This made for safety, but limited any increase in activity and intelligence.

The Arthropods, especially the insect class, mark the group in which the external protective skeleton (*exoskeleton*) reaches its highest development in being jointed, so that activity need not be sacrificed to safety. This has produced the winners in life's race, if numbers be the standard. But the external skeleton and the ventral nervous system imposed obstacles to a large increase in size and to a highly developed brain.

Vertebrate development. A third line of development, with the internal skeleton (*endoskeleton*), and with the nervous system dorsal in the body, is represented in the group of animals called the *vertebrates*. This permitted great increase in size of body and brain, but gave less protection, and necessitated an active, intelligent life to escape enemies.

Characteristics of vertebrates. Vertebrates include many very different animals, but all agree in the following points, in which they also differ from all invertebrates. All vertebrates have:

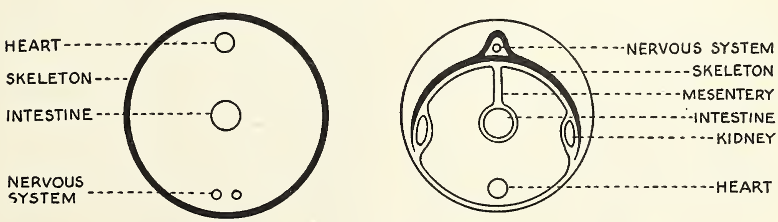
1. An internal skeleton (endoskeleton) of bone or cartilage (a gristle-like tissue)
2. A spinal column composed of vertebrae



Comparison of Skeleton and Muscle of a Vertebrate (Man) and an Invertebrate (Grasshopper). The vertebrate has an internal skeleton with muscles on the outside. The invertebrate skeleton, if present, is external and the muscles are located inside.

3. A dorsal nervous system
4. Two body cavities: a dorsal one for the nervous system and a larger ventral one for the other organs
5. Eyes, ears, and nostrils always in the head
6. Eyelids and separate teeth usually present
7. Heart ventral, and red blood
8. Never more than two pairs of limbs

Highly developed systems of a vertebrate. Vertebrates are characterized by having highly specialized systems for performing each of the life processes.



Location of Similar Organs in Vertebrates and Invertebrates

These systems include:

1. *Integumentary system.* Composed of the outer body covering and special outgrowths such as scales, feathers, or hair for protection.

2. *Muscular system.* Composed of several different kinds of muscles, many of which accomplish the most efficient form of movement found in any living organism.

3. *Skeletal system.* Composed of the bones which are internal and provide support for the body without hampering its movement.

4. *Digestive system.* Including many specialized organs concerned with the preparation of food for use by the body tissues.

5. *Respiratory system.* A highly specialized system including gills or lungs which are used in the exchange of gases between the organism and its external environment.

6. *Circulatory system.* Including the heart and blood vessels which function as the transportation system of the body.

7. *Excretory system.* Accomplishes the removal of waste products from the body.

8. *Endocrine system.* Composed of glands which produce secretions necessary in the operation of the other systems.

9. *Nervous system.* A very complex system composed of the brain, nerves, and special sense organs. This is the most highly specialized system of the vertebrate.

10. *Reproductive system.* Including the organs of reproduction.

Classes of vertebrates. Most of the familiar vertebrates are included in five large groups or *classes*. While each class is distinct in having definite characteristics of its own, all classes are similar in possessing the main characteristics of vertebrate animals. The principal classes of vertebrates are:

1. Pisces [*Pis′eez*] (fishes)
2. Amphibia [*Am fib′ee ah*] (frogs, toads, salamanders)
3. Reptilia [*Rep till′ee ah*] (snakes, turtles, lizards)
4. Aves [*Av′eez*] (birds)
5. Mammalia [*Mam mail′ee ah*] (mouse, elephant, whale, cat, man)

The classes are listed in the order of their complexity. Fishes are the simplest of the classes while the Mammalia include the most complex forms. The classes show, also, an interesting transition from water to land. The simpler vertebrates inhabit water, a characteristic of most of the invertebrates, while the more complex forms usually live on land. In studying the Amphibia, you will find an interesting change from water to land occurring in the life of each individual. The Amphibia represent a very significant group among the vertebrates, because they always begin their life in an aquatic environment.

Man and the other vertebrates. The human body is a true vertebrate type. It is similar in general structure to the other vertebrates. Superior brain development alone has placed man far above the other vertebrates. Every one of the lower groups has members which excel man in some other respect. We cannot compare with the fish in swimming nor with the deer in running. Human strength is no match for the horse or elephant. Flight, a characteristic of most birds, is entirely impossible in our case, except with the aid of machines which have been made by our ingenuity. It is the development of our brain that has enabled us to retain the lead in the race of life. Superior intelligence compensates many times for physical disadvantages.

Using Your Knowledge

1. What compensations have most vertebrates for the lack of external protection?

2. Can you enumerate reasons to show why man is regarded as the highest vertebrate, in spite of the fact that he is relatively defenseless without weapons?

3. Which do you regard as more efficient, the endoskeleton of the vertebrates, or the exoskeleton of the invertebrates?

4. Can you show how existence which is too protected or safe is likely to prevent adaptations and specialization?

5. Why can we make pets of vertebrates but not of invertebrates?

Expressing Your Knowledge

specialization	vertebrate	Pisces
survival	invertebrate	Amphibia
endoskeleton	Mammalia	excretory
Reptilia	intelligence	circulatory
spinal column	Aves	endocrine

Applying Your Knowledge

1. List the vertebrates you might find around your own home.

2. All of the classes of vertebrates may be found living together in a lake. If you live near a lake, visit it and see if you can find at least one representative animal in each class.

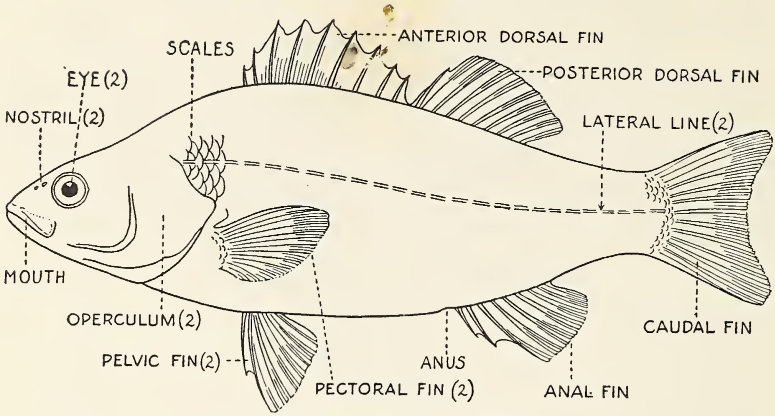
3. Enumerate some of the ways in which a cat is superior to a goldfish. In what respects are you superior to both?

Chapter 32

Rulers of the Deep—the Fishes

Interest in fish usually begins when one is old enough to carry a can of worms and a willow pole to some favorite spot along a stream. In such surroundings, the young fisherman frequently begins his study of biology for he observes carefully the habits of the fish, the kind of water each prefers, and the type of bait he should use to entice a particular variety. From childhood on, fishing continues to be a favorite sport. Fly rods and casting rods may replace the willow pole, and tackle boxes the can of worms, but the tug of a fish on a line gives the same thrill.

In the study of fish, we deal with a group of vertebrates of great biological importance, economic importance, and recreational value. In a wide variety of forms, they inhabit nearly all bodies of water the world over. Fresh water varieties inhabit the brooks and streams, ponds and lakes—even subterranean streams in caves. Salt water species range from the frigid waters of the polar regions to the tepid waters of the equator.



External Structure of the Fish

They range in size from species less than an inch to those many feet in length. No one knows better than the fisherman the tremendous variation in the form and habits of the fishes.

With the exception of a small group of fish called lungfish, these vertebrates are adapted to a water environment. Water offers utterly different conditions from land and air. Consequently, the fish shows many interesting adaptations in its body structure. You will learn in this chapter many ways in which the fish is modified for life in the water. In the study of its internal systems you will learn the basic plan of structure of all vertebrates. You will follow the salmon in its amazing journey to find suitable places for depositing eggs. This chapter will include, also, a discussion of the economic importance of fish and some of the measures which have been taken to insure a supply of fish for future generations.

What is a fish? We call many animals " fish " which are not even remotely related to them, merely because they live in the water. Almost every group of animals has some member classed as " fish " either by name or association. The " jellyfish " is related to the *Hydra* and coral. The " starfish " is an echinoderm. " Shellfish " include mollusks such as clams and oysters. The " crayfish " is a crustacean and the " silverfish " is an insect! Then there is the whale which many consider a fish, though it is a mammal, and even the seal is sometimes put in this class, though more nearly related to the cat.

True fish are aquatic or marine vertebrates, with a skeleton of either bone or cartilage; they breathe by means of gills, are usually covered with scales, and have limbs in the form of fins.

The body can be divided into three regions, the head, trunk, and tail. There is no narrowing to mark the neck, since the smoother outline is better fitted for passing through the water. The general outline of the body is spindle-shaped, flattened more or less at the sides to aid in locomotion by displacing the water as easily as possible.

Scales. The whole body, except the head and fins, is covered with scales overlapping toward the rear, giving protection and at the same time allowing great freedom of motion. In some fish, such as the trout and catfish, the scales are minute or lacking. In most cases the color of the skin, seen through the transparent scales, blends with the surroundings and is therefore a protection. The skin is supplied with a slimy secretion which, passing off between the scales, aids in locomotion and in escape from enemies.

Head. The head is usually pointed, protected by plates instead of scales, and attached directly to the trunk. The lack of a neck is no disadvantage, as the fish can turn its whole body as quickly as most animals can turn their heads.

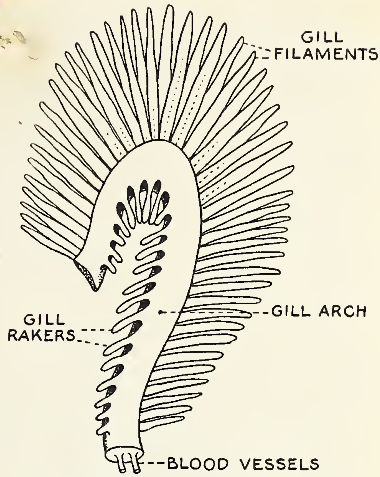
The mouth is usually at the extreme anterior end, since it is the only organ for food getting or defense. It is provided with numerous sharp teeth, arranged on three sets of jaw bones and slanting inward, so that there is little chance for a victim to escape.

There are two *nasal cavities* each with two nostrils. They are used for smell only, since they do not connect with the throat and cannot be used in breathing.

The *eyes* are large, somewhat movable, and have no lids, but have a cornea, lens, retina, etc., somewhat similar to our own, and entirely different from the compound eyes of the insects.

The *ears* are embedded in the skull and do not show externally; they probably function as balancing organs and are used to detect vibration rather than sound. Fish probably cannot " hear " in the sense that we do.

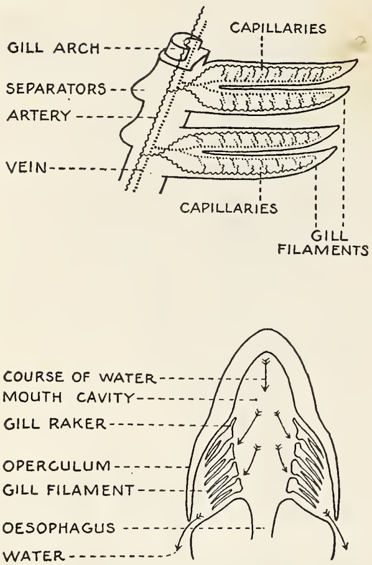
The gills. At each side of the head is a crescent-shaped slit which marks the rear border of the gill cover or *operculum*. These slits almost meet on the ventral side, leaving only a narrow isthmus at the throat region, and thoroughly exposing the gills to the water. If we look inside the mouth we can see that the throat has five slits on each side, leaving four gill *arches* between them. If the operculum is lifted the outer sides of these gills can be seen.



AN ENTIRE GILL SEEN FROM THE SIDE (ENLARGED)

Each gill consists of an arch of bone between the slits in the throat wall, to which are attached two rows of thin-walled threadlike appendages called the gill *filaments*. These filaments are richly provided with capillaries, so that the blood is brought into close contact with the water over a large surface. This permits the exchange of oxygen (dissolved in water) and carbon dioxide. The gill arches have fingerlike projections called gill *rakers,* on the side toward the throat, which prevent food or dirt from getting into the filaments and also keep the arches separate to allow free circulation of water.

The water is taken in at the mouth, which is then closed for a moment, forcing the water through the gill slits over the filaments and out beneath the operculum; the forward motion of the fish aids in this process.



Gill Structure in the Fish. Top: gill filaments and arch, greatly enlarged. Bottom: diagram of mouth showing location of gills and course of water over them.

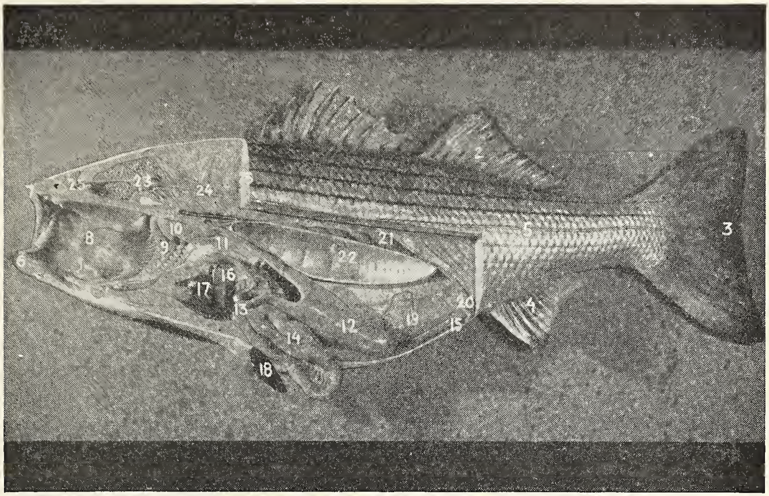
Here, as in all breathing organs, we find a large extent of surface, thin membranes, and rich blood supply, all adaptations for diffusion together with protective devices in the form of operculum and gill rakers, and provision for a free circulation of water.

Trunk. Extending along both sides of the body backward from the operculum is a row of pitted scales with sense organs beneath them, known as the *lateral line*. This probably aids the ears in feeling vibrations, and functions as a pressure organ to indicate the depth at which the fish may be swimming. The fins are the most characteristic and noticeable appendages of the trunk and consist of a double membrane, supported by cartilaginous or spiny rays, and operated by powerful muscles. Their shape and number vary with the kind of fish, but there are always two pairs, the *pectoral* (anterior) and *pelvic* (posterior) fins, which are homologous with the arms and legs of other vertebrates. The other fins are all on the median (middle) line of the trunk, there being sometimes two *dorsal* fins, always a large tail (*caudal*) fin, and an *anal* fin just back of the anus. In general the fins are beautifully fitted for locomotion in the water, but they are differently used in this process, the caudal fin being the chief propelling and steering organ. The paired fins aid in locomotion and in balancing, and also support the body when the fish is resting on the bottom. The other median fins aid in steering and they are often provided with sharp spines for defense.

The bulk of the fish's body consists of powerful muscles arranged in plates. The flexible backbone is made up of numerous vertebrae, which permits the fins to be utilized to the fullest extent and, aided as it is by the pointed, scale-covered, slippery body, provides a system of aquatic locomotion second to none in the world.

Digestive system. The food of most fish consists of other aquatic animals, though a few are vegetarians. The food is seized by the mouth, but the teeth serve only for grasping and not for chewing. On this account the gullet is large and short, and the stomach is provided with powerful digestive fluids. As in most carnivorous animals, the intestine is rather short. Opening into it is the duct from a well-developed liver between whose lobes is the *gall sac*. As in other animals, the food is either assimilated or oxidized. The waste materials are excreted.

Circulation. The fish has a heart consisting of two chambers, an *auricle* and a *ventricle,* located just posterior to the



A Dissected Fish Showing Internal Structure. 1. Spinous dorsal fin. 2. Soft dorsal fin. 3. Tail or caudal fin. 4. Anal fin. 5. Lateral line. 6. Lower jaw or mandible. 7. Upper jaw or maxillary. 8. Mouth cavity. 9. Gills (rakers showing). 10. Pharyngeal teeth. 11. Gullet. 12. Stomach. 13. Caeca. 14. Intestine. 15. Anus. 16. Liver. 17. Heart. 18. Spleen. 19. Ovary. 20. Ureter. 21. Kidney. 22. Swim bladder. 23. Brain. 24. Spinal cord. 25. Olfactory lobe. 26. Body muscle sectioned.

isthmus, so it is almost literally true that its "heart is in its throat." The blood leaves the heart by a large artery that branches to each of the gills, in whose filaments it is relieved of its carbon dioxide. Then laden with oxygen it flows into a dorsal artery which has branches to all the muscles and internal organs, where it exchanges this oxygen for carbon dioxide. The blood which flows to the digestive organs receives the foodstuffs which they have prepared, passes through the liver, and so back to the auricle of the heart. The blood from the muscles returns to the auricle of the heart by the caudal vein and other smaller veins. A part passes through the kidneys each time, where urea and other wastes are removed. Thus it happens that the heart is always pumping blood that is rich in nutrients and carbon dioxide but poor in oxygen.

Nervous system. The central nervous system in all vertebrates is located in the dorsal body cavity, protected by outgrowths from the spinal column. This arrangement is entirely different from that found in the invertebrates, where the nervous system lies along the ventral side and is not so completely separated from the other internal organs.

In the case of most fish the nervous system consists of the spinal cord extending the whole length of the body, and protected by arches of bone attached to each vertebra. From it many nerves extend to the muscles and internal organs. At the anterior, the cord enlarges to form a brain, entirely different in structure from the so-called brain of lower forms in that it has developed separate regions for different functions. The fish's brain consists of five principal parts. At the anterior are the *olfac-*

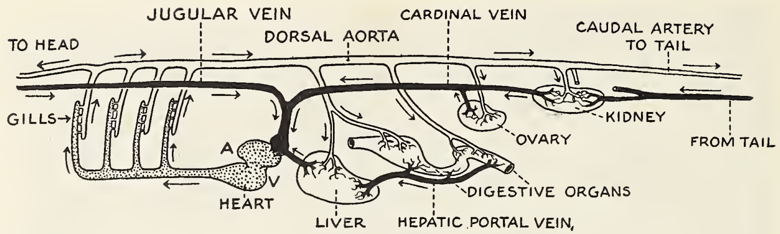


Diagram Showing the Circulation in the Fish. Note that the blood flows in a single circuit, from body to heart, to gills and to body again.

tory lobes from which the nerves of smell extend to the nostrils. Posterior to these, and considerably larger, are the two lobes of the *cerebrum,* which control the voluntary muscles of the animal. The largest parts of the brain are the two *optic lobes* connected directly with the eyes and concerned with the sense of sight. Behind them comes the *cerebellum,* and finally the enlarged end of the spinal cord, the *medulla,* both of which have to do with regulating muscular action and with the work of the internal organs. The medulla is also a region from which branch many important nerves.

The brain as a whole, compared with other vertebrates, is not highly developed. The cerebrum, the center of voluntary control, is actually smaller than the optic lobes. The real advance of the fish brain can be realized only when it is compared with invertebrate forms. In invertebrate brains there are no special parts for separate uses and so a highly developed instinct is the best such a brain can achieve.

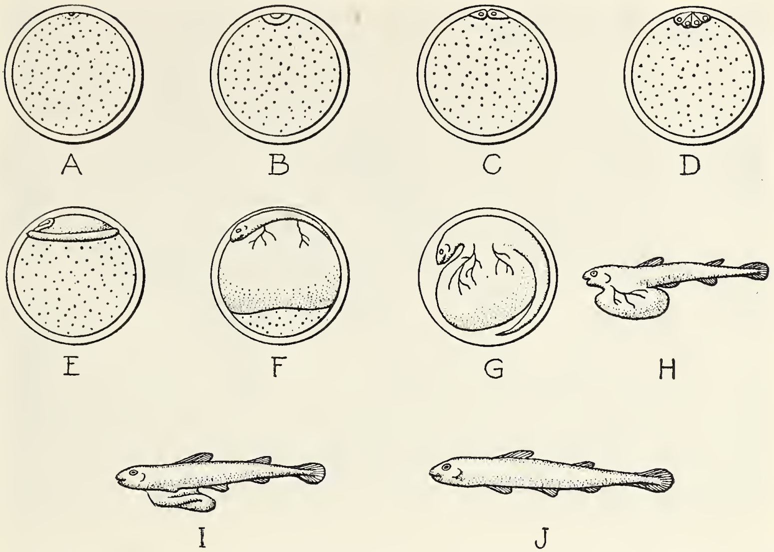
In the vertebrate, the development of specialized parts of the brain, though primitive at first, paved the way for a cerebrum which would exceed all the other brain regions in bulk, and make possible voluntary motion, thought, and reason. Fish have no external ears; nerve endings on each side, called the *lateral line,* convey to the brain impulses from vibrations. Some fishes have sensitive feelers or *barbels* around the mouth.

Air bladder. Another organ, simple in the fish, but with a great future before it, is the air bladder which is found in most species. This consists of a thin-walled elliptical sac, located in the dorsal part of the body cavity and sometimes connected with the throat by a tube. Its function is to assist the fish in maintaining a level in the water; by contraction of its walls the fish can sink, and by expansion, rise without other effort.

It develops in the embryo fish as an outgrowth from the throat, from which it extends back and enlarges into the adult form, often losing all connection with the outer air. In just the same way the lungs of all higher forms develop in the embryo stage from the throat, while retaining their connection with the mouth and performing an entirely different function. In fact, the remote origin of the vertebrate lung is undoubtedly the air bladder of fishlike ancestors.

In certain Australian fish the air bladder is actually used as a lung and the gills are poorly developed for breathing.

As the development of the higher forms goes on, the simple air bladder becomes two lobed, its walls develop ridges, and finally many-celled cham-



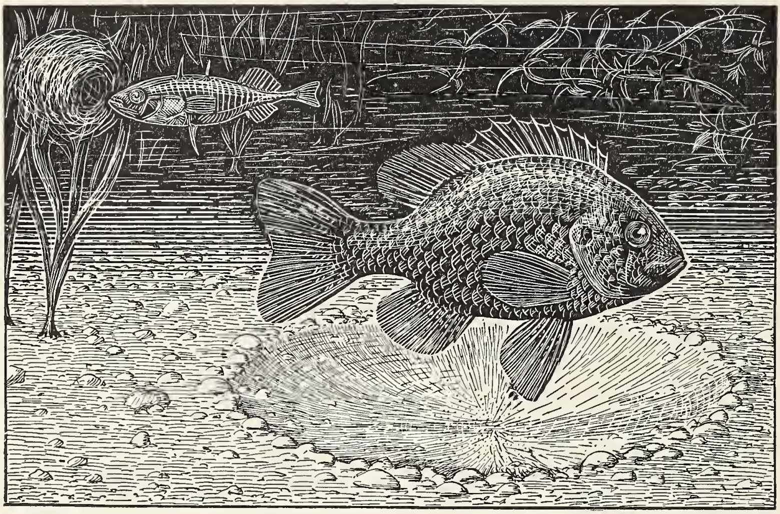
Early Stages in the Development of a Fish. A. Unfertilized egg, mostly yolk with egg nucleus at top. B. Fertilized egg. C and D. Stages in cell division. E. Embryo beginning to develop. F. Embryo showing further development, blood vessels, membrane nearly covering yolk. G. Embryo with complete yolk sac (the blood vessels are larger). H. Young fish just hatched, called "fry" until yolk sac is absorbed. I. Sac partially absorbed. J. Sac entirely absorbed.

bers, which enormously increase the interior surface. To the walls of these delicate cells a network of capillaries brings the blood, and devices are provided to pump air in and out. Thus from the air bladder of the fish the lung of a bird or mammal may trace its origin.

Life history. The breeding habits of fish vary so greatly that it is difficult to make any general statements about their life history to which there will not be many exceptions.

The eggs vary in size from over an inch in the skate, to the tiny eggs of herring and eel. Their number may vary from five hundred in the trout to millions in cod, sturgeon, or flounder. The eggs are fertilized after being laid, by means of the spermatic liquid (*milt*) which the male sprays over them, sometimes stirring the eggs and milt together so that more will be fertilized. Even so there is little chance that all the eggs will be fertilized. Hence the large number of eggs seems partly to make up for the small chance of fertilization. *Oviparous* animals, like the fish, are those whose eggs are hatched outside the body.

The eggs of aquatic animals such as fish are usually laid in very large masses. These eggs are called *spawn*. Out of such enormous numbers of eggs, so few survive, in some species, that artificial culture has to be utilized to prevent total destruction. In many cases both the fertilization and the care of young are left to chance. In others, such as the sunfish and trout, the eggs are deposited in a depression on the stream bottom, made by the parent fish, where the eggs are guarded by the male, or may be covered with sand for protec-



Nests of Fish. As a rule fish do not construct nests, but the stickleback and sunfish are exceptions. The stickleback (left) makes a delicate nest usually of strands of algae. The sunfish, on the other hand, makes an excavation on the bottom of the stream.

tion. The catfish likes to use a discarded can or any other receptacle which it finds on the bottom.

A few fish, such as the sunfish and the stickleback, construct a real nest, that of the stickleback being made of algae. The male is not only the architect of the delicate affair, but he takes entire charge of the eggs, watching over them until they hatch. As development proceeds, the form of the embryo fish may be seen within the egg, from which it soon emerges with the yolk of the egg attached to the body, to be absorbed as nourishment until the tiny fish can shift for itself, and grow gradually to its normal size. Fish eggs, since they are laid in water, need no protective shell to keep the contents moist.

The life history of fish varies considerably with different species. As a rule, fresh-water fish spawn in the waters where they normally live. Several kinds of fish, however, migrate either short distances or hundreds or even thousands of miles to reach spawning regions. The eel travels *downstream* to spawn in the ocean. Examples of fish which go *upstream* are the shad, sturgeon, herring, and salmon. Aside from the four marine fish just mentioned, as yet very little is known about the breeding habits of salt-water fish which do not go into fresh water to spawn.

Life history of salmon. The adult salmon live in the ocean all along the northern Pacific coasts. In spring or early summer both sexes migrate in enormous numbers up the Columbia and other rivers, often hundreds of miles. It is during these "runs" that the canners make their annual catches by means of barriers or machines which scoop up the passing fish.

This migration may be for the purpose of finding greater safety, cooler water, or better food, or it may be a relic of a time when they were entirely fresh-


William Thompson

MIGRATING SALMON. Salmon manage to leap through torrents of water in their mad rush upstream.

water fish. At all events they begin in March to make their last journey. Slowly at first and later many miles per day they work their way against the current to the spawning beds far from the sea. Here, in water not warmer than 54 degrees, each female deposits about 3,500 eggs. The male spreads over them the "milt" or spermatic fluid, a process somewhat like wind-pollination in flowers. Many eggs are not reached by the sperms, hence do not develop.

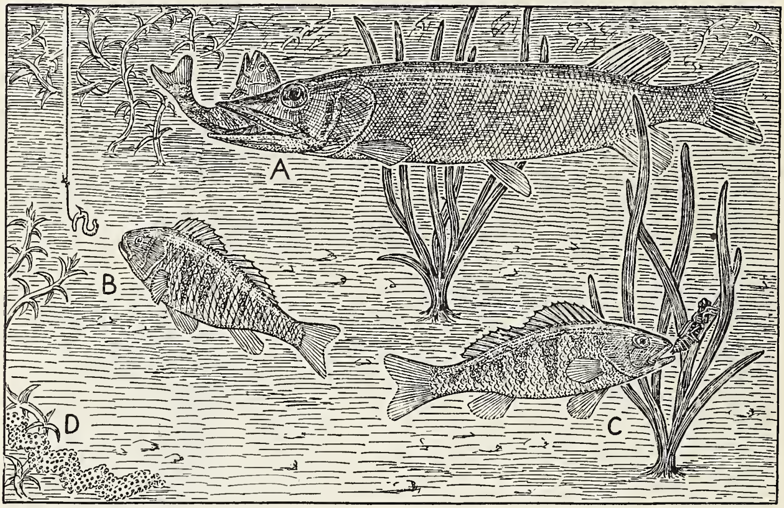
The males are brilliantly colored at the breeding season but both sexes soon lose their beauty and strength, partly in fighting other fish and partly by injuries from the stones in the spawning beds.

The eggs are deposited on fine gravel, the process extending over several days, after which the strength of the parent fish seems to be exhausted and both die. After from thirty to forty days the eggs hatch, but as usual with fish, the yolk remains attached until it is absorbed and the "fry," as they are then called, can shift for themselves.

Although many young salmon fall prey to other fish, the majority find their way back to the ocean where they reach adult life and, if they escape the canner's machines, live to repeat the self-sacrifice of their parents.

Economic importance of fish. The chief value of fish is as food, both for animals and for man. Out of 13,000 known species, at least 5,000 are valuable as human food.

The annual catch of salmon, cod, halibut, mackerel, and herring amounts to many millions of dollars, while the shad, smelt, perch, and bass are almost as valuable. The Pacific salmon alone are worth about $15,000,000 per year and the Atlantic cod returns about $20,000,000. In fact it was the cod returns in fisheries that induced the settlement of New England, and pictures of this celebrated fish may yet be seen in the Statehouse



Events in the Life of Perch. A. Caught by a common enemy, the pickerel. B. Enticed by a baited hook. C. Eating larva of dragonfly. D. Eggs (laid in April or May) on the bottom in a gelatinous mass curiously resembling accordion-pleated lace.

of Massachusetts, on the bank notes of Nova Scotia and the postage stamps of Newfoundland.

Fish are eaten fresh, smoked, salted, dried, pickled, and canned. Despite these various ways of preparation we do not use them as extensively as we should.

The Government maintains in thirty-two states departments of fisheries which regulate the times and methods of catching, provide hatcheries for artificial raising of valuable kinds, and distribute young fish to stock ponds and rivers. In addition, all of the states have fish commissions or conservation departments.

Another important use for fish is as fertilizer, since they are rich in phosphorus compounds which most plants need. The menhaden is much used for this purpose as well as for its oil.

Cod-liver oil is the most easily oxidized fat food in the world and is valuable as a medicine. Isinglass, a fine quality of gelatin, is obtained from the air bladders of certain fish. Glue is another important product made from waste parts and bones of all sorts of fish. The scales of certain fish are used as the base for making artificial pearls.

Commercial fishing. Various methods are used by the commercial fisherman in obtaining his catch. Ocean fishing usually involves a fleet of small boats which tow nets between them or set nets in the form of a large trap. The ocean or marine fisherman usually concentrates upon a few varieties of game fish which are abundant in the waters of his region. In the case of the tuna, the fish are caught individually with hook and line from the sides of special fishing boats. When a large school of tuna is located, fish weighing up to one hundred pounds are pulled over the side almost as rapidly as hooks can be baited and thrown into the water.

Philip D. Gendreau, N.Y.

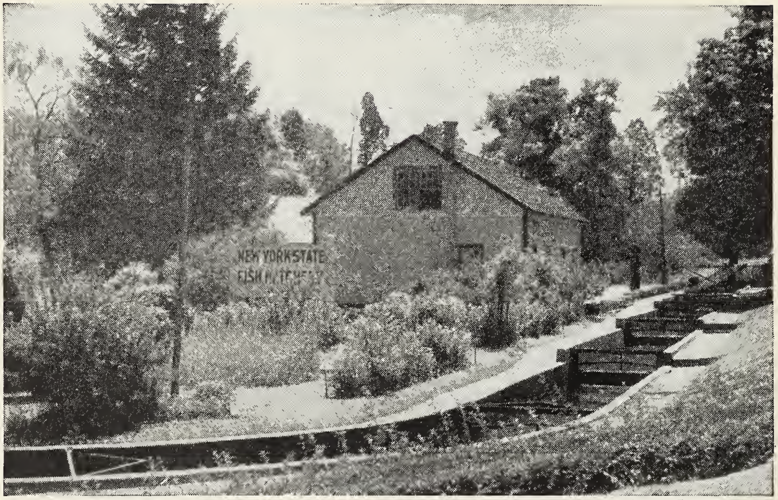
COMMERCIAL FISHING. Fishermen aboard a trawler at sea.

Fresh water commercial fishing is most frequent in the Great Lakes and in the larger rivers. Gill nets, which hold the fish just below the gill covers, are widely used in the Great Lakes for catching whitefish, lake trout, wall-eyed pike, and yellow perch. Catfish, buffalo fish, carp, sheepshead, and suckers are caught abundantly in the larger rivers by means of nets, hook and line, and trotlines. The latter are long lines containing numerous hooks spaced at intervals. Trotlines are examined regularly to remove fish and rebait hooks.

Game fishing. *Game fish* are the delight of the angler because of the sport in catching them. Many game fish exceed the food fish in flavor, but the demand for these species is due more to the pleasure in catching them than the actual food value. To save the game fish for anglers, most states have imposed rigid regulations upon the methods which can be used in obtaining them.

The yellow perch has been called the fish for the beginner because so little skill is required in catching it. It abounds in the Great Lakes and in many of the smaller inland lakes. The bass family is well represented in inland lakes and streams in the form of the large-mouthed black bass, the small-mouthed black bass, the silver bass, the rock bass, the crappie, and others. Bluegills and sunfish are the delight of the " worm fisherman " with long cane pole and bobber. The members of the sunfish are abundant in the shallow waters of most lakes and streams.

The members of the pike family are especially pugnacious and are therefore much sought by the angler in the larger lakes. Among the pikes are the great northern pike which reaches a weight of twenty-five pounds or more, the pickerel which is smaller but none the less interesting to catch, and the giant of them all, the muskellunge. This latter prize has made the Lake of the Woods and other Canadian lakes famous. Mus-



Philip D. Gendreau, N.Y.

FISH HATCHERY

kellunge are found to somewhat less extent in the larger lakes of northern United States.

Trout are the prize of the more advanced angler who has mastered the use of the fly rod. This fresh water member of the salmon family is found in cold mountain streams, in streams of the northern states, and in the case of certain species, in lakes. Among the more famous trout are the eastern brook trout, the rainbow trout, the cutthroat trout, the golden trout, the Dolly Varden trout, and the lake trout.

Fish protection. Civilization in America has brought a sharp reduction in the numbers of fish which inhabit our streams. One might assume that the increased number of fishermen had brought about this decrease. To some extent this is true. But the fisherman is usually a friend of the fish. He is interested in maintaining a supply in the streams. The greatest enemy of the fish is stream pollution. Factory waste and sewage dumped into our streams kill many more fish than are caught in any season. Entire stretches of streams and rivers are completely without fish due to poisoning of the water with these waste materials. Our problem in conserving fish lies first in making the water suitable for them to live in.

To meet such a situation, states have been forced to pass stringent laws and appoint game wardens to see that these laws are enforced. The following laws are generally recognized:

1. Closed seasons for various species, especially during breeding
2. Restriction as to size and number to be taken
3. Use of explosives or draining ponds to kill fish forbidden
4. Restriction as to use of nets and mechanical devices
5. Fish ways required in dams
6. Pollution by factories or sewage regulated

The particular laws of your own state

can be had on application to the state game warden or commissioner.

Fish hatcheries. In addition to enforcement of restrictive laws to protect native fish, the federal and state governments " stock " the waters of the nation with artificially propagated fish of the most desirable varieties. Millions of small fish called " fry " are reared annually in protected pools of fish hatcheries. The hatcheries maintain a stock of adult breeders of certain varieties which are placed into special pools to spawn. After spawning, the adult fish are removed to prevent destruction of the small fish. While still quite small, the young " fry " are placed into special tanks aboard trucks or special railroad cars to be carried to streams and lakes for " stocking." Through the activity of numerous hatcheries scattered over the nation, the supply of game fish has been maintained in most of our bodies of fresh water.

Observing fish. Only a few of the thirteen thousand species of fish known to science are familiar to the average person. However, everyone should learn to recognize the more important fish of his vicinity, especially if he enjoys the sport of fishing.

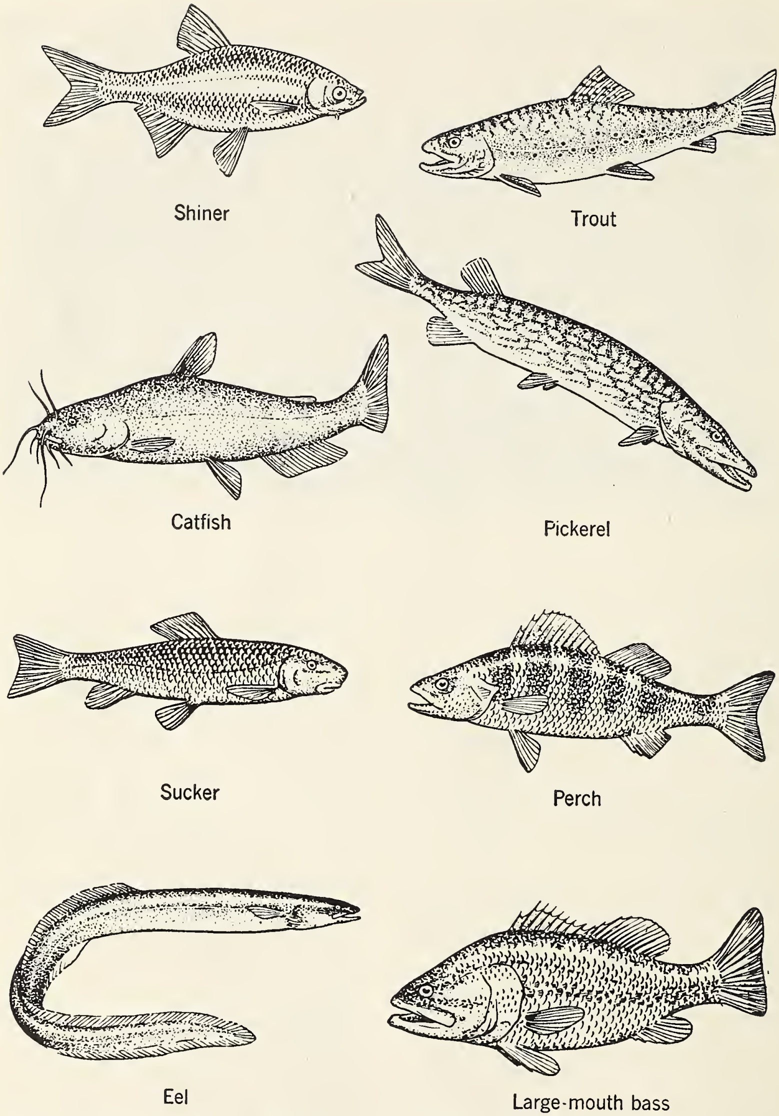
In addition to the food and game fishes to be found in near-by streams, rivers, and lakes, there are numerous varieties which have no food or sporting value because of small size or other reasons. The most common of these fish are probably minnows, the object of most young fishermen from the bent-pin age up to the time they start to angle with a real hook for perch and bass, and use these smaller fish for bait. The shiner with silvery sides, dace, and chub are among the common minnows. In the same streams will probably be found the bull-head catfish and the pugnacious pumpkin seed sunfish. The curious darters which swim through the rapids with a characteristic jerking motion rival even the brilliantly colored tropical fish in beauty.

Many large cities maintain public aquariums in which several hundred species of fish are displayed in attractive glass-fronted tanks. With such an opportunity at hand, one may soon become familiar with the fish of his region as well as interesting varieties from other regions. The fish market is an ideal place to become acquainted with the important varieties of food fish. The fish market offers the resident of inland states about the only opportunity to see salt-water species.

The amateur aquarist. An interesting hobby, rapidly growing in popularity, is the maintenance of aquariums in the home. Many collectors specialize in small varieties of native fish, such as darters and minnows. The collection of native fish may be housed in any standard aquarium, although an air pump is usually necessary to maintain a sufficient supply of oxygen in the water. In collecting native fish, one should be careful not to include small specimens of game fish which are under the legal size limit. The number of small varieties upon which there are no restrictions is great enough to provide the collector with abundant collecting possibilities.

Goldfish are a specialty among many collectors. As a result of years of specialized breeding, a large selection of beautiful forms is available. Comets, fantails, veil-tails, telescopes, moors, and shubunkins are among the many forms available.

Brightly colored tropical fish in a wide variety of forms are ideal subjects for the more advanced collector. The supply of



SOME COMMON FRESH WATER FISH. The trout, pickerel, and bass are considered "game fish." "Game fish" put up a considerable fight when caught on a hook, and make the act of catching them a thrill for the fisherman.

these varieties has become an important industry in America and many other countries. Species from southern United States, Central America, South America, Africa, China, and far off Borneo are available in tropical fish stores. They must be maintained in water ranging from 78–80° F., thus necessitating artificial aquarium heaters in most sections of the country. Along with the brightly colored fish, the tropical aquarium provides opportunity to grow numerous aquatic plants. Details for establishing a balanced tropical aquarium may be obtained from your local pet shop or by writing any of the numerous aquarium companies. You will find such a collection a source of constant pleasure as well as beauty in your home, and will learn the habits of some interesting fish.

Summary

The fish represents the lowest form of vertebrate animal, yet is far superior to the most complex invertebrates in its body structure. It differs from other vertebrates in form and shows numerous adaptations for life in the water. The body is spindle-shaped and covered with scales. Limbs are modified into fins for swimming, most of the power being derived from the tail or caudal fin.

The internal systems of the fish are highly developed and include such specialized organs as gills, heart, stomach, liver, intestine, kidneys, and brain. Sense organs include well-developed eyes, nostrils for smell only, ears which are embedded in the skull, and a specialized set of nerves running along the side of the trunk and called the lateral line.

Large numbers of eggs destroyed before hatching and high mortality among the small fish is compensated for by the enormous numbers of eggs most species lay. The salmon is an interesting example of a fish which migrates great distances during the spawning season. Biology still cannot explain this action.

Fish are very important economically as a source of food, fertilizer, and other special products as well as a source of great pleasure for the sportsman. Many varieties are maintained in home aquariums as an interesting and profitable hobby.

The decrease in numbers of native fish has necessitated the enforcement of rigid regulations for their protection. Extensive hatchery programs maintained both by the federal government and the states make up the deficiency in natural reproduction of the widely sought game fish.

Using Your Knowledge

1. What characteristics of the fish make it a vertebrate animal?

2. Why does the fish need a more complex breathing structure than the sponge?

3. Can you explain why fish may freeze solid in the ice in winter and yet seem to be none the worse when they are thawed out?

4. Explain the use of the air bladder.

5. Account for the fact that fish, even though they lay such great numbers of eggs, seldom become overabundant. Why is it necessary to stock streams each year?

6. Name at least three ways in which the fish is important economically.

Expressing Your Knowledge

operculum	cerebrum	optic lobe
dorsal fin	filament	oviparous
caudal fin	raker	air bladder
pectoral fin	arch	spawn
pelvic fin	barbels	milt
anal fin	gill	stock
lateral line	olfactory lobe	closed season
trunk	gullet	open season

Applying Your Knowledge

1. Place a living fish in an aquarium and watch its movements carefully. See if you can determine the use the fish makes of each if its fins.

2. Dissect a freshly-killed fish and see how many of its internal organs you can locate.

3. Place several scales under the microscope and examine their structure.

4. Visit your meat market and find out what kinds of food fishes are most popular in your community.

5. Make a list of the game fish of your region and the type of water preferred by each.

6. Visit your local conservation office and a fish hatchery if possible. Find out what species of game fish are stocked in the waters of your region.

7. Start an aquarium of small native fish, such as sunfish, bullheads, perch, and minnows (not game fish) in your schoolroom. Be sure to add plenty of aquatic plants to supply sufficient oxygen.

Chapter 33

Vertebrates with Double Lives—the Amphibia

Nature has divulged a very important secret in the group of salamanders, frogs, and toads called Amphibia, for they show exactly how vertebrates left the water to live on land. Each individual resembles its fishlike ancestors early in its life and, in most species, becomes much more complex later in life to emerge from the water and assume a land phase of its existence. The term "double life" refers to the two distinct phases of the life of most of these curious animals. All stages in the transition from water to land are represented in adult forms of Amphibia. Certain kinds remain aquatic throughout life, others live in marshes and alternate between sun baths and dips in the pool, while still others leave the water entirely early in life, and never return except to establish new generations of their kind in the water where they began their lives.

Few people are well acquainted with amphibians. We are all familiar with the nocturnal choruses penetrating the marsh air on warm spring nights when the soprano notes of spring peepers and cricket frogs blend with the baritone croaks of leopard frogs and the deep bass grunts of bullfrogs. But few ever investigate these sounds to discover the nature of the soloist. Instead, we go through life believing that toads, among our best friends in the garden, are the origin of warts and that a harmless amphibian called the "mud puppy" is deadly poisonous. Unscientific indeed is the manner in which these and countless other valuable forms of wildlife are condemned without even a trial.

This chapter will acquaint you with many different kinds of amphibians and will enlist your aid in their protection. In the detailed study of the frog, you will see an organism which is so like man in its internal structure that it may well serve as an introduction to the study of human anatomy. The study of metamorphosis will show you the complete transformation of an individual from one form to another — a much more amazing change than Dr. Jekyll to Mr. Hyde, and one which actually occurs in every pond and marsh.

Characteristics of the Amphibia. The name *Amphibia* means, literally, "having two lives," and refers to the fact that the frog and its relatives are, for the most part, aquatic, fishlike animals when young and abandon that manner of life for land when they become adults. This series of changes is a metamorphosis, just as is the life history of certain insects. In this transition from water to land forms, many strange combinations of gills and lungs, fins and legs occur, gills being found on animals with legs, and fins sometimes accompanied by lungs. This is a good object lesson in the development and adaptations of animal forms.

In general, the Amphibia are distinct from other vertebrate animals in possessing the following characteristics:

1. Body covered by a thin, flexible, usually moist skin, without scales, fur, or feathers
2. Feet, if present, often webbed
3. Toes soft and lacking claws
4. Immature, or larval forms, vegetarian; adults usually carnivorous
5. Heart three-chambered in adults; circulation well developed
6. Eggs directly fertilized as laid
7. Development in stages called a metamorphosis

Examples of Amphibia. The class Amphibia includes several groups which are quite different both in body form and in life habits. As mentioned, these groups show a transition from water to land in the adult stages, although all forms begin life in the water. The groups, listed from aquatic to entirely terrestrial forms, include:

1. Salamanders and newts
2. Frogs
3. Tree frogs
4. Toads

Salamanders and newts. You are probably familiar with some of this group of amphibians but have been in the habit of calling them "lizards." They resemble the true lizard, a reptile, only in the general form of the body which is elongated, ending in a long tail, and supported on four short legs. Had you examined the creature more closely, however, you would have found that it differed considerably from the lizard, for it has smooth, moist skin like a frog rather than the scaly covering of a lizard, and soft toes lacking the characteristic claws. As a matter of fact, many salamanders have no legs at all and might easily be mistaken for eels.

The terms salamander and newt are somewhat confusing and are used interchangeably in referring to many forms. Generally speaking, however, the term

Tiger Salamander

newt applies to small species of salamanders. You would not be incorrect in referring to all of them as salamanders.

Some salamanders are aquatic throughout life and are, therefore, considered to be the most primitive amphibians. One of the most familiar of the large, aquatic salamanders is the *mud puppy* or *water dog* (*Necturus*), which has frightened many an unsuspecting fisherman nearly out of his wits when he pulled this slimy creature from the muddy bottom of a river. They reach a length of two feet, have a flattened head, two tiny eyes, a long body, a flattened tail, and two pairs of short legs. The most striking feature of the body is two sets of dark red, bushy gills which are attached at the base of the head just above the front legs. When the animal is in the water, these gills are slowly waved back and forth. The mud puppy spends most of the day hiding under rocks or buried in the mud of a stream bottom but comes forth at night in search of crayfish, insect larvae and worms. When caught, the mud puppy usually bites vigorously, although its bite is not dangerous and definitely not poisonous. The animal does secrete a poison from glands in its skin, but this poison is not injurious to man.

Numerous species of smaller salamanders emerge on land during adult life and live in moist ravines and lowland areas. While they do not live in water as adults, they cannot survive in places far removed from water. One of the most common of these forms is the *spotted salamander* which has a typical elongated body, a rounded tail, and four well-developed legs. The terrestrial habits of this salamander are revealed in the absence of webbing between the toes. The blue-black body, six inches long, and covered with round, yellow spots, makes it easy to identify.

The *tiger salamander* resembles the spotted salamander in general appearance but differs from the former in having large, elongated blotches and a tail which is decidedly flattened. Other forms include the beautiful *crimson spotted newt* which is olive green with numerous crimson spots, the *slimy salamander* with its black body, numerous tiny, white spots and characteristic sliminess and the *two-striped salamander,* a slender form with a yellow body and a dark line on either side.

Salamanders may be obtained if one looks carefully under flat rocks in moist stream beds, under leaves and other wet places along the edges of pools, or in abandoned wells. They live well in moist terrariums and, with a little coaxing, can be induced to take worms and small insects from the hand.

Frogs. The most common frog in the United States is the *leopard frog,* which inhabits nearly every pond, marsh and roadside ditch. It frequently travels considerable distances from the water and may be seen hopping through the grass in meadows. The name, leopard frog, comes from the large black spots or blotches surrounded by yellow or white rings which cover the grayish green background color of the skin. The under surface of the leopard frog is creamy white, thus blending with the light sky when viewed from below while resting on the surface of a pond.

Because of its abundance and the ease with which it may be obtained, the leopard frog is widely used in the study of vertebrate anatomy. You will use this animal as a type study of a vertebrate.

The *bullfrog,* so named because its sound resembles the distant bellowing of a bull, is the most aquatic of all frogs. It never leaves the water except to sit on the bank of a lake or pond at night. The color of the bullfrog varies from green to nearly yellow, although the majority of individuals are greenish brown. The undersurface of the body is grayish white mingled with numerous dark splotches.

The large, fully webbed hind feet of the bullfrog make it an excellent swimmer. The hind legs are well developed and fully ten inches long in large specimens. They are considered a table delicacy and have made the artificial raising of bullfrogs a profitable business in the warmer sections of the country. The diet of the bullfrog is quite varied and includes insects, worms, crayfish, and small fish.

Bullfrog

Economic importance of the frog. Frogs render a much more valuable service than most of us realize in the destruction of insects. If they had no other value, this point alone would justify their protection. Many states have imposed rigid regulations on the hunting of frogs, prohibiting their capture during the breeding season. In addition, bullfrogs have a definite market value while the smaller species are widely sought as biological specimens and by fishermen for use as bait.

Tree frogs. Another member of the Amphibia is the tree frog (*Hyla*) or tree toad which, although common, is seldom seen, because of its almost perfect protective coloration. Its song is familiar enough when the "peepers'" cheerful chorus ushers in the early spring. It seems hardly possible that so loud a song can come from a tiny frog, little more than an inch in length, but if we are patient and successful enough to hunt one out with a flashlight at night, the reason is clearer. The little *Hyla* can expand its throat into a vocal sac twice the size of its head, and with this enormous drum can produce its remarkable music.

On each toe these true tree climbers have a sticky disc by which they can

Gray Tree Toad

climb safely on the bark of trees and even cling to glass. Their color, stripes, and shape protect them perfectly from observation.

The eggs are laid in April, and the tiny reddish tadpoles feed on mosquitoes. The adults eat ants and gnats, which ought to give them a place in our affection. A curious fact about their tadpole stage is that they often leave the water before the tail is entirely absorbed, being apparently able to breathe air earlier in their metamorphosis than most other frogs.

Toads. We now come to the most abused, yet the most valuable member of the class Amphibia, at least from the standpoint of insect destruction. This unfortunate individual has been accused of giving warts, living in solid rock, and raining from the sky. If we are going to associate silly superstitions with certain animals, we should pick on some form less valuable than the toad. While some people are carefully avoiding toads in the woods or destroying them with clubs, better informed gardeners are protecting them for the service they render in destroying insects.

The toad is the most terrestrial of all amphibians and, after leaving the water early in life, never returns except to lay eggs. The toad starts life as a tiny black tadpole which soon grows legs, absorbs its tail (rather than eating it), and hops onto land as a tiny, black, frog-like creature. It soon develops the ugly, warty skin characteristic of its kind. Adults of the common toad (*Bufo*) are usually greenish or reddish brown above and grayish yellow beneath. The only redeeming feature in the appearance of the toad is its golden eyes which are truly beautiful.

Toads sleep most of the day under rocks or boards, but are active at night, snatching insects with their quick, sticky tongues. When disturbed, they have no choice but to lie close to the ground, for the toad has lost the swimming ability of other amphibians and on land moves with clumsy motions. In its " in between " existence, this unfortunate creature lacks efficient locomotion in any environment and is able to survive only because of its protective resemblance.

Quite different from the numerous species of common toads which inhabit all of the United States is the curious spadefoot toad of the Eastern and Gulf states. This species is distinct in having a spur on each heel which is used in digging backwards into the ground. They live as hermits in burrows, coming out only at night in search of food.

Common Toad

The Frog, a Typical Vertebrate

The frog. The frog will be taken as a type, not only because common and convenient, but also because of the resemblance of its structure to that of the human being.

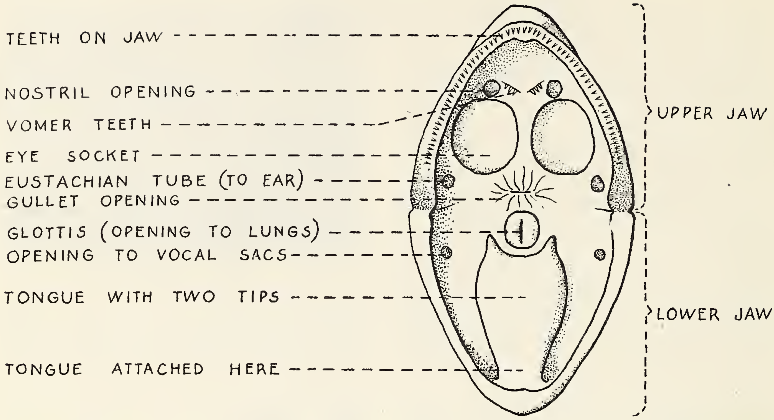
In the study of the frog, it is particularly desirable to compare its structure and development with that of the fish, whenever possible, noting those points in which it is more highly developed, and the differences which its land life has made necessary in its structure.

External features. The frog's body is short, broad, and angular, evidently not so well adapted for submarine locomotion as the fish, nor has it achieved the graceful form of a highly specialized land animal. The covering is a loose skin, in color resembling its surroundings, and provided with no scales or hairs, but supplied beneath with many blood capillaries. It is evident that the skin is not for defense, like the scaly armor of the fish, but it attains somewhat the same end by its protective coloration. The thinness of the skin and the rich blood supply permit a certain amount of respiration to take place through it. Many amphibians absorb water through the skin instead of by drinking. Some secrete a slimy *mucus* which assists in locomotion and in escape from enemies. The head is broad, flat, and attached directly to the body. The nostrils are located near the anterior end and connect directly with the mouth cavity, thus permitting them to be used for breathing. When the frog is under water, they can be closed by a valvelike flap.

The mouth. The mouth is enormous and extends literally from ear to ear. This is a necessary adaptation for food getting as the insects which constitute its principal diet have to be snapped up in this veritable trap. Another striking adaptation for the same purpose is the arrangement of the tongue. This is attached at the *front* of the lower jaw, is very muscular, and has two sticky, fingerlike projections at its tip. This peculiar tongue can be flipped out of the mouth so quickly that the eye cannot see the motion; the insect sticks to it and is instantly thrown back within the capacious jaws, just where a set of teeth on the roof of the mouth will catch and hold it. There are no teeth on the lower jaw. Those on the upper jaw are small, and in toads both sets are lacking entirely, as the real organ of prehension in either case is the remarkable tongue.

As we look inside the frog's mouth the nostril openings can be seen in the anterior part of the upper jaw; the tongue folded back occupies the floor of the lower jaw; farther back at the sides are the openings of the *Eustachian* [*you-stay'shun*] *tubes* from the ears; and at the extreme rear, in the middle, can be found the wide gullet and slitlike opening of the breathing tube or *trachea* [*tray'kee ah*]. The walls of the throat are loose and can be expanded when the frog is calling, thus acting as resonating chambers. This gives volume to the sound for which frogs are noted.

Pickerel Frog



Internal Features of Frog's Mouth. As revealed by opening the mouth to its fullest extent.

Other head structures. The eye of the frog is one of the most beautiful in all the animal kingdom, having the black pupil surrounded by a handsome bronze-colored iris of large size. It projects conspicuously from the top of the head, but can be withdrawn, level with the skull. It is protected by lids and an extra covering, the *nictitating membrane,* which can be raised from below and probably protects the eye when under water.

The location of the nostrils at the very tip of the head, and the high projection of the eyes enable the frog both to see and breathe while the rest of the body is covered by water. When in this position it is able to avoid observation, and so escape from large water birds which feed upon it.

The ears are located just behind the eyes and consist, externally, of the round *tympanic membrane* which is connected with the internal ear within, and also with the mouth cavity by means of the short Eustachian tube.

Legs. The anterior legs are short and weak. They are provided with four inturned toes, which help little in locomotion but serve as supports to the body when on land. The hind legs, however, are enormously developed and adapted in several ways for leaping and swimming. The thigh and calf muscles are very powerful and are so attached to the hips that they move the legs as efficient levers. Added to this is the great development of the ankle region and toes, which together are longer than the lower leg and add greatly to the leverage of these organs. Between the five long toes there is developed a broad, flexible, *web membrane,* which accounts for the fact that the frog is a really good swimmer.

Some frogs can leap fifty times their own length or twenty times their height. A man, to equal this feat, would have to make a broad jump of three hundred feet or clear the bar at a height of one hundred and twenty feet.

The legs of the frog correspond in structure to the paired fins of the fish but resemble much more closely our own arms and legs. A study of a prepared skeleton of the frog shows that the foreleg has the same regions as our arm. The hind leg even more closely resembles the human leg, though with many differences due to being adapted for very different functions.

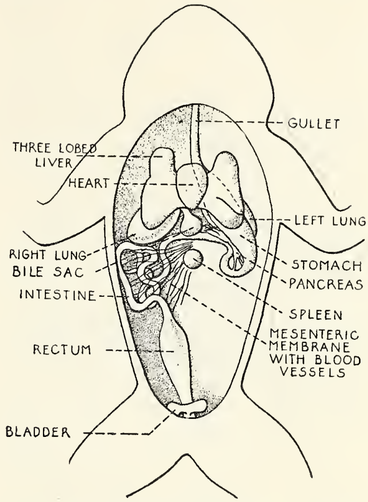
Not only are the regions and the bones similar in general structure, but many of the muscles, blood vessels, and nerves of the limbs of man and frog are of similar form and name. The chief difference lies in the fact that man has developed his forelegs into organs for *prehension* (grasping) and no longer uses them in locomotion. This has resulted from his erect position and has produced many changes in structure to adapt the arm and hand for their altered functions.

The muscles of the fish are in the form of flat plates, extending across the body and moving it as a whole, while in the frog the muscle tissue is grouped into true muscles like our own, attached to bones by tendons, and acting on them as levers, thus marking a great advance in structure and permitting greater variety of motions.

Digestive system. The digestive system of any animal begins with the mouth, teeth, and food-getting adaptations which we have already described.

A short *gullet* connects the large mouth cavity with the stomach, which is an oval enlargement of the digestive tube. The stomach is set diagonally in the body cavity and is partly covered by the liver. Continuing from the stomach is the *intestine,* of medium length, coiled, and enlarging near the anus into a short, broad rectum. The digestive tract is longer than that of the fish, the absorbing surface being increased by the coiled intestine. Connected with the food tube are the mucous glands in the mouth and gullet, *gastric* glands in the walls of the stomach, and the large *liver* and smaller *pancreas,* opening into the intestines. There are, however, no salivary glands in the mouth.

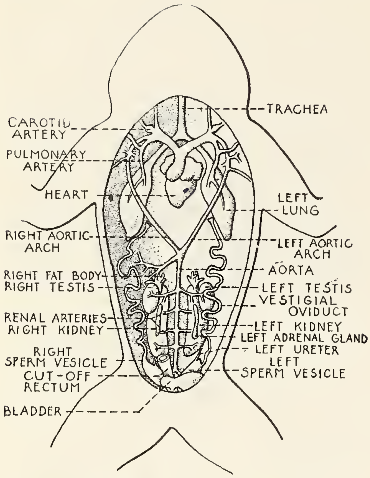
Here as usual we have the essential



SOME OF THE INTERNAL ORGANS OF THE FROG

features of any vertebrate digestive system: a tubular canal, provided with large extent of surface for absorption and a series of glands which secrete the fluids used to get the food into soluble form for this absorption.

Circulatory system. In so complicated an animal as the frog, it is to be expected that the circulatory system would be better developed, especially since lungs are now present. To provide for this added burden, we find a three-chambered heart located well forward in the body cavity, and consisting of two *auricles* and one muscular *ventricle.* Extending from the ventricle is a large artery which at once divides into two branches like a letter Y and each of the arms again divides into three separate arteries on each side. The anterior pair of these branches (the *carotids* [*kar-rot′ tids*]) carry blood to the head; the middle pair arch around to the back of the body cavity and unite to form the dorsal aorta which supplies the muscles and viscera; while the posterior (*pulmo-*



Some of the Internal Organs of a Male Frog

nary) arteries carry the blood to the lungs and skin where it is supplied with oxygen. This process is called *oxygenation,* and the blood is said to be *oxygenated*.

The blood supplied to the muscles returns laden with carbon dioxide and other oxidation products, while that going to the digestive tract takes up the digested foods as well. It returns by way of the veins, part passing through the liver, to the right auricle of the heart. Meanwhile the blood which went to the lungs and skin has been relieved of its carbon dioxide and has been resupplied with oxygen. This returns by the pulmonary veins to the left auricle of the heart. The blood from both the general and the pulmonary circulation then enters the ventricle, where by means of a complicated valve the blood having most oxygen is sent to the head and brain. The next best goes out into the *aorta* [*ay or′tah*], while that with most carbon dioxide is sent into the pulmonary arteries and goes to the lungs and skin.

On each complete trip some of the blood passes through the kidneys, so that all of the nitrogenous waste can be removed as *urine*. Really, the purest blood in an animal's body is that which has just left these very important organs, even though it may have more carbon dioxide than when leaving the lungs.

The blood which returns from the digestive tract is gathered into a large vein (*portal*) and passes through the liver, where some food substances may be stored and certain impurities removed, after which it flows back to the right auricle.

Several important differences will be noted in the frog's circulatory system, as compared with that of the fish. The three-chambered heart receives both oxygenated and deoxygenated blood. *Deoxygenated* blood is that which has had the oxygen removed from it. The blood leaves the heart in *two* circuits, the pulmonary and the systemic, while in the fish, it makes only one continuous trip. In other words, in any single complete circulation, the blood twice returns to the heart of the frog and only once in the fish.

Breathing. The frog has no special cavity known as the chest in mammals. Neither has it any ribs. It cannot therefore enlarge an internal cavity, as man does, causing an inrush of air to fill the lungs, nor can it depend on ribs for forced exhalation. The frog is obliged, therefore, to force the air in and out of the mouth by a pumping motion, up and downthrusts of the floor of the mouth, which can be observed in any living frog.

Air is taken into the mouth cavity only through the nostrils, when the floor of the mouth is lowered. In breathing, the mouth opening must be kept closed at all times to produce the proper pressures in the mouth cavity. Having obtained a mouthful of air in this way, the frog raises the floor of the mouth, compressing the air in the mouth and causing some of this air to escape through the nostrils. This can easily be observed by the movements of a silk thread held at the rear of the nostril opening.

The lining of the mouth is well adapted for breathing, because it is very thin, moist, and well supplied with blood. The mucous membrane of the mouth, with the aid of the moist skin, and the lungs to a limited extent, seems to serve the respiratory needs of the frog when the animal is very quiet. Oxygen enters the skin continuously and more carbon dioxide is released through the skin than from the lungs.

Normally air is pumped in and out of the mouth for some time without using the lungs. When the frog is active, however, there is need for more frequent emptying and refilling of the lungs to obtain more oxygen and to get rid of accumulated carbon dioxide. Lacking other means, the frog employs lateral muscles to help compress the lungs. This action is apparent as twitches on the sides, which occur at intervals, increasing with the activity of the frog and varying greatly with individual frogs. This can be observed in live frogs which have been stirred up in a battery jar. The twitch seems to act in degree very much like a blow which " knocks the wind out of us."

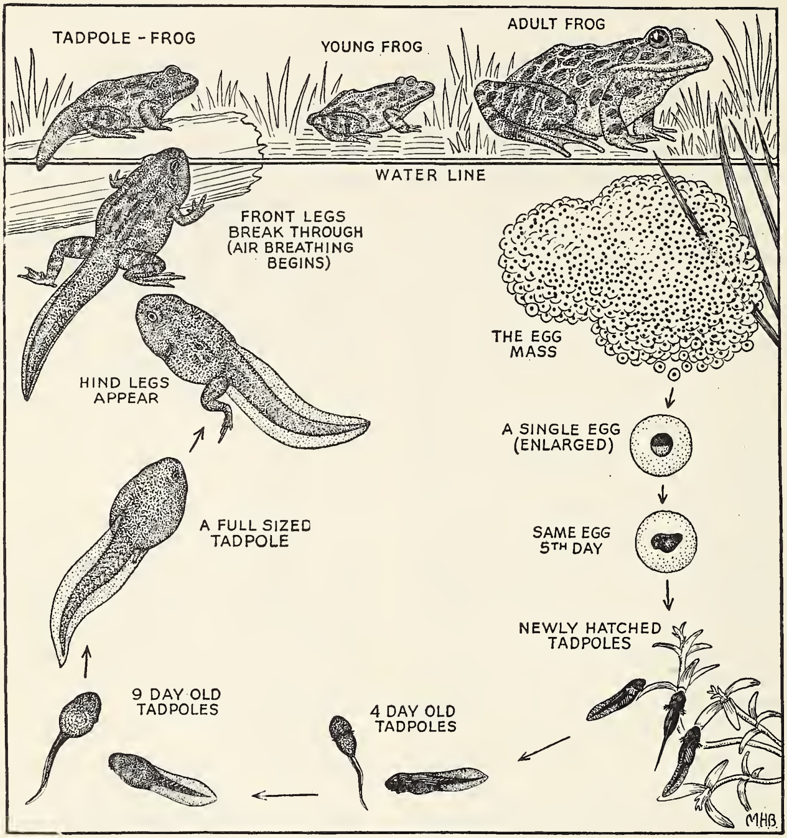
In addition, the frog closes the nostrils simultaneously with the twitching, and makes a deeper downthrust of the floor of the mouth, thereby producing a partial vacuum in the mouth cavity. The closing of the nostrils at this time helps by preventing the entrance of any air from the outside, and the air in the lungs is thus forced into the mouth. The upthrust of the floor of the mouth, immediately following, seems to be higher than usual and forces some of this mixed air back again into the lungs. After exchanging air once or twice from lungs to mouth and mouth to lungs, the frog resumes the mouth breathing as at first through the now open nostrils.

Nervous system. The nervous system shows considerable advance over that of the fish. The *cerebrum* [*ser'e brum*] is larger compared with the other brain parts. The brain as a whole is more specialized and more nearly fills the *cranial cavity* of the skull; the spinal cord is shorter, thicker, and has its branches arranged much more like those of the higher animals.

Observation of the living frog shows that the senses of sight, hearing, and touch are well developed. Smell and taste are undoubtedly weak. The frog's varied life on land and water necessarily presents a wider range of experience and hence some advance in intelligence. This involves a better brain.

Excretory system. Excretion is provided for by a pair of well-developed *kidneys* connected with a large *bladder.* Water, uric acid, and other nitrogenous waste are removed by these organs, while the lungs and skin also help dispose of waste matter, particularly carbon dioxide and water.

Reproduction. The female sex organs consist of a pair of thin-walled sacs called the *ovaries,* which are filled with eggs during the early spring. The male sex organs include a pair of small, yellow, capsule-shaped bodies called the *testes,* which contain the sperms. Both sets of reproductive organs send the eggs and sperms to a passageway located just back of the rectum called the *cloaca* [*klo ay'ka*]. In the male frog the sperms reach the cloaca by means of *vesicles*



Life History of the Frog

[*ves'sick kulls*]. In the female, the eggs reach it by way of a pair of coiled *oviducts*.

Life history. The life history of a frog is a true metamorphosis and illustrates the development of an air-breathing land animal from a gill-using aquatic form.

The female lays the eggs in the water early in the spring, and they are fertilized immediately by the sperm of the male frog, thus assuring more certain development than in the case of most fish. The jellylike coat which surrounds each egg swells in the water until all are joined in a gelatinous mass. In this clump, the dark eggs appear like tiny beads, each surrounded by a transparent covering.

Each frog's egg is partly black and partly white. The white portion is the yolk or stored food material which is to be used during the complicated stages which the egg must go through before hatching. The black portion represents the living protoplasm of the egg with dark pigment to protect it. The yolk is heavier than the living part of the cell, so that the position of the egg is always dark-side-up.

The frog's egg has very little yolk, however, compared with that of the fish egg. The tiny fish hatches with yolk still attached to it. The tadpole hatches with none. The little tadpoles leave the mass as black, elongated creatures, mouthless, but with a suckling disc by means of which they hang on to the jelly or plants.

At this stage there are two pairs of external gills, a narrow, well-developed, fishlike body, and a caudal fin, flattened from side to side. When the mouth opens, it has horny lips, by means of which the tadpole scrapes off vegetable matter for its food.

Next they become free swimmers. The horny lip now disappears and a long, coiled digestive tract begins work on the vegetable scums which are the tadpole's food. Gradually a fold of skin grows backward over the gills, like an operculum, leaving only a small opening on the left side. The mouth cavity connects with both sets of internal gills — as in the fish — so that both are constantly supplied with water.

These latter changes may have occupied many weeks, and the tadpole is now a fishlike animal with gills, lateral line, fins, two-chambered heart, and one-circuit circulation. Yet it resembles its parents in having four legs, the hind pair appearing first. Other changes gradually adapt it for land life.

A sac-like chamber develops backward from the throat like the fish's air bladder, but soon separates into two lobes, with cellular walls, which we recognize as lungs. To correspond with this, the circulation is gradually modified; the gill arteries are changed to carotids, pulmonaries, and aortic arches; the heart becomes three-chambered. At this stage the tadpole may be seen coming to the surface for air to fill his new lungs. His gills no longer are used for breathing but are being resorbed and the material taken away by the blood to be used in building other organs.

While these notable changes are occurring to the respiratory and circulatory systems, others no less remarkable are taking place elsewhere. The mouth widens, teeth develop, and the intestine becomes shorter and larger to adapt it for animal diet which the young frog now begins to use.

The external changes, which have accompanied these last mentioned, have been more conspicuous, though less important, and are as follows. The tail has been gradually resorbed (not shed), hind legs have developed at the place where it joined the body, and the body itself has changed shape. The front legs begin growth about the same time but do not show so soon since they start beneath the operculum in the gill chamber and are smaller even when full-grown.

By this time, the tadpole is a well-developed frog which comes on land, breathes air, eats animal food, and gradually grows in size till he reaches the full stature of an adult. These latter changes have occupied usually another month, making a total of about three months for an average frog metamorphosis, though growth in size may continue much longer. In the case of the bullfrog, the tadpole stage is much more prolonged, usually continuing for two or even three years.

Hibernation and estivation. The disappearance of frogs in the late autumn is due to the fact that they have begun their *hibernation*. To meet the rigors of winter they dig down under stones or roots or bury themselves in mud. They do not eat, but lie quiet as though in a stupor. The heart beats very slowly and the moist skin furnishes all the oxygen necessary. In the spring they emerge somewhat emaciated.

Estivation [*es ti vay'shun*] is similar to hibernation except that it occurs under opposite conditions. During the hot summer months, the small bodies of water in which frogs are living may dry up, forcing the animals to seek refuge in the moist, cool mud. With the return of water to the pond, usually in the early fall, they emerge and resume normal activity until hibernation.

Functional Adaptations of the Frog

Making possible	By means of
A. EXTERNAL	
Escape from enemies	Protective coloration
Locomotion	Shape; slimy secretion
Catching food	Long, forked, sticky tongue; large mouth
Holding food	Tiny sharp teeth in upper jaw; vomer teeth; lowered eyes
Breathing when partly submerged	Nostrils at tip of nose
Vision when partly submerged	Projecting eyes
Special protection for eyes	Third eyelid
Hearing	Large eardrums
Leaping and swimming	Powerful muscles
Increased leverage for leaping	Long, jointed hind legs; long toes
Landing after leaping	Short front legs
Swimming	Webbed hind feet
B. INTERNAL	
Swallowing food	Gullet: mucus from mucous glands
Digesting food	Stomach: gastric juice from gastric glands
	Intestine: pancreatic fluid from pancreas; intestinal fluid from intestinal glands; bile from liver
Absorbing food	Intestinal walls: capillaries
Increase of absorbing area	Countless villi
Forcing blood through body	Three-chambered heart
Carrying blood to heart	Veins
Carrying blood from heart	Arteries
Transportation of food, oxygen, wastes	Blood plasma; red blood corpuscles
Combating disease germs	Antibodies; white blood corpuscles
Absorbing dissolved oxygen; giving off carbon dioxide	Thin-walled gills in tadpole
Absorbing free oxygen; giving off carbon dioxide	Two thin-walled lungs; thin-walled lining of mouth
Additional breathing, especially when submerged and when hibernating	Thin vascular skin
Increase of absorbing area	Cellular lungs
Removing gases from lungs	Muscles; flexible throat; closable nostrils

Functional Adaptations of the Frog

b. internal (*continued*)

Removal from blood of urine: water, nitrogenous waste, uric acid	Two kidneys
Storage and discharge of urine	Bladder
Excretion of carbon dioxide and some water	Gills; lungs; lining of mouth; skin
Stability for body; attachment for muscles; use as levers in motion and locomotion	Skeleton
Production of white blood cells	Long bones
Formation of egg cells	Two ovaries of female
Gelatinous covering added to eggs	Two oviducts of female
Passage of eggs to exterior	Cilia in oviducts
Formation of sperm cells	Two testes of male
Fertilization of eggs	Thin-walled eggs; motile sperms
Voluntary and reflex acts	Nervous system

Summary

The Amphibia are unique among vertebrates in that their members pass through two entirely different stages. They live as fishlike creatures in their early stages, after which many forms enter a land phase as a result of modifications in body structure. An excellent example of the complete changes or metamorphosis from aquatic to terrestrial life is found in the development of the tadpole into a frog.

Body characteristics which distinguish amphibians from other vertebrates include: thin, moist skin without scales, webbed feet, soft toes lacking claws, and a three-chambered heart. The groups of Amphibia, ranging in order from aquatic to terrestrial forms in the adult stage, include salamanders and newts, frogs, tree frogs, and toads.

The greatest economic importance of the Amphibia lies in the destruction of insects, although certain frogs are used extensively by man for food. None of the Amphibia are harmful or dangerous to man, and all forms should be preserved as an important part in the balance of nature.

Using Your Knowledge

1. Name several characteristics of the salamander which distinguish it from the lizard with which it is frequently confused.

2. Explain why the lungs of the adult frog must be internal although the tadpole is successful with external gills.

3. Assuming that a frog weighs one-half pound and can jump fifty times its length, calculate from your weight how far you would have to jump to equal this feat.

4. Enumerate the special adaptations of the frog's hind legs; the front legs.

5. Name several superstitions you have heard in connection with the toad and, if possible, account for each.

6. List ways in which the tadpole resembles a fish.

7. Why is the development of the frog from the tadpole called a metamorphosis when the term was not used in connection with the fish?

8. Enumerate, in order, the external changes which occur in the tadpole during its development into an adult frog.

Expressing Your Knowledge

transition	Eustachian tube	iris
terrestrial	hibernation	pupil
mucus	estivation	oxygenated blood
nostril	tadpole	rectum
deoxygenated blood	salamander	lung
nictitating membrane	web membrane	pulmonary
vocal sac	cloaca	oviduct
Amphibia	ventricle	auricle

Applying Your Knowledge

1. Collect some frog eggs in the early spring, place them in a jar containing water plants, and watch the hatching and development of the tadpoles. Record the date of hatching and each significant change thereafter.

2. Make a trip to a near-by pond or marsh some night and, using a strong flashlight, see how many different kinds of frogs you can find. Try to discover the characteristic sound made by each.

3. Make a woodland terrarium with rich woods earth, mosses, ferns, and other woodland plants. Obtain several small salamanders either from nature or from a biological supply house and observe their activities carefully.

4. Prepare a terrarium similar to the above and include a pair of toads. Feed them worms and small insects and observe carefully their feeding habits.

5. Obtain from your teacher a frog prepared for dissection and see how many of the internal organs you can locate.

Chapter 34

Vertebrates with Scales and Claws—the Reptiles

Even the sound of the term "reptile" is disagreeable to many who have come to associate these creatures with mystery and evil. No other group of animals is so surrounded with prejudice, superstitions, and foolish notions. True, the reptiles include in their numbers many poisonous species, but condemning an entire animal group because of the behavior of a few members is as logical as saying that all humans are dangerous because some have resorted to crime.

The biologist finds reptiles a fascinating group for study. He learns to recognize the relatively small number of dangerous reptiles and gives them free range. But his knowledge of the group prevents him from mistreating the large number of harmless and beneficial reptiles he encounters. In your study of biology, you should adopt the same attitude. You will learn to recognize four kinds of poisonous snakes, one poisonous lizard, one dangerous turtle, and one group, the crocodiles and alligators, which should be avoided. Aside from

DINOSAURS FIGHTING

these specific reptiles, you need fear none. You may even be surprised to learn that many reptiles make interesting pets, though they are not the affectionate creatures we find in dogs and cats.

We have discussed the balance of nature and the control of that balance by natural enemies. Reptiles are a part of this world and the wanton destruction of large numbers of valuable reptiles has upset the balance. You, as biologists, should join in the campaign to preserve the beneficial members of this group. You will undoubtedly need all of your powers of persuasion to convince your friends and neighbors that they are not rendering a service in killing harmless snakes and lizards, but the service you will be rendering in furthering conservation of these reptiles will be worth your effort.

The age of reptiles. Unfortunately, the reptile enthusiast has arrived upon the earth about 150 million years too late. While about 300 species of reptiles still inhabit North America, this number is only a sampling of the widely varied forms which roamed our land during the Age of Reptiles. Today, the biologist must resort to fossil bones, eggs, and footprints, and considerable imagination to picture what the world must have been like when the reptiles held full sway.

Most famous of these ancient reptiles were the *dinosaurs* [*dī'no sors*], which ranged in size from creatures no larger than many modern lizards to monsters far exceeding the elephant in size. The largest of dinosaurs was the *thunder lizard* or *Brontosaurus* [*Bron'toh sor'us*] which measured 75 feet long and 15 feet high and reached the amazing weight of 30 tons or more. This giant creature must have consumed several tons of aquatic vegetation daily in the marshes where it lived. The king of dinosaurs was the ferocious *tyrant reptile,* called *Tyrannosaurus* [*Ty ran'oh sor'us*], which is probably the most terrible creature which ever roamed the earth. It walked erect on its hind legs and balanced its heavy body with its long tail, much in the manner of a kangaroo. The front legs were short but powerful and its long claws could tear most prey into shreds. Its large mouth was rimmed with double-edged teeth three to six feet long and could rip through the hide of even its armored victims. Great must have been the battles between these giant reptiles, when tons of flesh were hurled against each other in engagements which rivaled the tank battles of the late war.

One might wonder how creatures such as these ever ceased to control the living world. Had they possessed a brain in proportion to their brawn, they might exist today. But many fell the victims of more intelligent animals which invaded their haunts, while others wandered into asphalt pits or bogs and sank to their doom. Other forms could not survive the gradually changing earth. Large numbers must have starved to death when their own numbers created serious food problems. At any rate, all of them have long since disappeared, and the only evidence we have that they ever existed is their fossil remains. Assembled skeletons may be seen in many of the larger museums, giving proof of their enormous stature. Evidence in nature may be found in the Dinosaur National Monument, an 80 acre tract in Utah, containing numerous deposits of fossil remains.

Living reptiles. Some 4,000 species of reptiles exist in the world today as remnants of their once flourishing age. Certain of these forms are much like their ancestors, although many have become modified during the millions of years since the Reptile Age. All living reptiles may be classified into four main groups as follows:

1. Snakes
2. Lizards
3. Turtles
4. Crocodilians (including alligators and crocodiles)

Characteristics of reptiles. Reptiles resemble the Amphibia in many respects, although they are higher in the scale of animal development. Like amphibians, all reptiles are cold-blooded, the body temperature being no higher than their surroundings. However, many of the body characteristics of reptiles distinguish them readily from the frog and its relatives. These differences include:

1. The body is usually covered with scales.
2. The skin is dry, not moist and slimy.
3. The feet, if present, are provided with claws.
4. Eggs are internally fertilized and, if laid, have a protective shell. Certain species retain the eggs within the body and bring forth the young alive.
5. They have no metamorphosis.
6. Gills are not present as in the fish and amphibian, both young and adult reptiles breathing with lungs.

Snakes, the most widespread reptile forms. Snakes constitute not only the most numerous reptile form, but the most widely distributed as well. They are most abundant in the tropical regions, but range over most of the earth. Of the more than 2,000 species, only a relatively small number are poisonous, though these dangerous members have caused the entire group to be condemned by man. The harm done by a few snakes is far overbalanced by the valuable service rendered by others in destroying large numbers of insects and destructive rodents.

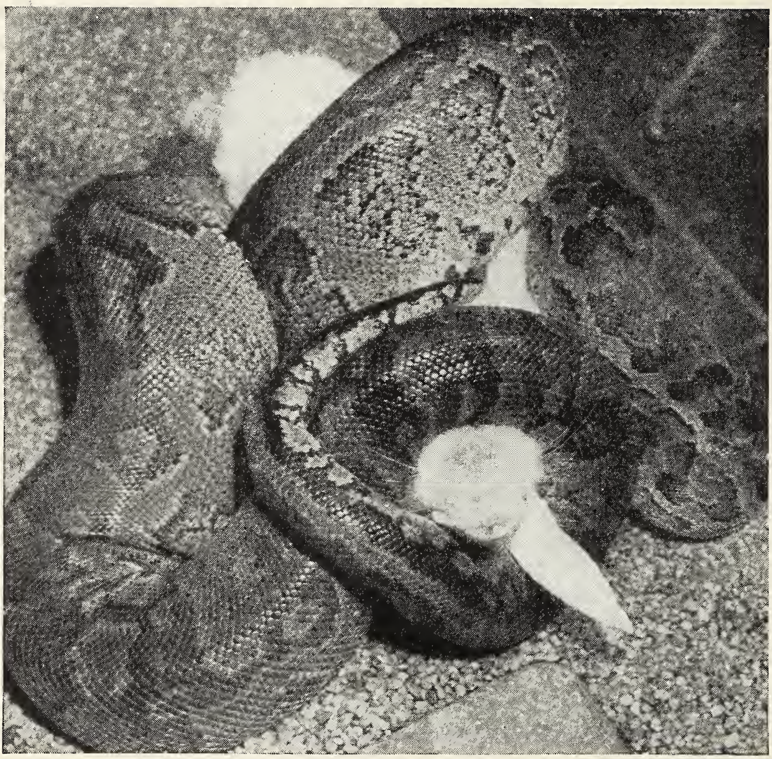
The body of the snake is highly specialized and quite different from other animals. It is legless, and most snakes have lost even the internal bones and muscles concerned with legs, although the rudiments of hind legs are found on certain species including the *boa constrictor* and *python*. The entire body is covered with scales; the upper surface with small, oval scales and the lower side with broad plates which are used in locomotion. The mouth is large and equipped with several rows of sharp teeth which point backward toward the throat. Near the front of the mouth in the floor of the lower jaw is a long, forked tongue which may be thrust through a small pore between the jaws when the mouth is closed. Snakes thrust out their tongues when alarmed, possibly as a frightening device, but more to sense what is going on, for the tongue is sensitive to vibrations and serves much as an ear. The tongue is not a fang and is an entirely harmless organ. Snakes have no eyelids and hence cannot close their eyes. The pupil may be round or vertical, depending upon the species. Most of the poisonous snakes of North America have characteristic vertical pupils, although inspection of a living snake's eyes to determine if it is poisonous is not recommended.

The internal organs of the snake are much like those of other vertebrates, although the long, slender body results in a somewhat different arrangement than we found in the frog. The heart is large and shows an advance in structure over the frog in that the ventricle is partially divided by a partition called the *septum*. The blood pumped through the body circuit is much purer than in the frog where a single ventricle pumps both to the lungs and to the body. Air is forced into the lungs by expansion of the ribs in the upper portion of the body, thus eliminating the mouth breathing which is characteristic of the frog. Ribs are attached to each of the nearly three hundred vertebrae in the snake's spine.

The peculiarities in the structure of the snake's body make its habits different from other animals and may possibly account for some of the myths and superstitions concerning it.

False ideas about snakes. In reading the following common superstitions which concern snakes, you will probably find several which you have heard and, perhaps, have believed. You can find many people who have friends who, in turn, have friends who have testified that these events actually have occurred. Reptile authorities like the late Dr. Raymond L. Ditmars, who have devoted their lives to the study of reptiles, say they are not true.

To begin with, snakes are not slimy and nasty. Their skin is usually clean and dry and feels cold merely because they do not maintain a body temperature higher than their surroundings. They cannot jump from the ground when they strike nor do they spring from a perfect coil. A wound cannot be inflicted with the tongue. Though reflex motion persists in a snake long after death, the setting of the sun has nothing to do with its death, although the cool temperature of evening may slow muscular reflex action. Snakes do not swallow their young to protect them. Certain kinds of snakes devour other snakes and digest them within their stomachs. The young would suffer a similar fate if swallowed for protection. No snake was ever known to take the tip of its tail in its mouth and roll down a hill like a hoop. While several species live around barns, they do not milk cows. Horsehairs do not turn into snakes. Rattle-



Lilo Hess, N.Y.

Boa Constrictor with Rabbit

snakes do not add one rattle per year, but usually two or three, though some may be broken off. Removal of its fangs does not render a poisonous snake permanently harmless as other fangs take their place very soon. Snakes do not possess hypnotic powers and cannot cause birds to fall from branches by swaying beneath them. Children have no inborn fear of snakes and adults should not fill their minds with silly, untrue, and ignorant ideas.

How snakes obtain their food. Snakes may be divided into three groups based upon the methods they use in obtaining food. They have no means of tearing or chewing the prey and must swallow it whole, either dead or alive. Many snakes, like the common garter snake, catch the prey in the mouth and *swallow it alive.* This process may seem cruel, although most of the victims are totally unaware of their fate. Other snakes, including the famous boas and pythons, crush their prey in powerful coils and, hence, are classed as *constrictors.* Still others, like the rattlesnake, copperhead, and cobra, *poison* the prey with an injection through hollow fangs which are driven into the victim. Needless to say, the snake is not affected by swallowing the prey containing its poison.

Adaptations for swallowing. The whole animal, but particularly the head, is adapted for this peculiar habit of swallowing prey actually larger in diameter than its own body. For this purpose, there are numerous sharp, incurved teeth on three sets of jawbones. Any of these teeth may grow again if broken off. The lower jaw is not fixed directly to the upper jaw, but is attached to a separate bone, the *quadrate*, which, in turn, is attached to the skull. This attachment permits the jaw to drop downward and forward and open as wide at the back as at the front. The two halves of the lower jaw are fastened at the front by an elastic ligament, allowing each half to operate independently of the other. During swallowing, one half of the jaw may be thrust forward for a new grip on the prey and, while that half is pulling the victim down the throat, the other half is pushed forward for another grip. The jaws operate much in the manner in which you pull in a rope by pulling with each hand alternately. In this manner, the snake literally crawls around its prey.

The process of swallowing is so long that special adaptations are necessary to permit breathing to go on. The trachea extends along the floor of the mouth to a glottis opening near the front rim of the jaw.

The gullet and stomach are highly elastic and the digestive fluids very powerful, to accommodate food in such large doses. The flexible ribs and lack of breastbone or limb girdles allow for the passage of these enormous mouthfuls.

The delicate and slender forked tongue is protected during swallowing by being drawn back into a sheath.

Snakes can endure long periods of time without eating. The longest recorded instance is, perhaps, the case of a regal python which, when brought to the New York Zoological Park, went on a hunger strike for almost two years.

Locomotion. Snakes have no legs, yet they travel, climb, and swim with ease and rapidity. They accomplish these feats by means of the broad plates on their ventral surface. These plates have their free edge toward the rear, so will catch against the slightest roughness. To each plate is attached a pair of ribs which operate somewhat as legs, with each plate as a foot. To allow free motion of the ribs, the vertebrae have a flexible ball-and-socket joint, and the whole body is provided with exceedingly strong muscles, so that a snake really travels on hundreds of musclar legs (ribs). This is a good example of analogy, the ribs and plates perfoming the same function as legs, but being of entirely different origin and structure.

Reproduction. The majority of snakes lay eggs which resemble those of the other reptiles. Each egg contains stored food to nourish the young snake during its development and is enclosed in a tough, white shell. The eggs receive no care from the female after being laid and no incubation except the warmth of the sun. Egg-laying snakes are called *oviparous*, and include the black snake and blue racer.

A somewhat smaller group of snakes, including the garter snake and the copperhead, bring forth their young alive, usually in the late part of the summer. The eggs are retained in the reproductive organs, where they develop into young snakes. During development, there is no nourishment provided from the mother's body as in the highest group of animals called mammals. Snakes which bring forth their young are classed as *ovoviviparous* to distinguish them from the higher animals, called *viviparous,* which nourish the young during development.

Some nonpoisonous snakes of North America. *Garter snakes* are the most common snakes in North America, about twenty species being included in its wide range. They live in fields and along stream banks, where they feed on insects, worms, frogs, and toads. They frequently wander into the cities, where large numbers are destroyed by misinformed citizens. Garter snakes are harmless and do considerable good in holding smaller animals in check.

Probably the most terrifying snake to approach is the *hog-nosed snake,* also called the *spreading viper* or *puff adder.* When surprised along the path, this plump-bodied little snake puts on an act which terrifies all but the most informed student of snakes. Amid loud hisses it suddenly raises its head and spreads its neck widely in true cobra fashion. At this point, one of two things usually happens. Either the surprised passer-by turns and runs or seizes the nearest club and begins to "fight for his life." But one familiar with the ways of this little creature merely smiles, for he knows that the hog-nosed snake is one of few species which will not offer to bite even when picked up. If the reptile fails in its efforts to terrify its intruder, it modifies its strategy and feigns death. As though suddenly seized with convulsions, it twists its head wildly, opens its mouth, and falls limp upon its back. The act is not entirely convincing, however, for if turned over, it suddenly rolls back as though it knew that a dead snake must lie upside down. The formidable appearance of this reptile is unfortunate, for it has resulted in the destruction of large numbers of its kind.

The *black snake* and its western variety, the *blue racer,* inhabit the central eastern United States. They are large snakes, usually four to six feet in length, and are covered with smooth, satiny scales. When disturbed, they may fight viciously, though their bite is not poisonous. They are exceedingly valuable since their diet includes large numbers of small rodents. The intelligent farmer never destroys a black snake near his barn, because one snake destroys more small rats and mice than several cats. Contrary to common opinion, blue racers do not chase people. While blue racers travel rapidly, their speed has been greatly exaggerated, the fastest moving individual not exceeding three miles per hour.

The *bull snake* of the Middle Western states is one of the largest snakes in the United States, reaching a length of nearly nine feet. It is a powerful constrictor and crushes rats, mice, gophers, squirrels, and rabbits in its coils. It is exceedingly valuable in the wheat fields where it lives, and certainly warrants protection.

Anyone who does not appreciate snakes should be especially interested in conserving the *king snake*, for this individual is among the worst enemies of other snakes. It attacks other snakes viciously and does not hesitate to seize the deadly copperhead or rattlesnake in its strong coils. Strangely, it is immune to the venom of poisonous snakes. King snakes vary in color from nearly black with narrow white lines to the brilliantly colored "milk snake" falsely accused of milking cows.

A discussion of nonpoisonous snakes would not be complete without a discussion of the *banded water snake* commonly seen basking on driftwood in rivers and streams. This harmless snake is incorrectly called the "water moccasin," which it resembles only in habitat.

FOUR NON-POISONOUS SNAKES. Top left: Milk Snake; top right: Ring Necked Snake; bottom left: Garter Snake; bottom right: Hog-nosed Snake.

Poisonous snakes of North America. As previously mentioned, there are only four kinds of snakes to be avoided in North America. They are the rattlesnake, copperhead, water moccasin, and coral snake.

The *rattlesnake* is the most widely distributed and in its twelve forms ranges over most of North America. It is found most abundantly in the dry regions of the Southwest. Rattlesnakes are characteristic in having a series of dry segments or rattles on the tip of the tail which are vibrated to produce a whirring noise when the snake is alarmed. The head is large, and the jaws puffy, due to the presence of poison glands. Near the front of the upper jaw is a pair of large, hollow teeth, the *fangs,* which are connected by ducts with the poison glands. Rattlesnakes strike fiercely, driving their fangs deep into the victim and inserting a quantity of poison in the process. With reasonable care, one can avoid being bitten, since the rattlesnake does not seek trouble and usually warns of its presence before striking. The largest rattlesnake is the *diamond back* of the Southeast, which is caught for its beautiful skin and for its *venom.* This venom is used in making biological preparations which are used to counteract snakebites.

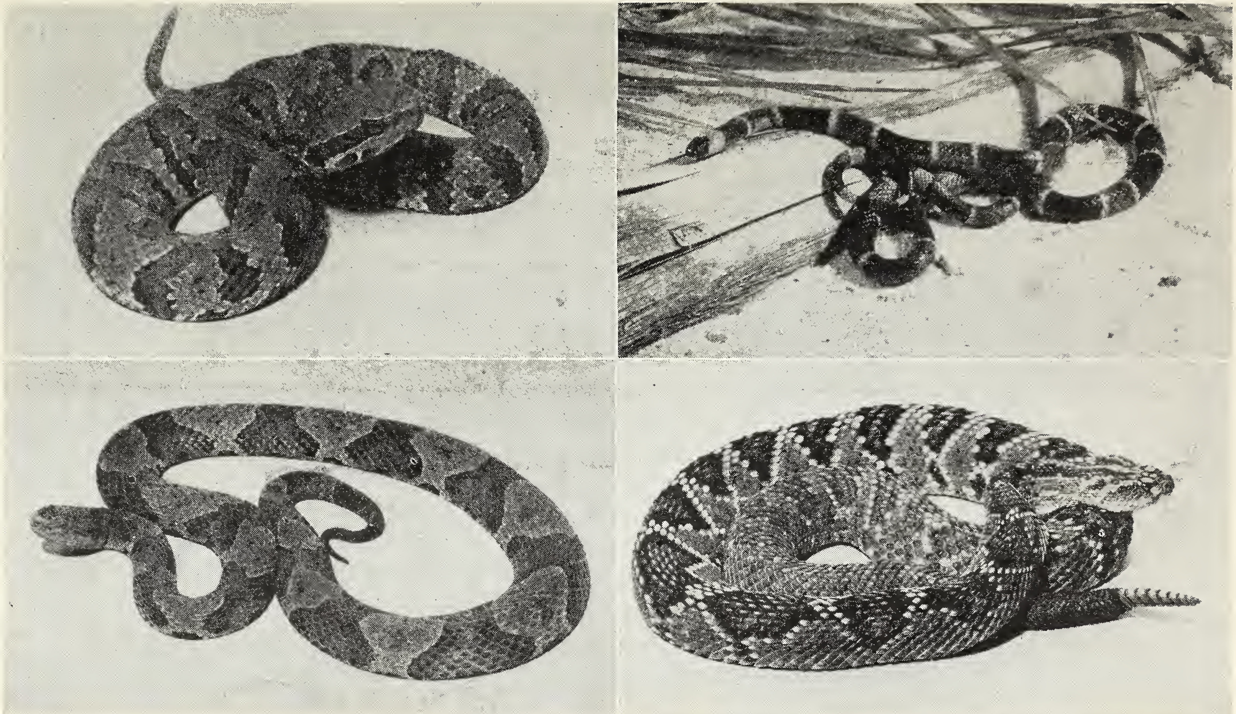
The *copperhead* is more dangerous than the rattlesnake since it strikes without warning. Fortunately, it is somewhat less poisonous than the rattlesnake. Copperheads are usually found in the dry upland woods of hilly country. Its plump body seldom reaches over three feet in length. The head is a bright copper shade and the body is covered with alternate bands of light brown and dark reddish brown arranged in an hourglass pattern. Copperheads are especially beautiful just after shedding the outer layer of their scales during the molting process which is characteristic of all snakes.

The *water moccasin* or *cotton-mouth moccasin* inhabits the warm, sluggish streams and bayous of the South. These snakes are especially abundant along the tributaries of the lower Mississippi River. The water moccasin is a relative of the copperhead. It has a plump, brownish body resembling a muddy stick as it basks along the stream or on a pile of driftwood. The head is white along the lower jaw, and the white lining of the mouth is responsible for the name, "cotton-mouth." Large specimens attain a length of from four to six feet. Its food consists principally of fish, frogs, birds, and other small animals. The water moccasin is sluggish in nature and becomes very tame in captivity.

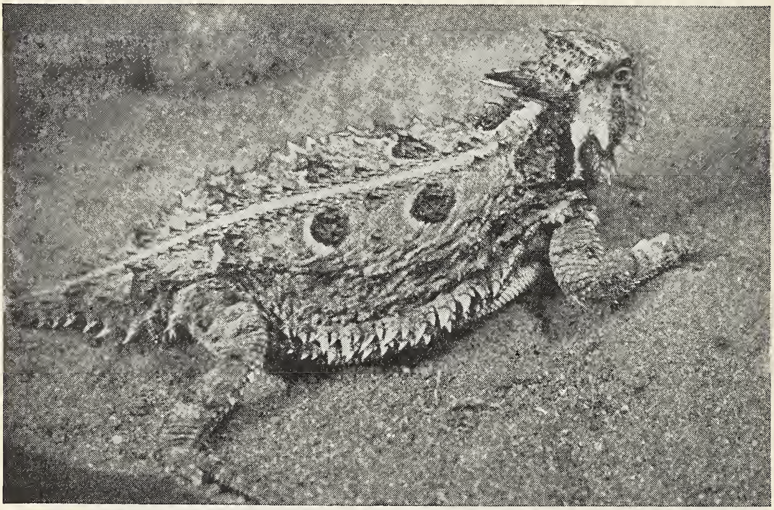
The *coral snake* or *harlequin snake* is a beautiful combination of broad bands of crimson, black, and yellow. The fangs are shorter than in the other poisonous snakes. They do not strike in the manner of the other poisonous snakes but bite viciously when handled. The coral snake is a relative of the deadly cobra of Africa and India. Its range is restricted to the South and it is most prevalent in the Southeastern states

Treatment of snakebites. Snake venom affects the blood, certain body tissues, and, in some cases, the nervous system. It does not affect the digestive system. For this reason, venomous snakes may swallow prey containing their own poison without ill effects, while the same poison injected in sufficient quantities into the blood would kill even the snake which produced it.

Modern medicine has produced efficient means of counteracting the effects of the venom of the poisonous snakes. The coral snake, whose poison acts directly upon the nervous system rather



Four Poisonous Snakes. Top left: Cotton Mouth Moccasin; top right: Coral Snake; bottom left: Copperhead; bottom right: Rattlesnake.



Horned Toad

than the blood stream, is an exception. Treatment must begin immediately after the bite is inflicted since much of the success of the treatment depends upon preventing the venom from spreading through the body. The following steps should be followed at once:

1. Place a tourniquet between the wound and the heart to cut off the flow of blood containing venom through the veins.

2. Cut several gashes around the fang wounds to induce bleeding.

3. Apply suction with the mouth immediately if there are no sores in the mouth and continue for at least thirty minutes.

4. Keep the patient quiet during these procedures.

5. After completion of treatment in the field, take the patient to the nearest doctor or hospital where antivenin may be administered to check the effects of the venom in the blood stream and suction may be continued with special cups.

Statistics from Texas hospitals show the importance of early treatment for snakebites. Mortality with no treatment averages about 15%; with antivenin and no preliminary treatment about 13.8%; with early treatment only about 2.7%; and with both early treatment and antivenin 1.8%. These figures show that early treatment in the field is far more important than the antivenin shots administered later.

In cases where the venom is injected directly into a vein, the patient has a fight for life, even with all treatments administered properly. In these severe cases, complete paralysis may result within an hour and the condition of the patient rapidly becomes critical. Suction over a period of several days and numerous transfusions may be necessary as the venom destroys the blood cells.

Description of the above treatments should prompt everyone to become familiar with the few kinds of poisonous snakes and to avoid them carefully.

Lizards. Although there are about 1,500 species of lizards known, only a

Monkmeyer Press Photo Service

GILA MONSTER

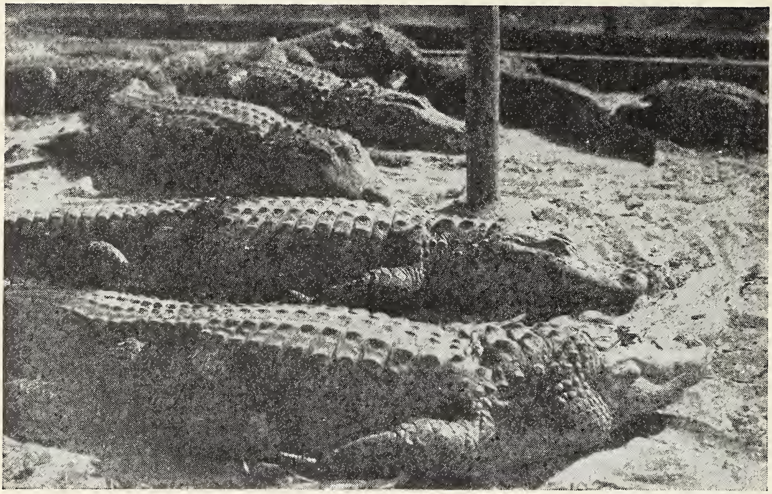
few are found in the United States. They are chiefly tropical animals, often fantastic and beautiful but the peculiar appearance and habits of many of them have given them the name of being dangerous. Many curious beliefs have arisen about such lizards as the *basilisk* and the *chameleon* [*ka meel′ee on*]. As a matter of fact most lizards are useful, all are interesting, and only one, the *Gila* [*heel′ah*] *monster* of Arizona and New Mexico, is poisonous.

They vary in size from the tiny ground lizards such as the common "swifts" or skinks, only a few inches long, to the tropical dragons of Komodo which may be fifteen feet in length. Most lizards are valuable because they eat insects.

The American *chameleon* has the ability to change color to match its surroundings. This is a protective adaptation and is caused by changing the relative size of pigment glands in the skin. Chameleons are sometimes brought north to be kept as pets. This is not a wise practice as they suffer from cold, improper food, and too much handling, and are liable to die.

The *horned toad* is well provided with horns, to be sure, but is not a toad by any means. It is a true lizard, a native of the dry plains of western United States, where its spiny skin not only protects it from enemies but prevents evaporation of water. Its color also resembles its surroundings and it is hard to see among the sand, rocks, and spiny cactus which form its environment.

Possibly because, in captivity, horned toads are likely to be inert and almost lifeless creatures, the idea has grown up that they can live for years without food or water. Only a few years ago the narrative was given nation-wide distribution that a horned toad had been found alive in the hollow of the cornerstone of a courthouse that was being demolished in a Texas town. Undoubtedly unscrupulous newspapers are the chief offenders in such sensationalism, but there seems to be a large and gullible audience



Philip D. Gendreau, N.Y.

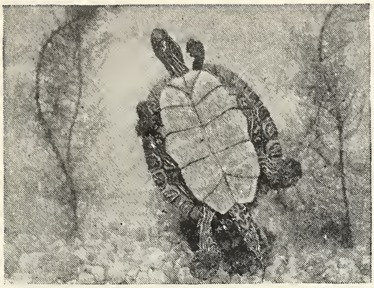
ALLIGATORS

ready to accept and repeat all sorts of fantastic yarns once they are printed. The regal python, referred to in this chapter, which went on a hunger strike, had access to water. Even this would not be possible in the case of a walled-up horned toad which probably would not be able to live more than a few days or possibly weeks under such conditions.

Common lizards include the *common swift* or *fence lizard* which may be seen darting swiftly along wooden fences and fallen tree trunks. The *skinks* include several kinds of lizards, some with and some without legs. They are characteristic in having large, rounded scales which are shiny and give the animal a glassy appearance. The *collared lizard* is one of the most beautiful animals of the southwestern desert region. These lizards, especially the males, have a bright green body covered with yellow spots. The collar is a sooty black and the throat a deep orange. Collared lizards make ideal inhabitants of a desert terrarium in the schoolroom.

The *Gila monster* of Arizona owes its fame to the fact that it is the only poisonous lizard. Its skin is covered with raised, rounded scales arranged in beautiful designs of orange or pink, and black or brown, resembling Indian beadwork. The name " monster " is misleading, for a large Gila monster does not exceed one and one-half feet in length. The poison glands and grooved teeth are situated in the rear of the lower jaw. Their location makes it necessary for the animal to get a good grip in order to insert poison into a wound. Hence, these lizards are not as dangerous as the more poisonous snakes. In captivity they become quite tame and do not offer to bite, but they should be handled with care.

Alligators and crocodiles. These giant lizard-like reptiles which have attracted so much attention and aroused so much fear belong to the *crocodilian* class. The stories about man-eating crocodiles have been exaggerated, although certain species of crocodiles in the Nile River in Africa are famous for this feat. The



Common Pond Turtle

gruesome appearance of the alligators and crocodiles had probably inspired many of the fairy tales of duels with monsters.

Alligators are common in Florida and other Gulf states. One species of crocodiles also occurs rarely in Florida, although they are common in Central America and the Old World. Unlike most lizards, all of them are aquatic, spending much of their time lying half submerged in the water or basking in the sun, sometimes several animals deep, on the edge of a stream or on an island. Projecting eyes and snouts enable them to float almost completely under water and still breathe freely and look about. Their scaly backs look like a rough log as they await the approach of their prey, which is usually a fish or some other aquatic animal.

Many crocodiles are larger than alligators, sometimes reaching a length of fifteen or twenty feet. They are more aquatic than alligators, have more webbing in their feet, and have a longer, more pointed head. Their skin is covered with horny plates which, although hard, will not stop a bullet, as is sometimes claimed.

Alligator hide is in great demand for the manufacture of fine shoes, handbags, and luggage.

Turtles. The name "turtle" will be here used to include true turtles, together with tortoises and terrapins. *Tortoise* is really the better name for the land species and turtle or *terrapin* for the aquatic forms.

Turtles form a large and interesting group in which adaptations for protection have been carried to such an extent that neither the rapid locomotion nor other defensive devices of the snake are necessary. The ribs are enormously widened, and joined edge to edge. They are covered, in most species, with horny plates and the under parts are similarly protected, though the extent of the armor varies with different kinds. Another curious adaptation is the horny beak which takes the place of teeth and is just as efficient in catching animal prey, or gathering vegetable food. Most turtles are carnivorous and live on insects, larvae, tadpoles, and fish. Some prefer water plants and fruits.

Box Turtles. These animals make excellent pets.

The *box turtle* (tortoise), found rather commonly in our woods, has the most complete protection. It can withdraw head, feet, and tail within the shell, and by means of a hinge on the ventral plate can so bend the under part of its armor that the whole body is enclosed in the shell.

Among the commoner turtles, the *snapping turtle* represents the other extreme. Its legs and head cannot be completely withdrawn under the upper shell, and the lower plate is small, affording little protection. The snapper makes up for this by its formidable beak and long, swift-moving neck. It can " snap " with great speed, is not afraid to attack any animal, even man, and can inflict severe wounds. It lives on fish, frogs, and waterfowl, and among all the turtles is probably the only one which does much harm. It is capable of holding its breath for long periods of time under water.

Other interesting turtles are the pretty *painted turtle* of our fresh-water ponds and the *wood turtle,* which is often found far from water along the roadsides and in woods. All of the common turtles are long-lived creatures. Authentic records have been kept of certain turtles which have appeared each spring in the same territory for at least half a century.

Summary

The reptiles include four principal groups of animals, the snakes, lizards, crocodilians and turtles. They are characteristic in having scale-covered bodies and claws on the feet, if present. Reptiles show several advances over the Amphibia in body structure, including lungs throughout life and a partially divided heart ventricle which aids in the separation of pure and impure blood.

Snakes are the most numerous and widespread reptile form. Numerous species range over all of United States. Most snakes are harmless, and are valuable because of their destruction of small animal pests. The rattlesnakes, copperhead, water moccasin, and coral snake are the only poisonous kinds inhabiting the United States. These forms are dangerous and should be strictly avoided.

Lizards are less common in the United States than snakes, although they are abundant in the tropics. They are beneficial and, with the exception of the Gila monster, are absolutely harmless. Alligators and crocodiles are limited to the southern part of the United States. They are not as dangerous as supposed and are valuable for their hides.

Turtles differ from other reptiles in possessing a shell. This makes them well protected but slow moving.

Using Your Knowledge

1. Can you account for some of the superstitions which have arisen in connection with snakes? What is the best way to remove such ideas?

2. Have you any idea whether in the case of snakes, legs are so to speak, " going out of style " (vestigial structures) or are being acquired? How can examination of fossils and snake embryos help to decide this question?

3. Name the poisonous snakes of your state and the exact regions where they may be found.

4. Those turtles whose normal habitat is water come on land to lay their eggs. Can you explain this?

5. Explain why the turtle resorts to mouth breathing while all other reptiles expand their ribs.

6. Distinguish viviparous and ovoviviparous reptiles.

7. Why do you think the eggs of reptiles must have shells while those of fish and frogs lack shells?

Expressing Your Knowledge

superstition	constrictor	terrapin
oviparous	quadrate	Gila monster
ovoviviparous	tortoise	chameleon
fang	septum	copperhead
venom	horned toad	rattlesnake
antivenin	garter snake	water moccasin
king snake	bull snake	coral snake

Applying Your Knowledge

1. Obtain a garter snake and keep it in a case or box for a few days. Observe its feeding, breathing, locomotion and other habits.

2. Obtain a box turtle or painted turtle for your terrarium and note its habits carefully. How does the turtle compare with the snake?

3. Make a chart of the snakes of your region. List the habitat for each, whether poisonous or non-poisonous and which varieties have economic importance and why.

4. Find out what reptiles in your state are protected by law. What others do you believe should be protected?

Chapter 35

Nature's Flying Machines—the Birds

For centuries man watched the birds soaring easily through the sky and wished that he, too, could fly. He had constructed devices for travel on land and had even mastered the sea with his ships, but he still dreamed of sailing the air currents with the birds. Just how to accomplish this was a perplexing problem, for with all of his special adaptations, he had nothing to compare with the wings of a bird.

His first attempt was a pair of large artificial wings to be fastened onto the arms. Whoever conceived this idea had neither knowledge of the bird nor of the strength of man, and the experiment ended in miserable failure. He found that his body lacked power even to manipulate the wings, much less raise his body from the ground. It was not until the development of powerful engines supplied the power lacking in the human body that man's dream was realized in the form of an airplane.

Birds have always been able to fly but man has acquired this ability only after centuries of scientific progress. Blue-winged teal ducks cut through the air with outstretched necks at ninety miles per hour and the ruddy turnstone flies each autumn from Alaska to Hawaii in a single flight, a distance of 2,000 miles! Compare the flight of the golden plover from northern Canada to southern South America, a distance of more than 8,000 miles over water, with the best records of transcontinental planes and you will have much more respect for nature's flying machines.

Only in the detailed study of the body structure of a bird can you understand how it accomplishes the amazing feat of flight. You will learn, in this chapter, how the bird is specially adapted for life in the air. You will study creatures which require tremendous energy for life and burn out within a short time, just like the high-powered engines of man-made flying machines.

Modern birds. Birds inhabit nearly all the regions of the earth, from the jungles of the tropics to the frigid wastes of the polar regions. They vary in size from the tiny hummingbird to the ostrich. Some, like the swallow, swift, and nighthawk live almost entirely on the wing, while others, like the curious penguin of the Antarctic and the domestic chicken, goose, and turkey live as land animals. The bird world is varied indeed.

Characteristics. Birds are sharply distinguished from all other animals by the following points:

1. Body covered with feathers
2. Forelimbs (arms) developed as wings, solely for locomotion and never for prehension
3. Mouth provided with a horny, toothless beak
4. Body supported on two limbs only (like man)

Adaptations for flight. The general smooth outline, due to the thick covering of feathers, permits easy and swift passage through the air, with little resistance. The flexible neck and legs provide for easy "fore and aft" balance, while the wings, being attached high above the bulk of the body, prevent the danger of tipping over sidewise. Lightness is secured by very slender, hollow, air-filled bones, with few heavy joints; by numerous air sacs scattered through the body; by feathers for covering and locomotion; and by having a light, strong beak instead of teeth. The chief flight adaptations, however, are the structure of the feathers and the wing. These will be discussed somewhat in detail.

Feathers. Feathers are modified forms of scales and like them develop from the skin. Some unchanged scales are always found on the feet of birds, and remind us of their relationship to reptiles. Feathers are not evenly distributed over the bird's body, but are found in certain areas between which the skin is nearly bare, though the overlapping feathers do not reveal it. There are three kinds of feathers: the soft *down* which retains body heat, the ordinary or *contour* feathers that cover the body and protect it, and the large *quill* feathers of the wing and tail.

The quill feathers are concerned in flight and consist of a broad *vane* spreading from an axis (the *rachis* [*ray'kis*]) terminating in a hollow *quill.* The vane is made up of innumerable rays called *barbs,* each like a tiny feather, having projections called *barbules* (little barbs) which, in turn, are held together by interlocking hooks of microscopic size. This complicated arrangement provides a vane which is strong, light, and elastic. Furthermore, if the barbules become unhooked as when a feather is "split" by accident, the bird merely shakes them or

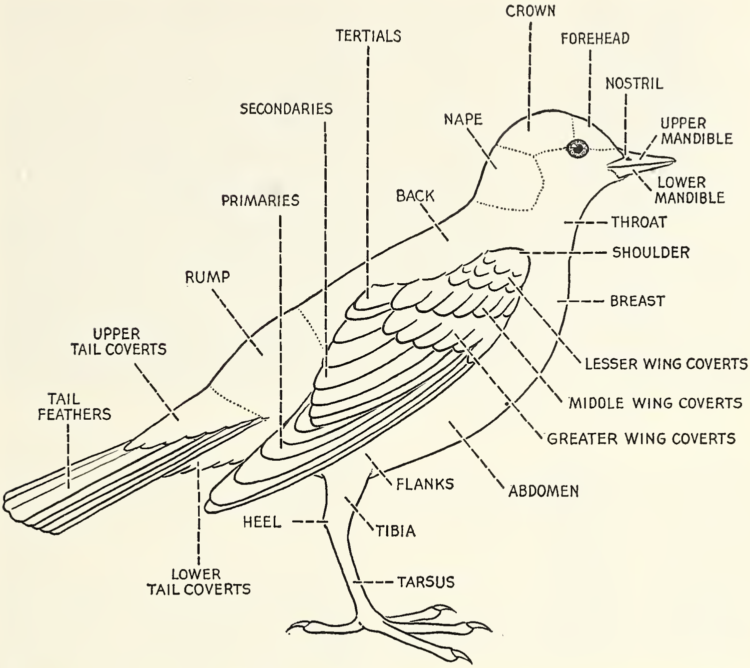


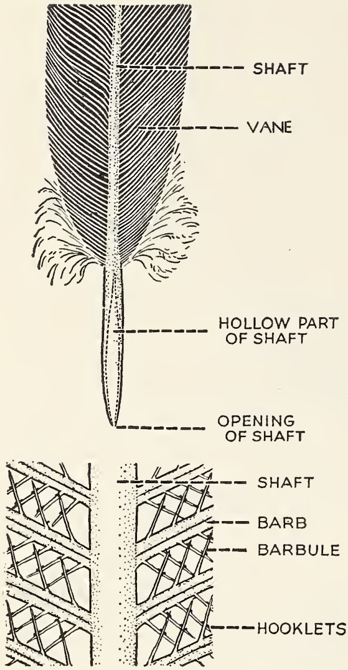
Diagram of a Bird's Body. The names of the external parts and regions are shown.

draws them through its beak, and the feather is whole again. This is a great advantage over a wing membrane such as is possessed by the bats which, if once injured, cannot be repaired.

The rachis is grooved and the quill hollow, both being adaptations to secure greater strength and less weight. At the base is an opening through which nourishment is supplied during the growth of the feather. The vane of the wing feathers is wider on one side of the rachis than on the other. When the wing strikes the air the vane tends to turn up, but rests against its neighbor and is held flat, while on the return stroke it is free to turn. The air passes through the wing as each feather partly turns on its axis (" feathering ") and the wing meets less air resistance.

Uses of feathers. The feathers provide the means of flight and aid in easy locomotion by giving the angular body a smooth outline. Moreover, feathers, being one of the best heat-retaining substances, serve to keep birds warm, even in the coldest weather, no matter how high or swift the flight. The great activity of birds necessitates high body temperature and the feather covering retains this heat and makes possible their life in the cold conditions. The feathers of most birds are oiled by a secretion taken from a gland near the tail and spread on them by the beak. This makes them waterproof. Swimming and diving birds can thus spend hours afloat and suffer no discomfort.

Feathers have a further use in providing a colored covering which, because



STRUCTURE OF A QUILL FEATHER. Top: lower portion of the feather. Bottom: portion of a vane seen under the microscope.

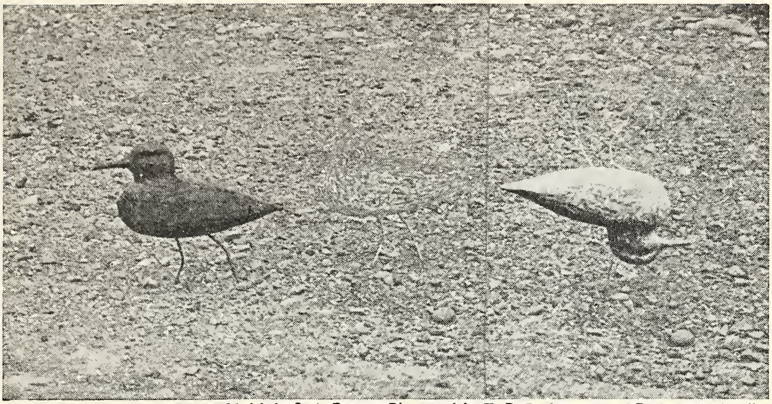
of protective resemblance, helps birds to escape discovery by enemies. Colors may also attract mates.

Examine a bird, either alive or mounted, and the back will be found to be dark while the under parts are lighter colored. When this bird is seen at a distance on the ground, the upper surface and lower surface seem to blend to about the same shade. If the bird is quiet, it may actually disappear from sight. The artist-naturalist Abbot Thayer discovered this effect produced when normal shadows are eliminated. This discovery, termed Thayer's Principle, states that the basis of most cases of protective coloration is having the brightest colors on parts which have the deepest shadow and the darkest colors where they will receive the strongest light.

Molting. Birds shed their feathers at least once a year, so that new ones may replace any that are lost or damaged. This is especially important in the case of wing feathers. Some species molt twice annually and may have differently colored plumage at different seasons. Wing feathers are shed in pairs and gradually, so as not to impair flight.

The wing. The wing is almost as wonderful an organ as the human hand. Although a modified arm, it has lost all power of grasping and is adapted entirely for flight. The shoulder is strongly braced by three bones, instead of two as in man, to withstand the tremendous pull of the powerful muscles. There are the shoulder blade, the collarbone ("wishbone"), and the coracoid bone extending to the *sternum* (breastbone). All three are devoted to supporting the wing, forming a sort of tripod arrangement, which is very strong. The upper and lower arm bones are long, strong, and slender. The wrist is lengthened as are also the fingers; only three are present, however, the other two being sacrificed for lightness. Thus we have a long, three-jointed lever, firmly attached to the shoulder, with its leverage greatly increased by the feathers. The problem now consists in providing the necessary muscle to swing such an arm.

Power required. To illustrate the difficulty involved, we may take as an example the pigeon. It weighs about a pound and has a wing spread of about two feet. This would mean that a boy or girl of ordinary weight would have to swing through the air a pair of wings each from fifty to seventy feet long at the rate of two hundred to five hundred strokes per minute. Try to swing your



Models by L. A. Fuertes: Photograph by H. D. Reed; courtesy of Professor A. A. Allen

THAYER'S PRINCIPLE. The model on the left was painted uniformly a dark color. Why is it so conspicuous?

The model in the middle is almost invisible because it was streaked underneath with light paint. This "counter-shaded" or neutralized the normal darker effect underneath.

This same model is shown on the right upside down. In this position it becomes conspicuous. Can you explain why?

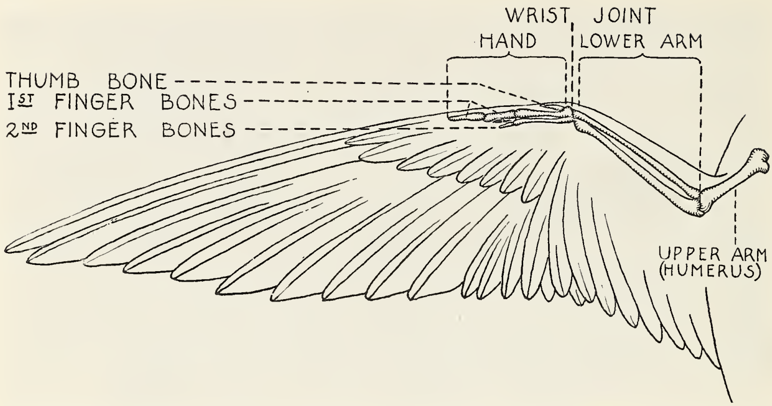
own arm at this rate for a minute, and then imagine the power needed for a wing as long as a building lot front. If we think of keeping up this form of exercise for forty-eight hours without rest, we shall have some idea of the bird's problem, and the marvelous way in which it has been solved.

Muscles competent for this task could not be located on the wing itself, as that would too greatly increase its weight, so we find the breastbone enormously enlarged, and attached to it muscle tissue equal in some cases to one-third the whole weight of the bird. To connect these muscles with the wing bones, a remarkable set of tendons pass over the shoulder joints like ropes over pulleys and transmit the motion to the wing, much as our fingers are closed by muscles located in the forearm.

Shape of wing. The attachment of the feathers to the wing is no less perfectly adapted for its purpose. The longest feathers (primaries) are attached to the *finger* bones where their leverage will be greatest. Back of them come the secondaries which brace them at the base and cover the spaces between their quills. These, in turn, are further supported by other rows, both above and below. The outline of the wing as a whole, with its concave under surface, thick forward edge, and thin flexible rear edge and tip, has just the form which man has recently discovered to be best for his airplane.

Flight. In ordinary flight the wing stroke resembles a horizontal figure eight — down and back, up and forward. The soaring of birds, like the hawk, where they seem to fly without any motion at all, is not understood. It may be due to slight wing motion, to balancing, or to utilization of wind currents, but so far, man has not satisfactorily explained, much less imitated it.

When man flies in the airplane, he flies not like the bird, with beating wings, but rather with stiff planes like



Structure of a Bird's Wing. Note the greatly lengthened " hand " region, and the reduced number of " fingers."

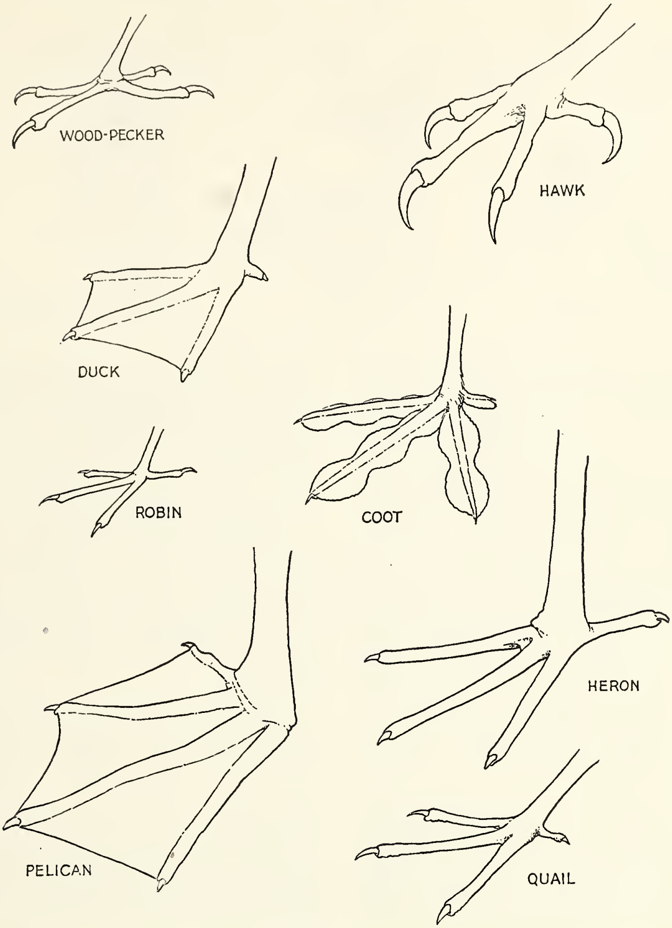
a kite driven from the front. Thus far we have no engine powerful enough to operate wings of sufficient size to carry a man in flight like a bird, nor has anyone discovered the additional secret of balancing such a machine.

Muscles. The " white meat " of a chicken is the mass of breast muscles used in flight, and the large breastbone with its projecting ridge is familiar to all of us. This ridge gives additional room to attach the powerful muscles. The outer layer of the white meat separates easily from an inside portion, this latter being very tender. The explanation is that the outer, larger, and tougher muscle is the one used in pulling the wing down and backward in the stroke of flying, while the inner and more tender muscle acts by way of a tendon over the shoulder to raise the wing for the next stroke, a much easier task and one which does not toughen it. The act of flight requires more work than any other form of locomotion.

Other adaptations. Since the bird devotes its forelimbs (arms or wings) to flight, it must balance the body on the other pair. As an adaptation for this, the legs are attached high on the hips, and the body hangs suspended between them. This prevents any tendency to lose balance when walking and permits the bird to bend easily and to pick up food, which has to be done with the beak since the forelimbs cannot be used for grasping.

Man, although he can balance on two legs, falls easily and has to learn to walk, but no one ever saw an adult bird fall down or have any difficulty in walking. The difference is due to the fact that the bulk of man's body is *above* the point of support at the hips, while that of the bird swings below.

Perching. When at rest or asleep the bird usually perches on a support and for this purpose has a very curious arrangement. The tendon that closes the claws passes over the leg joints, hence the more the leg is bent, the tighter the claws close up. Thus when the bird settles down on a branch to sleep, the more it relaxes and the more its legs bend, the closer the claws grasp the perch. This and the balancing adapta-



Different Types of Birds' Feet. Can you tell for what activity each one is best adapted?

tions enable birds to cling to a swinging twig when awake, or to a perch when asleep, with no possibility of falling.

Neck. The very flexible neck is another adaptation, especially for food getting, since the wings cannot be used for that purpose. Not only is the bird balanced so as to bend easily but the length of the neck corresponds to that of the legs; because of this the bird can always reach the ground to pick up food.

Feet. The feet of birds differ widely in structure, depending on the particular purpose required, and are in themselves a splendid example of adaptation.

The common perching birds, such as the lark and other small birds, have three toes in front and one behind. Climbing birds, like the woodpecker, have two toes

Types of Feet

Structure of Toes	Examples	Adapted for
3 front; 1 rear	Song birds	Perching
2 front; 2 rear	Woodpecker	Climbing
All webbed, separate	Coot	Swimming
All webbed, united	Pelican	Swimming
3 webbed, united	Duck, goose	Swimming
3 front; 1 rear, heavy claws	Hawk, owl, eagle	Catching prey
Small, weak	Hummingbird, swift	Little used
Long legs	Crane, heron	Wading
Legs short, far back	Loon, duck	Diving

in front and two behind; swimming birds may have each toe with a separate web, like the coot, or a web connecting all four, like the pelican, or only the front three, like the ducks and geese.

Scratching birds, like the hen, turkey, grouse, and peacock, have strong toes and heavy nails adapted for obtaining food from the ground.

The birds of prey (hawks, owls, and eagles) have the toe provided with powerful muscles and sharp claws which constitute their *talons* for catching food. At the other extreme are birds like the swifts, hummingbirds, and whippoorwills, which have very tiny and weak feet, since they live on insects or nectar, and spend most of their time in the air.

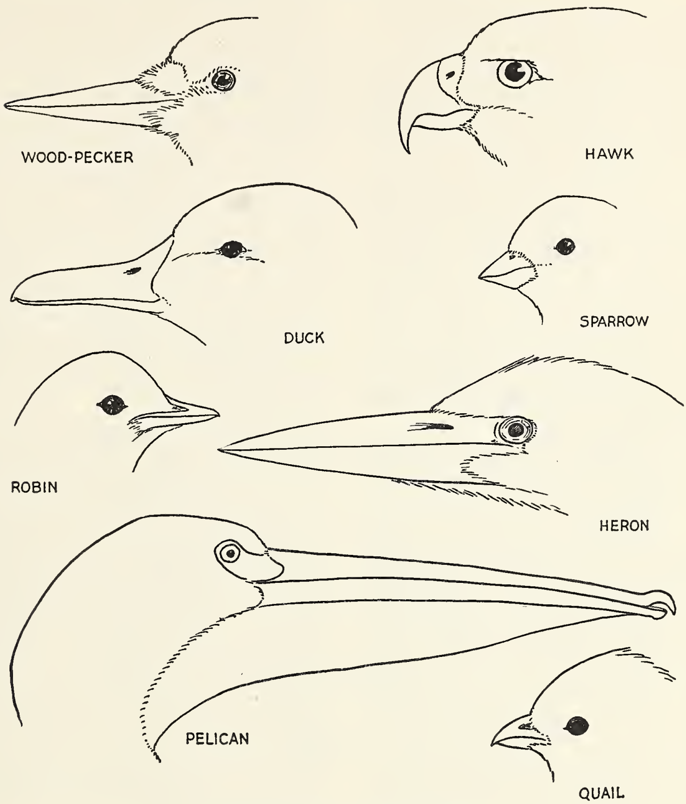
Birds which wade along the shores in search of food have long, slender legs and wide-spreading toes for support, like the heron, snipe, crane, and plover; while with diving birds, such as the loon and duck, the legs are so short and so far back as to make walking very awkward, but in the water their membranous feet give them the speed of a fish.

Beaks. Just as great a range of adaptation is shown by the beak of the bird. In all cases it is light, strong, and horny, thus avoiding weight. With each class of birds the beaks vary depending on the nature of their food and the manner of catching it.

The strong, hook-shaped beak of the hawk and owl is a familiar adaptation of the birds of prey. The very sharp, chisel-shaped beak of the woodpecker enables him to drill deep into the trees for nest holes and for food. Birds like the swift, nighthawk, and whippoorwill, which catch insects on the wing, have

Types of Beaks

Kinds	Examples	Adapted for
Hooked	Hawk, owl	Catching prey
Chisel-shaped	Woodpecker	Drilling in trees
Wide but weak	Nighthawk, swift	Catching insects on wing
Broad and notched	Duck	Scooping and straining
Slender and sensitive	Snipe	Probing in mud
Notched and hooked	Parrot	Climbing
Short and thick	Sparrows	Seed eating
Crossed mandibles	Crossbill	Opening cones
Slender tube	Hummingbird	Sucking nectar



Adaptations of Birds' Beaks

weak but enormously wide beaks, often surrounded by hairlike feathers, making a regular trap to catch their food. The duck's wide beak with toothed edges is provided for scooping food from the mud and straining it out between the notches when the head is shaken. The slender and sensitive beak of the snipe is used to probe in the mud for single pieces of food. Parrots use their short, hooked beak for defense, food getting, and for climbing. Sparrows and finches have short straight beaks for crushing seeds. The crossbill has developed a real pair of pliers for opening cones which contain the seeds he eats. At the other extreme is the hummingbird with its delicate tubular beak, which enables it to suck the nectar of flowers, though it also eats insects.

Feeding. Almost everything that can be eaten is eaten by some bird. Certain birds eat animal food exclusively, others are strict vegetarians, while many use a mixed diet. Their intense activity requires large amounts of food.

The method of food getting varies with the kind of food used. Usually the beak alone is employed, and is adapted in various ways. Occasionally the feet assist in catching or holding food, as in the case of hawks, owls, and others.

Since birds require so much food that they seem to be eating nearly all the time, it is only necessary to watch any common bird, such as a robin, for a few minutes, to observe the manner of feeding. Robins are, in general, ground feeders and may be seen searching the lawn for insects and earthworms. Both sight and hearing seem to be employed in locating their quarry and a swift motion of the beak usually secures it, though an earthworm, with its tail securely anchored in its burrow, sometimes requires a considerable amount of pulling.

Most birds drink by taking a beakful of water and tilting back the head, so that it will run down the throat. They drink a good deal, especially in hot weather, and also frequently enjoy bathing their feathers. One of the easiest ways to attract birds is to provide them with a shallow dish of water for a bird bath. It need not be an ornate or costly affair; a vessel two feet across and a few inches deep at the center, kept full of fresh water, will be patronized by the birds all summer. The edges and bottom should be rough enough to afford safe footing and the bath should be placed where cats cannot attack its visitors.

Among those using animal food are large birds of prey, such as hawks and owls, which feed upon rats, rabbits, field mice, and other small animals, also upon some other birds. Then there are many whose diet is largely or entirely fish, which they catch by diving, as do the loon, grebe, pelican, and kingfisher. Some, like the vulture, or buzzard, are scavengers and eat any dead animal that they can find; such birds have sight very keenly developed. Probably the largest number of birds which enjoy an animal diet live chiefly on insects which they may catch in the air (swifts), in wood (woodpeckers), on the ground (robins), or on trees (warblers).

Many birds live almost exclusively on seeds, doing much good by the destruction of weed seeds, while others, such as blackbirds and bobolinks, do considerable damage by their preference for grain, peas, and rice. Various kinds of both wild and cutivated fruits, especially berries, are preferred by certain birds for all or part of their bill of fare, though usually the fruit eaters have to change to an insect diet during seasons when fruit is scarce.

It sometimes happens that birds enjoy the same seeds or fruits that man raises, or they may at times rob his yard of a stray chicken, but very careful study has proved that there are but three or four birds which do more harm than good. The rest many times repay for their fruit by destruction of insects and vermin. Birds in whose favor little can be said are the Cooper's and sharp-shinned hawks, great horned owl, and English sparrow. The first three destroy poultry and useful birds, while the sparrow drives away many valuable and attractive native birds.

Digestion. The activity of birds requires large amounts of energy, which involves great food-getting and digestive ability. This, in turn, demands a remarkably complete respiratory system to provide for rapid oxidation of food and release of energy. Birds have a crop for storage, a stomach, and a gizzard with small stones for grinding tools, all of which work together to care for the vast amount of fuel needed to run so powerful an engine. A young bird may eat its own weight of food every day, so the common expression to " have an appetite like a bird " is hardly a suitable comparison for a light eater. After absorption,

FOOD USED BY SOME OF OUR COMMON BIRDS

Name of Bird	Insect Food	Vegetable Food	Rodents, etc.	Possible Harm
Quail	Potato bugs, etc., 14%	Weed seed, 63%		
Woodpecker	Wood borers, ants			
Nighthawk	Grasshoppers, flying ants, and fleas			
Kingbird	Flies, bees, beetles	Wild fruit		
Phoebe	Beetles, spiders, 93%	Wild fruit		
Bluejay	Harmful insects, 19%	Nuts and acorns	Mice, fish, salamanders	Eats some corn, eggs, young birds
Crow	Grasshoppers, beetles	Corn, wild fruit	Mice	Pulls corn, eats eggs, chicks, frogs
Redwing	Grasshoppers, weevils	Weed seed, 57%		Grain, fruit, peas, and corn
Meadow lark	Grasshoppers, etc., 73%	Weed seed, 12%		
Grackle	Insects, 35%	Grain, fruit	Mice and snails	Some fruit, grain
Junco	Beetles, caterpillars	Weed seed		
Field sparrow		Weed seed mainly		
Swallow	Flies, ants, wasps, in enormous numbers			
Cedar bird	Insects, caterpillars	Wild fruit, seeds, 74%		Cherries, 5%; cultivated fruit, 13%
Wren	Insects, 98%			Some cultivated fruit
Robin	Grasshoppers, 43%, caterpillars	Wild fruit, 47%		
Bluebird	Insects, 76%	Wild berry seed		
Horned owl			Rabbits, rats, mice	Some native birds
Cooper's hawk			Rabbits, birds	Chickens, grouse
Sharp-shinned hawk			Mice, birds	Chickens, other birds

enough food is assimilated to repair body tissues.

Respiration. The respiratory organs consist of very finely cellular lungs, and in addition nine air sacs which hold reserve air and act as extra lung tissue to be used in supplying oxygen to the blood. The rate of respiration is very high and the normal temperature is from 102 to 110 degrees, which would be fatal to man and to most other animals. Rapid oxidation means rapid production of waste matters, and these are removed largely by the highly developed lungs, there being little liquid eliminated by the kidneys. Crystals of urea are excreted by the kidneys. There are no sweat glands.

Not only do the lungs provide the blood with oxygen for oxidation, and also remove waste, but in addition supply the air for singing. It might be of interest to mention that the bird's song is not produced in the throat, but at the base of the trachea where the tubes from each lung join. Here is located the " song box," a delicate and highly adjustable structure called the *syrinx* [*seer'inks*].

Circulation. To transport this large amount of digested food, oxygen, and the waste products of oxidation, there is required a large, powerful heart and well-developed blood vessels. The rate of the heartbeat is rapid.

Nervous system and sense organs. Properly to co-ordinate and control so complicated and highly adapted an organism, a well-developed brain is necessary. In birds, the brain completely fills the skull; the *cerebrum* is broad and the *cerebellum* especially large, as is to be expected in so active an animal.

The optic lobes are also well developed, but the *olfactory* (smell) lobes are usually small and the sense of taste is poor.

The bird's eye is a very wonderful instrument, the sight being keen both for distance and for close vision, and the change of focus quickly made. This is very valuable to birds, because they must see clearly to pick up food at their feet, detect an enemy at a distance, observe their prey far off, or weave a nest close at hand.

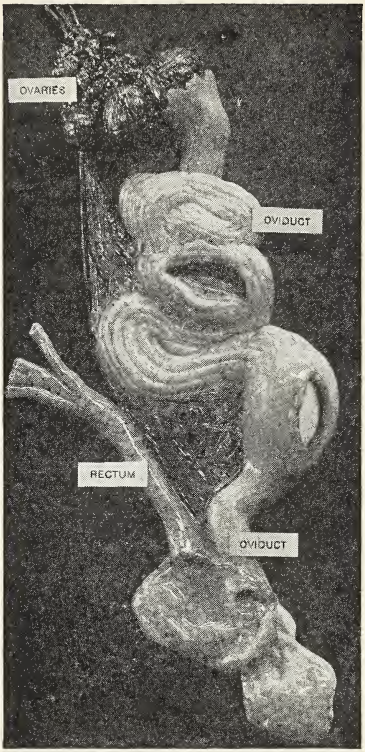
Their hearing is usually acute though there are no external ears, the openings being protected by a ring of feathers. Keenness of this sense is useful to detect danger and to recognize the songs and calls of their mates.

Reproduction. Reproduction in birds is by means of eggs, but the structure and larger size of birds' eggs place them in a higher plane of development than the animals thus far studied.

The egg of the bird has a porous, brittle *shell* which is needed to protect the contents from drying since the eggs are not laid in water. Two thin membranes within enclose the *white* of the egg. In the middle is the spherical *yolk*, on the surface of which can be seen a little white spot — the egg nucleus and adjoining protoplasm — the only living part of the egg. The nucleus and yolk constitute the real egg, corresponding to that of the fish or frog, while the white is added nourishment and the shell is protection, somewhat like the jelly that coats the frog and toad eggs.

This nucleus is the beginning of an egg. If the hen you have bought for dinner is examined before it is cooked, in the region of the back will be found small orange-colored spheres of varying sizes, together with tiny white spots. In a living bird, when these immature eggs — for such they are, constantly being formed in the ovary — grow to full-sized yolks, they are drawn by the lashing of cilia into the open end of a corrugated and twisted tube, the oviduct. This is much wider and shorter than that of the frog and is single instead of paired. As the yolk slowly moves downward, it is surrounded with layers of " white," over which the two enclosing membranes are formed. These layers are sometimes seen in a hard-boiled egg.

If an egg is laid in this condition, as sometimes happens, it is called a *soft-shelled* egg. Normally, a shell is formed by secretion from calciferous (meaning " lime-producing ") glands in the lower part of the oviduct where the egg remains about twenty-four hours before being laid. This shell seems close-grained, but actually it contains pores through which air can enter for the developing chick and carbon dioxide can escape. These pores are large enough, also, to admit bacteria. This accounts for the rapid spoiling of an egg in warm weather. If hens' eggs that have no bacteria in them (" fresh ") are sealed air-tight by a coating of hot paraffin or by immersion in a solution of water glass, they do not decay because no bacteria can get in. If eggs are kept in cold storage, they " keep " for another reason — the bacteria, even though present, cannot develop.



Reproductive System of the Hen. The left ovary with immature eggs and oviduct are shown here. There are two incisions in the oviduct, the upper one to show the corrugated lining, and the lower one to show an egg with the shell forming. Note the dark blood vessels. Why are they especially important?

Variations in the form and number of eggs. The shape of most eggs is oval. In fact, the word oval means " egg shaped " and is derived from the Latin word for egg, which is *ovum*. Oval eggs seem to pack better in a nest than would be the case if they were round, and certainly they will not roll out so easily. In many cases, birds that make deep, safe nests have eggs less oval, perhaps because they are safe from rolling out without this adaptation.

The number of eggs varies with the amount of care that the parent birds give the young. It is greatest in those kinds whose young receive the least attention and which try to shift for themselves early in life. This increases their chances of destruction and makes necessary more eggs if any are to survive. In the case of birds that are helpless when hatched and are fed and protected by parents, the number is lower. Common wood and field birds average about five, while game and water birds have twelve or more; birds of prey produce one or two.

The size of the egg is greater in those

species which hatch well developed, since more stored food is required to carry on the longer development. In all cases, however, they are large in comparison with eggs of other animals.

The color varies greatly and is probably protective in some cases where nests are open and exposed. On the other hand, eggs laid in burrows and deep dark nests are usually white, and thereby rendered more visible.

Egg development. The chick can develop only from a fertilized egg cell. Fertilization follows mating and takes place in the ducts leading from the ovaries before the shell is formed, since sperms are too delicate to penetrate the shell. Cell division goes on for about twenty-four hours and then ceases, only to recommence when the egg, after being laid, is kept at proper temperature.

The time of "sitting" or *incubation* is in proportion to the size of the egg and varies from thirteen to fifteen days for small eggs, to forty or forty-five days in the case of the swan. With hens' eggs it is twenty-one days. It is usually the female who hatches the egg. But some male birds, the ostrich for example, help in the incubation. The temperature required is 105 degress and must be kept almost constant. In birds which are helpless and have parental care, the incubation begins as soon as the first egg is laid, the chicks hatch one after the other, but in those birds like our hens, whose chicks hatch fully feathered and able to feed themselves, all the eggs are laid before sitting begins, so that they may all hatch at one time.

Use. Since the egg is practically a store of food, to be used by the growing embryo, it provides an especially nourishing and concentrated form of human food, which has been used by man for ages. Eggs require no cooking, are rich in protein and fat, and are practically all digestible. The egg crop of the United States is worth over $300,000,000 per year.

Summary

Birds differ from other animals in having a body covering of feathers; the forelimbs developed as wings; a horny, toothless beak; and a body supported by two limbs, although this last characteristic is shared by man and a few other animals. The bird's body is remarkably adapted for life in the air. Hollow bones, a light beak, air sacs, and feathers are some of its special adaptations for lightness.

The internal systems of the bird are highly developed and include a large digestive system, lungs and air sacs, a large four-chambered heart, and a brain which entirely fills the cranial cavity. The cerebrum and cerebellum are well developed, indicating higher intelligence and better muscular control than any of the animals previously studied. The extremely active life, resulting in strain upon the internal organs, accounts for the fact that most birds are rather short lived.

Reproduction is highly developed and includes mating and fertilization of the eggs internally. The eggs are large, containing a large amount of stored food, and are protected by a shell. They vary in number from one or two to more than twenty. The amount of care required by the young usually determines the number of eggs which are laid. If food is brought to the young, the number is small. If, on the other hand, the young are taken to the food supply, the number may be much larger.

Using Your Knowledge

1. Name the special adaptations of the bird for life in the air.

2. Explain how a duck may maintain a high body temperature and yet swim in icy water.

3. Can you account for the fact that chickens have " white meat " on the breast while the same meat on wild birds is tougher and darker?

4. Why do you think respiration and oxidation must be so rapid in a bird? Why more so than in other animals?

5. Name all of the parts which compose a bird egg and indicate which parts are living.

6. What color, shape, and approximate number of eggs would you expect to find in a woodpecker's nest, and why?

7. A baby chick is able to walk and find food within a few hours after hatching, while the baby robin is helpless for many days. Explain in terms of the incubation period.

8. Explain why a single duck, goose, quail or pheasant may rear a brood of as many as fifteen young.

Expressing Your Knowledge

beak	barbule	yolk
feather	plumage	calciferous
down	leverage	co-ordinate
contour	primaries	oviduct
quill	secondaries	ovary
vane	Thayer's Principle	air sac
rachis	talon	lobed
barb	syrinx	webbed

Applying Your Knowledge

1. Dissect the end joint of a chicken wing and see how many finger bones you can locate.

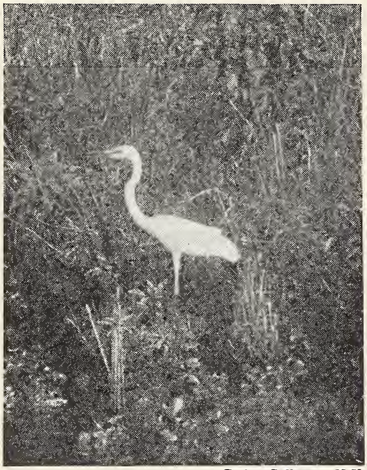
2. Obtain a chicken foot and dissect the joint end to expose the tendons. See if you can find the tendons which operate each toe and the one which closes the entire foot.

3. Obtain a pigeon, weigh it, and keep track of the weight of the food it consumes daily. How would flight activity affect food consumption?

Chapter 36

Bird Study

In the year 1810, a young man of thirty, his wife, and child descended the Ohio River from Pennsylvania, bound for the wilderness. The young man, a naturalist, was John James Audubon, and his mission was one that was to bring him everlasting fame. With pencils and sketch pads, and provisions for several years, he was prepared to make sketches of the birds of North America in their native haunts. Audubon roamed the forests and fields in every direction for many years,



Ewing Galloway, N.Y.

White Crane in a Florida Swamp

studying the birds he encountered and sketching each one in life-sized drawings. In 1826 he went to England where he supervised the coloring of his priceless sketches and published them in four volumes which he titled *The Birds of America.* Thus, John James Audubon contributed immeasurably to the study of birds, for few bird students are not familiar with his beautiful illustrations of North American bird life.

From the time of Audubon, scores of other great *ornithologists,* students of birds, have answered the call of the wilderness to add their contributions to the study of bird life. Today, bird study is a highly organized science. National, state, and local bird societies list thousands of members in their roles. Men and women and young people in all walks of life traverse the fields and woodlands with field glasses and notebooks as members of the great society of ornithologists.

Getting acquainted with birds. Perhaps you have already had opportunity to study birds in the field with the Scouts, Campfire Girls, or some other organization of young people engaged in out-of-door activity. If not, you may be able to organize some bird study hikes during your biology course. These activities will serve as an introduction to bird study and will acquaint you with some of the methods used in the field. However, this worthy pursuit should not end with your biology course, for the real thrill comes when you make frequent trips by yourself or with small, interested groups and visit the more secluded havens of bird life.

Bird study is a delightful challenge. It frequently becomes a game where you test your knowledge and powers of observation with a momentary glimpse of a flash of color darting through the leaves and thickets or passing quickly overhead. Distinctive marks like wing bars, white outer tail feathers, a black band under the throat, or white lines on the crown may be a means of identifying a bird with only a brief glimpse. A good pair of field glasses will greatly assist you in bird identification, since even the trained student of birds often has difficulty approaching them closely.

In addition to size, shape, and color, birds may be recognized by the manner in which they fly, walk, hop about, and seek their food. Songs, likewise, are very characteristic. At first, most bird notes may seem to be alike, but you will soon learn to associate certain calls with the birds which make them. When you have reached this advanced stage in bird study you can stand quietly in the woods and determine what birds to expect by merely listening to their sounds. Thus, bird study becomes a study of form and color and personality as well.

Bird habitats. In selecting the places for your bird study, you will want to include a variety of habitats, for birds, like all other animals, are restricted in their surroundings. You will soon learn just what birds to expect in a particular environment at a certain season of the year. Large bodies of water are inhabited by certain species of ducks, loons, and gulls, while sandpipers and other shore birds wade the shallow water along the beach in search of food. In the marsh, you will find the rails and herons, the bitterns, coots, swamp ducks, and red-winged blackbirds. Woodland species include the thrushes and orioles, thrashers and warblers. In the open field, one finds the goldfinch, sparrows, and meadowlarks. Identification of the hawks requires an especially good observer, for these large birds of prey are usually seen soaring high in the air and must be identified on the wing by special markings, shape of the tail, and other characteristic features.

Bird migration. One of the most mysterious and wonderful instincts in the world is that which controls the migration of birds. The causes of migration are not fully understood. It would seem that birds possess some sense not present in other animals which warns them of approaching weather changes and guides them on their long flights, for the seasonal migration of birds is usually a good indication of weather conditions.

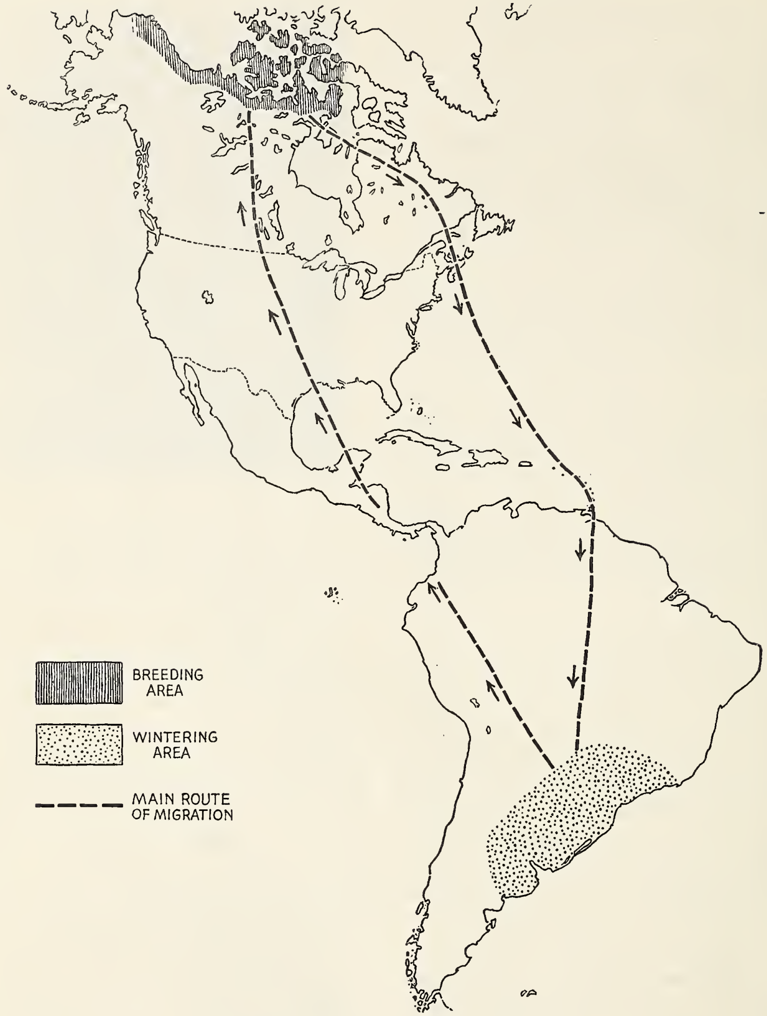
Migration may be caused by food needs, climatic changes, or breeding purposes. It is not easily understood why some species leave abundant food and warmth in the tropics and migrate to breeding grounds in the far north. Much more explainable is the southward migration of insect eaters when cold weather kills their prey and the southward flight of water birds before the ponds and lakes freeze over. It is logical, too, that fruit and seed eaters would tend to follow the crops, but even these reasons do not explain fully the phenomenon of bird migration.

Migratory flights may be made at night or during the day, depending upon the species. Many are familiar with the flights of geese during the spring and autumn nights when they become confused by the lights of the city and circle about, honking noisily. The daylight flights of red-winged blackbirds and grackles numbering thousands of individuals are familiar sights during spring and fall.

While many birds migrate slowly, feeding by the way and averaging only twenty to thirty miles per day, there are others which are marvels of speed and endurance. Bear in mind that it is considered good performance to drive a car from San Francisco to New York in less than a week, and that the train requires about four days.

The ruddy turnstone travels each autumn from Alaska to Hawaii in a single flight, and the golden plover travels from Canada to South America, a distance of more than 8,000 miles. Over the open ocean, with only occasional rests on the surface of the water, this bird uses two ounces of its fat as fuel for the entire journey. Compare this with the fuel consumed by a transoceanic plane and you will see the efficiency of the bird as a flying machine. Even the tiny hummingbird flies across the Gulf of Mexico, a distance of over 500 miles in a single flight, and in a single night! Even then it is not tired enough to rest but flies inland to make a good trip of it.

Migratory routes. Wonderful as are birds' speed and endurance, an even greater mystery surrounds the instinct which governs the time and routes of migration. Any given species follows the same routes year after year, and may be



Migratory Route of the Golden Plover

expected to arrive at a certain point within a few weeks of the same time each season, depending upon the weather.

As though to vary the scenery, certain species travel northward along one route and return by an entirely different route. How do they know the way? Keen sight may help, but not over water or through dark nights and fogs. Even the memory of old birds which have made the flight before cannot account for unescorted flights of young birds. We must assume an instinct of migration and a "sense of direction" developed to a degree that

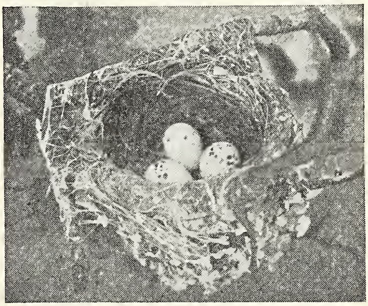
WOODCOCK JUST BANDED

we can only imagine, and this is really no explanation at all.

Bird banding. You many wonder how ornithologists trace the migratory routes of birds. This interesting phase of bird study is carried on by bird students scattered over the land who carry on the practice of bird banding. Individuals of certain species are caught in special cage traps, removed carefully, and marked with a light aluminum band. Each band contains the date of banding, the place, and the individual who caught the bird. It is then released to go its way. Later, it may be caught by another bird bander who examines the band and reports its new location. Through the Bird Banding Association and other bird societies, records of banding and observations of banded birds are assembled. Bird banding is also valuable in determining the age to which a certain species may live.

Seasonal bird study. Migration adds much to the study of birds, for new species are arriving during many seasons of the year. Each locality has *permanent residents* which remain the year around. In addition, certain species may be present in the winter only, moving farther north with the coming of spring. These species are called *winter residents. Summer residents*, as the name implies, spend the summers in a given locality and migrate southward with the approach of fall. Many species are found only at certain times in the spring and fall. These are the *migratory birds* which are passing through a given locality on their journey from wintering areas farther south to breeding grounds farther north. Because of these seasonal migrations, the bird student must be active the entire year or he will miss entirely many species which inhabit his vicinity for short periods.

Nest building. The ornithologist does not confine his interest to the identification of the adult birds of his region, nor to the tracing of migratory routes. During the breeding season, he watches carefully for nests in the variety of places birds choose to rear their young. Nests and young birds may be studied by the skilled observer without any annoyance to the parent birds. The place selected, form and size of the nest, color and number of the eggs, and the manner in which the parents rear the young are as characteristic as the birds themselves. The trained ornithologist can identify the nest by the form and materials used in building it as readily as he can identify the bird which constructed it.



WOVEN NEST OF YELLOW THROATED VIREO

NESTS OF SOME COMMON BIRDS

Name	Location of Nest	Material and Description
Kingfisher	Hole in bank	6 to 8 ft. deep; eggs on ground or on feathers
Woodpecker	Holes in trees	Usually cut into hollow, or dead tree through side
Crested flycatcher	Holes in trees	Bulky, of grass, etc.; may use a snake skin
Robin	On branch or crotch	Bulky, case of mud, grass-lined, heavy
Bluejay	On branches	Bulky, ragged, of twigs, leaves, rags, string, etc.
Crow	In trees	Very bulky, of sticks, cedar bark, sod, hair, etc.
Grebe	In bogs	Decayed damp plants
Redwing blackbird	In bushes and reeds	Deep, mouth contracted, of grass and rushes
Phoebe	Under bridges or on houses or rocks	Moss, cemented with mud and lined with hair
Barn swallow	Hollow trees or eaves	Mud and straw, lined with hay or feathers
Chimney swift	Hollow trees or chimneys	Sticks glued with "saliva," cup-shaped
Whippoorwill	Dead leaves	No real nest, slight depression
Quail	Underbrush	Arch of vegetation over nest made of grass
Meadow lark	Underbrush	Similar to above, but smaller
Marsh wren	On reeds in swamps	Made of reeds and grass, down lined; many dummy nests
Hummingbird	On high branches	Tiny, deep nest, saddled on branch, moss covered
Oriole	Overhanging branch of elm tree	Pendant, woven of hair, string, and grass
		Bottom compact, sides loose, resembles hornet's nest
Oven bird	On ground	Under arch of grass, entrance at side

Next to migration, the highest development of bird instinct is shown in nest construction. We must remember that they have no hands or forelimbs to help, but merely beak and feet, and their materials are only such as they can find. Yet, when the wonderful home of an oriole or hummingbird is studied, we realize that even with hands, and brain, and tools, we could not imitate them. Nests differ widely both as to materials and construction. Earth, clay, sticks, grass, hair, feathers, moss, and even strings are used, and the structure itself may vary from a mere hole in the sand (ostrich) to the dainty nest of a vireo.

Philip D. Gendreau, N.Y.

BUILT-UP NEST OF ROBIN

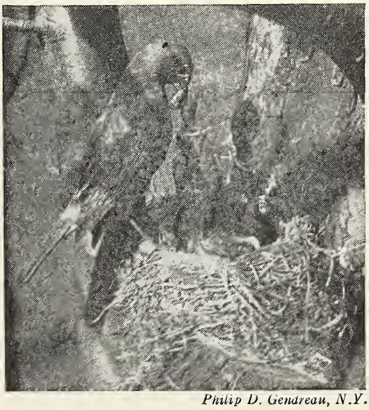
Excavated nests. Water birds usually lay their eggs on rocks, with only sticks enough to keep the eggs from rolling. The kingfisher and barn swallow dig holes in cliffs; while owls and woodpeckers live in excavated homes in dead trees.

Woven nests. Very simple grass nests are made by ducks and wading birds. Among the most remarkable woven nests are the covered pendant homes of orioles and vireos, hanging from slender limbs where no thieving cat or red squirrel can come. Horsehair and plant fibers are used and so well are they selected and woven that the nest often withstands the storms of several seasons, and is repaired and used again, frequently by the same pair that built it.

Built-up nests. Robins make a clumsy nest of clay, lined with grass, and placed in crotches or on big branches. Swallows are much better masons and build clay nests on barns and cliffs, strong and inaccessible. They roll the clay into pellets with the beak and build the walls a little at a time, leaving one layer to dry before adding more, lest it all collapse. The chimney swift builds a nest of sticks held together by a sticky "saliva" which hardens into a strong glue. In China a similar bird makes a sort of edible gelatin, the basis of bird's nest soup. Each species of bird builds its own peculiar structure, always in the same way, of similar materials, and in the same kind of location. There seems to be no way by which one generation is taught to build like its ancestors, and when we say it is due to instinct, we have not explained how they learn to construct such perfectly adapted nests.

Both the nest building and the incubation (sitting) are usually done by the female, though in some species the male helps in both processes. The cowbird avoids the responsibilities of a parent by laying her eggs in other birds' nests, where the young cowbirds sometimes crowd out their foster brothers.

Care of the young. With the hatching of the young birds, the parents begin a period of tremendous activity, for probably no animal consumes so much food in proportion to its size as a nestling bird. Usually, both parents assist in the task of filling the hungry mouths which gape widely each time a parent approaches the nest with a mouthful of



Philip D. Gendreau, N.Y.

A ROBIN FEEDING HER YOUNG BROOD

food. During the period of rearing the young, the bird student has a good opportunity to observe the birds at close range. The bird photographer finds this the ideal time to focus a concealed camera sharply on the nest and await the arrival of one of the parent birds.

Economic importance of birds. Whether one is a student of birds or not, he should be familiar with their economic importance. Few species are definitely classed as harmful and the majority have tremendous importance in maintaining the balance of nature.

Insect destruction. It is estimated that insects, if unchecked, would destroy all vegetation in three years. Even as it is, insects do two billion dollars worth of damage each year in the United States. About one-half of all animal species are insects. In proportion to their size they are among the most rapacious feeders. They frequently display a preference for the plants which man raises for his food.

Birds are the chief enemies of insects. There are about thirteen thousand species of birds in the world, of which eight hundred and fifty live in North America and about two hundred kinds may be found in one region. On the other hand, there are fifteen thousand species of insects within fifty miles of New York City, many of which are harmful to man. The fact that such hordes of insects are even partially held in check by the birds shows the services which birds can render.

Nature tends to establish a balance. Man often disturbs it, to his sorrow. Native birds could completely regulate native insects, but man has introduced many insects from other countries, such as the gypsy moth and corn borer. These, not having their natural enemies to check them, multiply almost beyond the power of bird or man to control, and constitute one of our hardest problems. Without our bird allies, it would be insolvable.

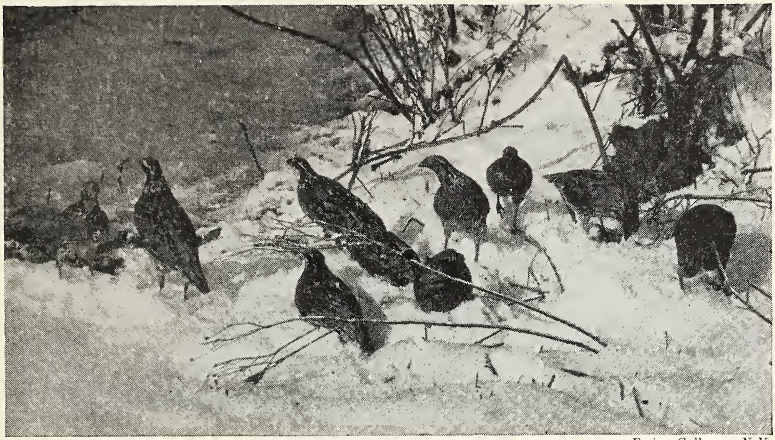
An unwise bird law cost the state of Pennsylvania nearly four million dollars in a year and a half, through the destruction which it permitted among useful birds. At the end of this period, the damage was so apparent that the law was repealed and a state ornithologist appointed to look after the birds. Actual experiments have been worked out with protected and unprotected bird regions so that their essential service can no longer be questioned.

Destruction of weed seeds. Reference to the food table will show that weed seed constitutes a large portion of the food consumed by many birds.

Weeds annually damage crops in the United States to the extent of five hundred million dollars, and in addition necessitate great expense for labor in attempting to destroy them. Sparrows, Juncos, quail, and similar birds destroy tons of weed seed every year. Without the aid of birds, weed control would be a losing battle.

Destruction of harmful mammals. Hawks, owls, and other birds of prey were formerly regarded as harmful, but recent studies have proved this to be a false idea. Only five species are harmful, six are wholly beneficial and thirty chiefly so, and seven others do about equal amounts of good and harm.

Their eating of mice, rats, squirrels, rabbits, and other harmful animals more than pays for any poultry these birds may take. Of the diet of the red-tailed hawk, commonly called a " hen hawk," harmful mammals comprise sixty-six per cent, while poultry forms only seven per cent. Cooper's hawk really should be called a " hen hawk " since poultry and wild birds constitute much of its fare. This hawk and the sharp-shinned hawk,



Ewing Galloway, N.Y.

Bob-White Quail

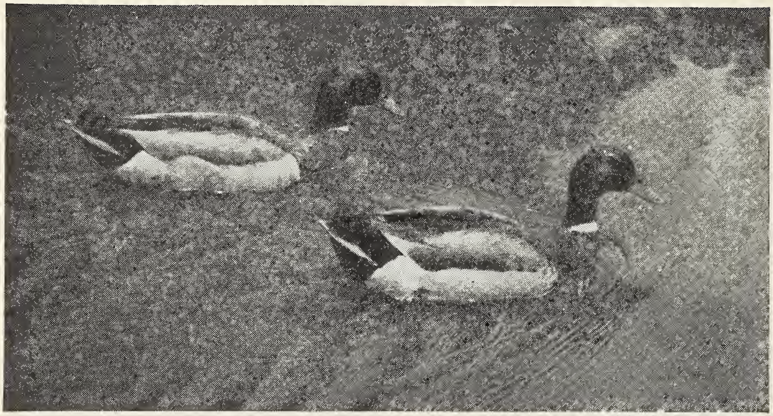
goshawk, great horned owl, and snowy owl do more damage than good.

Game birds. Many species of wild birds are hunted both for sport and food value. Such game birds as quail, pheasant, partridge, grouse, geese, ducks, and turkeys draw scores of hunters into the fields, marshes, and woodlands annually. The supply of these game birds is maintained by protective laws which govern the bag limit and hunting season, and, in many states, by scientifically operated hatcheries which greatly assist the wild birds in propagating their numbers.

The hunting activity of the sportsman is not to be confused with the extensive market hunting of wild birds which, in past years, exterminated the passenger pigeon and heath hen and nearly destroyed other species including the prairie chicken, wood duck, and others. Public sentiment and legislation have forced the prohibition of market hunting in most states. Game bird conservation programs, encouraged and assisted by the sportsmen of the nation have now increased greatly our supply of valuable game birds.

Domesticated birds. A traveler in the forests of India might be surprised to hear a familiar cackle reminding him of the barnyard fowl back home on the farm. As a matter of fact the red jungle fowl of India is the progenitor of all our varieties of hens and we owe to some Oriental poultry man of long ago the domestication of our most valuable tame bird.

Wild geese still can be found as the Canada goose, and also the graylag goose of the British Isles, the probable ancestor of our domestic geese, now so valued for flesh, eggs, and feathers. The beautiful mallard duck, highly regarded as a game bird, is the ancestor of the domestic form and still can be raised in captivity and tamed. The turkey, despite its name, is a truly American bird, a native of this country and common in the woods when the Puritans landed in New England. There are three wild species in North and Central America from which our domestic varieties are derived.



Philip D. Gendreau, N.Y.

WILD MALLARD DUCKS

Other economic uses of birds. In Peru and in some Pacific islands where millions of sea birds have roosted for centuries, vast deposits of manure, called *guano*, have accumulated and furnish a valuable fertilizer.

Another use of birds, now fortunately restricted by law, is for millinery. The only plumage that may now be legally used is that from domestic birds and from ostriches.

Carrier pigeons have been useful in military and naval activities because they can be trained to return to their homes when brought to any strange region. From these strange regions they bring back messages to the home base, often going through shellfire in time of war.

Harm done by birds. Three hawks and two owls have been mentioned as killers of wild and domestic birds. To them must be added the English sparrow which drives away native birds, kills the young, and breaks up nests, especially of bluebirds and swallows. The starling is a similar pest in some regions. Both are immigrants and, lacking their natural enemies, have multiplied too fast in their adopted country.

Crows do considerable harm to corn and, together with their cousins the bluejays, they destroy eggs and young of other birds. To balance this, both birds destroy many insects and it is doubtful if they ought to be killed, except in certain regions where the harm they cause is serious.

Bird destruction. The advancing tide of civilization has swept away much of our bird population and has made necessary protective measures for those that remain.

The cutting of forests and clearing of underbrush have removed vast areas of bird homes. Forest fires have destroyed birds and their nesting places. Drainage has robbed the water bird of its marshy pool and dams have covered the shore birds' homes with water. Thousands of birds have been killed by dashing against high buildings, lighthouses, and electric wires.

Man is responsible perhaps for greater destruction, by deliberate hunting of birds for sport, food, or feathers, or with the usually erroneous idea of protecting crops. Our domestic cat and certain birds introduced from foreign countries, chiefly the English sparrow, have increased the destruction of our native bird population.

Due to these and other causes, the great auk, passenger pigeon, Labrador duck, and other birds are now extinct. The wild turkey, white egret, prairie chicken, bald eagle, and ivory-billed woodpecker will soon follow unless they receive better protection. The last heath hen in the world, so far as known, died in 1932–1933 on Martha's Vineyard, an island off Cape Cod in Massachusetts.

Natural enemies. Birds also have many enemies among the other animals. Cats probably do the most damage, especially when allowed to hunt at night. Ownerless stray cats should be confined or destroyed and pet cats kept from bird hunting. A conservative estimate of this source of destruction is fifty birds per cat each year.

Red squirrels, rats, deer mice, and weasels take their toll of eggs and young birds, and should be controlled. As has already been noted, certain birds are destructive to our valuable wild species. Nearly all snakes will eat eggs or young birds but the black snake is the worst offender.

Against these natural enemies, birds could hold their own if man would not interfere. However, with the cat raised and protected by him, and foreign birds introduced by his agency, the balance is turned against the birds, even if man did not kill them himself. It is important to keep in mind that a war of extermination is likely to produce disastrous results in the upsetting of a normal biological balance. A wiser policy is to *destroy obnoxious animals only to the extent demanded by control.*

Bird protection. The surest way to secure protection for anything is to convince people of its value. In the case of birds many agencies are working to this end, having in view the spread of information regarding the great usefulness of birds and creating a sentiment favoring their protection.

One of the most active organizations for bird protection is the National Association of Audubon Secieties, founded in 1902 by William Dutcher and named after John James Audubon, who was the most noted early student of American birds. The Audubon Society supplies literature regarding birds and bird habits, doing this educational work through its publications, the schools, and the press.

The Audubon Society also uses its influence to secure the enactment of state and federal laws for bird protection. Another agency constantly working for bird protection is the United States Department of Agriculture, through the Bureau of Biological Survey and through Farmers' Bulletins. This important bureau has charge of the conservation of birds and other animals, controls the national bird reservations, administers laws regarding commerce in game, and publishes many bulletins and much other information as to the distribution and value of birds and other animals.

Other organizations helping in this work are the American Ornithologists' Union, the League of American Sportsmen, the Agassiz Association, and the Society for the Prevention of Cruelty to Animals.

Laws. As early as 1885, the Ornithologists' Union drafted a Standard Bird Law, called the Audubon Law, which was adopted in most of the states. Federal and state laws now cover these items. The provisions of the Audubon Law are as follows:

1. Game and non-game birds are defined.

2. Non-game birds may not be killed at any time.

3. Closed seasons are provided for game birds.

4. English sparrows, sharp-shinned and Cooper's hawks, great horned owls, ravens, and crows are not protected.

5. The nests and eggs of protected birds are also protected.

6. Protected birds may not be sold or transported.

7. The taking of birds or eggs for scientific purposes under an official permit is permitted.

8. Fines or imprisonment are provided for violations.

In 1900 the Lacey Law was passed. As amended in 1909 it covers the following points:

1. The Department of Agriculture is authorized to preserve, restore, and distribute game and other birds.

2. The Secretary of Agriculture may buy and distribute such birds as seem necessary.

3. The Secretary is also instructed to publish information as to the use and preservation of birds.

4. Shipment of birds from states where it is illegal to kill them is forbidden.

5. Special protection is provided for federal bird sanctuaries.

The Federal Tariff Bill of 1913 as amended in 1919 forbids importation of feathers, skins, plumes, wings, or quills of wild birds, except for educational purposes.

Of perhaps even greater importance is the Weeks-McLean Law of 1913 which is embodied in the Federal Migratory Bird Treaty Act, ratified in 1918. This is not only a federal law but is combined for enforcement by treaty with Canada and Great Britain, thus giving uniform protection to migratory birds on both sides of the Canadian boundary.

Nearly all states have some bird laws, some weak and others excellent. New York has the Bayne-Blauvelt Law which protects all birds and forbids the sale of native wild game birds, no matter where killed. In New York, cats found at large, hunting birds, may be killed, and foxes are also outlawed because of their damage to the ruffed grouse or partridge.

The United States Department of Agriculture publishes a free bulletin giving the game laws of every state. More complete information as to birds and other game can be had from your own state capital or college of agriculture.

Reservations. Another effectual means of bird protection has been the establishment of bird sanctuaries, refuges, and preserves, both by government and private action.

Such sanctuaries are areas of various extent, set apart by national, state, or local governments or by private individuals, in which no hunting is permitted. Birds and other animals soon locate the areas where they are undisturbed and flock there in amazing numbers.

At the request of the Audubon Society, Theodore Roosevelt established Pelican Island Reservation in 1901. In 1902 the society began work in Florida for protection of the snowy heron or egret, rapidly being exterminated for its "aigrette" plumes. Refuges were established and wardens were sent to protect the few remaining heron colonies from the plume hunter. So ruthless was the demand for these plumes for millinery use that in 1905 Warden Bradley was murdered while defending his reserva-

Ewing Galloway, N.Y.

WILD DUCKS AT WINTER FEEDING STATION. Vast flocks of these birds are caught in cages, fed, and banded so that authorities can ascertain how many return next winter. The feeding grounds shown here are located at Oakland, California. Many ducks return year after year.

tion, and in 1908 Warden McLeod met a similar fate. With increasing protection, better laws, and more and larger sanctuaries, this beautiful bird may be saved from the fate of the passenger pigeon and Labrador duck.

These reservations were but a beginning. Government refuges have since been established from Hawaii and Alaska to Puerto Rico and Panama. They number nearly two hundred and vary in size from Yellowstone Park with an area of over 3,000 square miles to Pelican Island, Florida, which was our first bird sanctuary and had an area of six acres. In addition there are nearly three hundred state refuges.

Private individuals early became interested in bird preservation and bought various tracts of land where they established sanctuaries, provided guards, and built feeding stations. One of the first of these, Marsh Island, Louisiana, with an area of 77,000 acres, was bought in 1912 by Mrs. Russell Sage. The Rockefeller Foundation bought a tract of 86,000 acres in 1914 and Edward McIlhenny and Charles Ward provided another preserve of 57,000 acres, all in Louisiana. It is said that more wild waterfowl now winter in Louisiana than in any two other states.

In the more thickly populated regions of the United States it is impossible to buy large tracts but often individuals make sanctuaries of their private grounds and are always rewarded by an influx of feathered guests. The Audubon Society sometimes leases islands or lakes for bird preserves and helps in providing guards. States, towns, and cities are devoting watersheds to the purpose of bird protection. It is to be hoped that a time may soon come when anywhere in the United States songbirds and harmless mammals may be safe, even without legal protection.

Methods of attracting birds. The ideal condition mentioned in the previous paragraph can be hastened if we all do what we can to protect and attract the birds around our homes. Planting fruiting shrubs such as elderberry, sumac, raspberry, dogwood, mountain ash, and cherry will bear dividends in attracting many bird visitors that otherwise would not be seen. Birdbaths will attract many of the feathered folk on any hot summer day, and richly repay the small trouble of preparation.

In winter it is both easy and interesting to feed birds by fastening suet to the limbs of trees, or hanging up pork rinds and bones with meat attached. Snow can be packed down and grain scattered where it will not be covered; feeding trays can be built outside your windows or out in the woods; the feeding devices are almost as various as the foods that can be used. *Wild Bird Guests,* by Baynes, and Farmers' Bulletin No. 621 of the Department of Agriculture give fascinating directions for this kind of bird protection.

Next to providing food, suitable shelters will attract bird neighbors. Anyone can make a birdhouse. It need not be large nor complicated but should be adapted to the kind of bird expected. Birdhouses should be put in sheltered places and at such height as to be protected from cats and other enemies. Details of construction can be had from Audubon Bulletin No. 18 or Farmers' Bulletin No. 609. Every yard ought to have one birdhouse and in winter one feeding device.

Summary

Bird study is one of the most delightful phases of field biology. It is an ideal combination of a scientific pursuit and pure recreation. As a bird student, you will find scores of others engaged in the same activity and organized into bird societies which you may someday wish to join.

Bird study involves not only the identification of adult birds in the field, but also their migrations, nesting habits and care of the young. You will wish to become thoroughly acquainted with the economic importance of birds in order to assist in the extensive program of conservation, so important in the future of America. As a member of an organized bird society, you can assist in the campaigns these organizations are conducting to protect the birds of America.

Using Your Knowledge

1. If you were a member of your state legislature, or of the State Conservation Commission, what measures would you advocate to insure general knowledge of the facts involved in conservation and active participation by all inhabitants of the state?

2. Why should the slogan of naturalists and conservationists be "control" instead of "annihilation" of all enemies of wild birds?

3. What is your opinion about the advisability of passing a law licensing cats?

4. How far from your school is the nearest bird reservation or sanctuary?

5. Can you identify at least twenty-five wild birds common during spring and summer in your vicinity?

Expressing Your Knowledge

ornithologist	migratory bird	guano
Audubon	instinct	Audubon Society
identification mark	excavated nest	American Ornithologists' Union
migration	woven nest	Audubon Law

bird band	built-up nest	Lacey Law
permanent resident	nestling	Federal Tariff Bill
winter resident	game bird	reservation
summer resident	sportsman	attraction

Applying Your Knowledge

1. In summer or autumn collect as many nests of wild birds as you can find. Put each in a suitable carboard box, label it, and add it to the school museum. (A small booklet, " Key to Bird Nests," by Dr. Allen, can be procured for a nominal amount from the Comstock Publishing Company, Ithaca, N. Y.)

2. Select one of these nests which is composed of different materials, and list the things used in its construction.

3. In midwinter or early spring, start to keep a check list of the wild birds you see, and continue through the year.

4. Find out all you can about bird banding. (Write to the Fish and Wildlife Service, Department of the Interior, Washington, D. C.)

5. Find out how many bird sanctuaries there are in the vicinity of your home, village, or city. (The Audubon Society of your state will assist you and doubtless will be glad to give publicity to such lists as you prepare.)

6. Write accounts of the contributions to the cause of conservation made by Theodore Roosevelt, Dr. William T. Hornaday, former director of the New York Zoölogical Gardens, Dr. T. Gilbert Pearson, former president of the National Association of Audubon Societies, New York City, and J. N. Darling, former chief of the Biological Survey, Washington, D. C.

7. Write articles for your school paper or magazine, or for local newspapers, on the conservation of wild birds.

Chapter 37

The Highest Forms of Animal Life—the Mammals

The animal life of the earth occupies three principal environments: water, air, and land. Fishes dominate the bodies of water which cover five-eighths of the earth's surface, since these rulers of the deep are more perfectly adapted for life in the water than any other animal group. In the air, birds are supreme and have little competition as long as they remain aloft. But on the land, animals have engaged in a terrific struggle for supremacy. Insects have succeeded in maintaining their numbers because of their small size, adaptability, and rapid rate of reproduction. But the land animals of larger size and less prolific nature have faced critical problems in preserving their kind in the tremendous competition among the land animals.

In the struggle for supremacy on land, the mammals have emerged as rulers of the earth. To some extent, they constitute a " super " group of organisms, since what the mammal may lack in special adaptations is more than compensated for in brain development far exceeding other forms of life. In the changing earth, the mammal has been able to apply intelligence and reasoning to the solution of new problems.

The supremacy of brains over brawn is especially illustrated in the development of man as the supreme form of life. Superior brain development placed the mammals above all other animal groups, but it remained for man, the highest of the mammals, to gain complete domination of the earth. In structure, man resembles the other mammals. In intelligence, however, man is far superior to even the highest of the other mammals.

Your study of mammals will include animals of the forest and field, as well as a few forms which live in the sea, and a limited number which fly like birds. In observing the habits of these well-developed animals you will understand how intelligence has made them the rulers of the earth.

Characteristics of mammals. Mammals are a very diverse group including about 4,000 species, although only a small number of the total species inhabit North America. They vary in size from the tiny pygmy shrew, less than two inches long, to the enormous whale, over a hundred feet in length. In their widely varied forms, mammals are found in all parts of the world except a few Pacific islands. They are, for the most part, land animals, although certain forms including the whale, sea cow, and porpoise are aquatic and others, like the bat, live in the air. While a shrew and a whale or a mouse and an elephant may seem entirely different, size alone is the main difference. All mammals are fundamentally alike in body structure and possess the following characteristics of the class *Mammalia:*

1. Young born alive; no external eggs, except in the duckbill (*Platypus*) and the spiny anteater (*Echidna*), and in most forms nourished during development from the body of the mother; hence *viviparous.*

2. Young nourished, after birth, by milk secreted from the mammary (milk) glands of the female, a characteristic for which the class is named.

3. Body more or less covered with hair.

4. Cerebrum highly developed.

5. Diaphragm (breathing muscle) present.

6. Two sets of teeth and fleshy lips.

7. High circulatory development; left aortic arch only; warm blooded.

Adaptations of mammals. Probably no other group of animals contains more differently adapted forms than the mammals. These variations in body structure account for the distribution of mammals among the various habitats. Differences in the form of the limbs, teeth, body covering, and other parts of the body account for the widely varied modes of life of the mammal. A few of the better known mammal species will illustrate the high degree of body specialization in the group.

Limb modifications. The limbs are the organs of locomotion, defense, and, in many cases, food getting. Consequently, the limbs are as specialized as are the modes of life. Most mammals have two pairs of limbs, although the sea cows and whales are exceptions to the rule in possessing only front limbs. The limbs of the whale are modified into fin-like organs for swimming. The seals and walruses, which spend much of their lives in water but emerge on land frequently, have their limbs modified into flippers. If you have seen performing seals in circuses, you have probably noticed that the seal is rather awkward on land and moves about by clumsy leaps. In the water, however, it is an exceedingly graceful swimmer. The forelimbs of bats are curiously modified into membranous wings for flying. A thin skin or membrane attaches the greatly lengthened fingers and fastens along the body to the very small hind limbs. They fly about gracefully at night and spend the day with wings folded along their sides hanging upside down by their hind limbs and grasping toes.

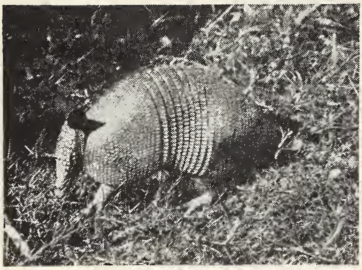
The horse, cow, buffalo (bison), and deer have limbs modified for running over hard ground. The toes serve no longer for grasping as in many other mammals, but are modified into hard hoofs. Because of this adaptation, the hoofed animals have attained a size much greater than could be supported on individual, flexible toes. Smaller animals, like the dog, fox, and wolf have separate toes suited to running on land. The cat family, including the lion and tiger, use their feet for defense and food getting as well as for climbing and running on land. The toes are strong and are provided with sharp claws used in ripping the flesh of the prey or enemy. The squirrel, raccoon, and opossum have flexible toes and claws adapted for climbing. Squirrels, especially, are masters in climbing, running freely through the branches, and leaping gracefully from tree to tree. The mole, which lives entirely underground, is quite a contrast to other mammals, both in its limb structure and in its mode of living. The front limbs are enormously developed for digging. The enormous front feet are really living shovels for gouging out the earth in burrows. As one might expect, the hind limbs are small, most of the activity of the animal occurring in the front region of its body.

Ewing Galloway, N.Y.

KANGAROO

One of the most striking adaptations of the limbs of mammals is found in the kangaroo. The hind legs are greatly enlarged for jumping, balance being maintained by the enormous tail. The front limbs are small and are used almost entirely for grasping. The greatest development of limbs for grasping is found in the monkeys, apes, and man. In these animals, the front limbs with hands and fingers are used for picking up objects. When a highly specialized brain controls the operation of these efficient organs, as in man, highly skilled activities such as playing a piano or violin or repairing a watch may be accomplished.

The teeth of mammals. Most mammals possess four kinds of teeth which vary according to the feeding habits of the individuals. They may be classified as *incisors, canines, premolars,* and *molars.* Gnawing animals, like the beaver, porcupine, and rat have greatly developed *incisor* teeth. These gnawing teeth, located in the front of the mouth, are chisel-shaped and grow rapidly. Enlarged *canine* teeth are found among the flesh-eating animals. The lion, tiger, cat, dog, and wolf use the strong, sharp canines called " fangs " for ripping flesh. *Premolars* and *molars* are large in the vegetarian mammals like the horse, cow, and deer, and serve for grinding hard plant substances.



Armadillo

Adaptations in body covering. The body covering of the mammal, likewise varies greatly in form. Hair is the most common outgrowth of the epidermis and covers such animals as the bear, muskrat, beaver, and cow. Hair serves to protect the mammal from loss of heat from within and from the cold without. The mane and tail of the horse and other animals are composed of long hairs which help to protect them against bothersome insects such as flies. Special forms of body covering are found on the porcupine and armadillo. The porcupine has long, barbed quills covering the back and bristling from the tail. Contrary to common opinion, the porcupine cannot throw its quills, but can fill its attacker with numerous quills with a quick motion of its tail. The armadillo's body is covered with protective plates or scales which form a coat of armor. When annoyed, the animal has only to roll into a ball to protect its vulnerable parts entirely.

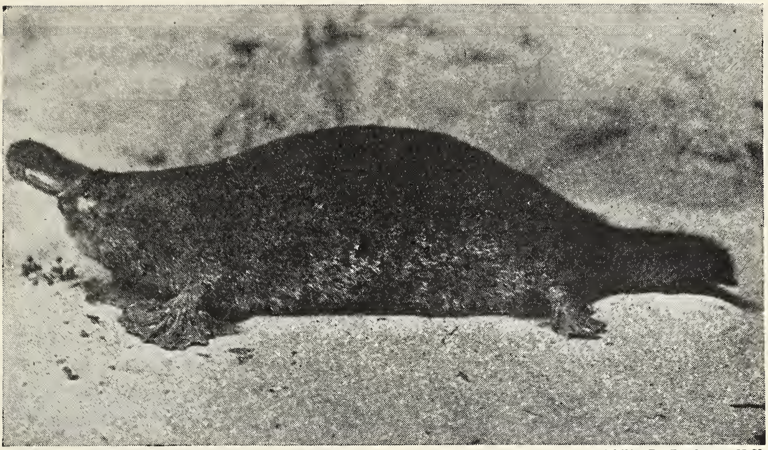
Claws, hoofs, horns, and antlers are all special outgrowths of the epidermis. Horns and antlers are especially characteristic of the males of most of the hoofed animals, although females of many species possess them too. Man has learned to respect the horns of a charging bull moose, elk, or domestic cow.

Special adaptations. In addition to adaptations of the limbs, teeth, and body covering, many mammals have other curious modifications. The flying squirrel has a fold of skin between the front and hind limbs which, while not permitting real flight, acts as a parachute for its long sailing leaps. The giraffe seems to have most of its modification in the neck, which is long enough to permit foraging among the leaves of trees. While this greatly lengthened neck is very useful in feeding, the animal must spread its front legs wide and bend awkwardly to obtain water. His famous neck has only seven *vertebrae* [*vert'ah bree*], the same number as in the neck of man.

The elephant's "trunk" is another curious adaptation for grasping. It seems to be a greatly lengthened nose with a delicate finger-like projection between the nostrils. With this wonderful organ the elephant can lift tremendous weights, defend himself against enemies, spray his back with water or dust, or pick a peanut from the hand of a child.

Perhaps the most curious adaptations of a mammal are found in the primitive duckbill. This creature is strange in that it lays eggs and nourishes its young after hatching on milk in true mammal fashion. But its curiosity does not end with reproductive habits, for it has a most peculiar horny bill like a duck, waterproof hair like a beaver, and webbed feet. We will not see this curious animal except in museums, for its home is in Australia, Tasmania, and New Guinea.

The orders of mammals. In the classification of mammals, as in the case of other animal groups, the class *Mammalia* is divided into orders. Each order is composed of animals which are similar



Philip D. Gendreau, N.Y.

DUCKBILL OR *PLATYPUS*

in body structure. Orders are, in turn, divided into families, families into genera, and genera into individual species. Complete classification of the mammals would require an entire volume. We shall consider, therefore, only the more common orders. Scientists place most of the mammals into twelve orders, of which ten are represented by a considerable number of individuals. Most of the North American mammals are included in but four of these orders, which will be the principal topics of discussion of the mammal groups to follow.

Gnawing mammals — the rodents. To the class *Rodentia* belong all of the animals which have well-developed incisor teeth for gnawing. The incisors are chisel-shaped, strong, and provided with a continuously growing root, so that they replace themselves as fast as they wear off. The front edge is harder than the rear edge and therefore they are self-sharpening, because the cutting edge is always worn thin. These tooth adaptations, together with powerful jaws, fit the rodents for their well-known occupation of gnawing their way through life.

The rodents of North America are numerous and include examples of great economic value because of their fur. Many are harmful because of their destructive gnawing habits and the damage they do to gardens and stored food.

The rabbit, ranging over most of the United States, is perhaps the most abundant form. The eastern cottontail inhabits the open fields of the eastern and middle western states. These animals frequently invade gardens and do great harm. Their principal value is to the sportsman who hunts them largely for food. The fur is soft and of little value when compared with the domestic varieties widely raised for both food and fur. In the Western states, the cottontail is replaced by its long-legged cousin, the jack rabbit. These high jumping, long-eared individuals cause great damage to alfalfa fields and frequently must be rounded up in great drives. The most common rabbit of the North is the snowshoe rabbit, so called

Philip D. Gendreau, N.Y.

Chipmunk

because of its enormous feet. Though a little awkward through the summer, the snowshoe rabbit runs with ease across the deep drifts of snow.

The squirrels are limited to forest regions since they spend most of their lives in trees. They are very skilled climbers, being able to circle the trunk of a tree with ease or run along the slender branches, leaping from tree to tree, much to the disgust of the squirrel hunter. The most common squirrels are the red squirrel, fox squirrel, and gray squirrel. The latter species is especially prized for its beautiful gray fur which is the envy of many women. Fox squirrels are beautiful creatures with long, bushy tails. The rusty brown color of the fox squirrel is responsible for its name. They become very tame and frequently find city parks as ideal abodes as native forests. The little red squirrel is the noisiest and most mischievous of its group. Among its bad habits is the stealing of eggs from the nests of birds. Aside from fur and flesh value, squirrels do much good in planting trees by burying nuts for future use and then forgetting them.

Closely related to the squirrels are the chipmunks and gophers. They are often called ground squirrels because of their habits of living in holes in the ground or running swiftly along the forest floor. The chipmunks delight in the safety of a brush pile or a hollow stump, where they may stare curiously at an intruder while sitting upright in squirrel-like manner and then disappear from sight with one short leap.

The beaver is one of the most important of the rodents and was responsible for the opening of the Northwest Territory. Early in the history of America trappers explored the forests of the Northwest in search of this highly prized fur. These large rodents, reaching a weight of fifty pounds, are famous for the dams they construct. They arrange small trees and sticks across streams according to the best principles of engineering and cement them firmly with mud. By damming streams, they form lakes which serve as swimming pools and as protection for their homes or lodges which resemble brush piles in the water. The food of the beaver consists of bark, especially of the birch, aspen, cottonwood and willow. They do not use their broad, flat tails as trowels in constructing dams, but, rather, as powerful organs of swimming. The frontispiece of this book shows a beaver gnawing a birch tree.

Other North American rodents include the muskrat, prairie dog, woodchuck or ground hog, and the various species of mice and rats. Muskrats are aquatic mammals, famous for their fur. The prairie dogs are common inhabitants of the western plains, where they live in large colonies. The prairie dog sitting upright near the entrance of its hole is a familiar sight to the inhabitants of this region. The woodchuck or ground hog is somewhat similar to the prairie dog, but much less sociable by nature. It is probably the sleepiest of all animals, entering its burrow about October 1 and remaining until about

Ewing Galloway, N.Y.

PRAIRIE DOG

April 1. It is fast asleep on February 2, and does not come forth to investigate the weather even on this special day named in its honor, as superstition and legend indicate.

Flesh-eating mammals — the Carnivora. The flesh-eating mammals include many widely varied forms which are similar only in their feeding habits. They include two main divisions: the aquatic forms, which include the seal, sea lion, and walrus, and the terrestrial or land forms, which are by far the most numerous.

The limbs of aquatic mammals are short and modified into flippers for swimming. The Alaska fur seals inhabit the icy waters of the Bering Sea. During the spring, they migrate from their homes in the Bering Sea, across more than two thousand miles of the cold north Pacific, to the Pribilof Islands beyond the Aleutians. There, half hidden by the fogs of the north Pacific, they breed and bear their young. Many are the battles between male seals for supremacy among a herd of females which may number nearly one hundred. At one time these animals, prized for their soft, brown fur, were nearly destroyed in their breeding grounds by seal hunters. Now, however, seal hunting is governed by rigid federal laws.

The California sea lion lives along the Pacific coast of North America. These animals lack the fur value of the Alaska seal, but are used by the natives of the North for food, blubber, and hides. The walrus is the monarch of the far north. It is a large, rather stupid, seal-like animal which may be approached and killed easily. It reaches a length of about ten feet and a weight of more than a ton. The upper canine teeth form large tusks which are used in probing in mud for food. During feeding, the mud is separated from the clams they dig up by a row of bristles around the mouth.

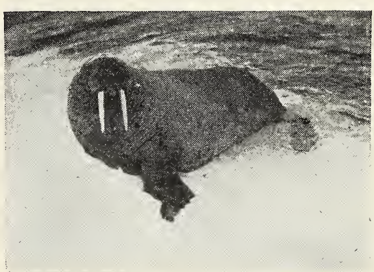
The land-dwelling Carnivora are divided into three classes according to the manner of walking:

1. Flat on the foot (bear and raccoon)

2. On the toes only (dog, wolf, fox, hyena, cat, tiger, lion)

3. Partly on the toes (marten, mink, weasel, otter, sable, skunk)

These Carnivora are highly specialized in structure for the pursuit of prey.



Philip D. Gendreau, N.Y.

WALRUS

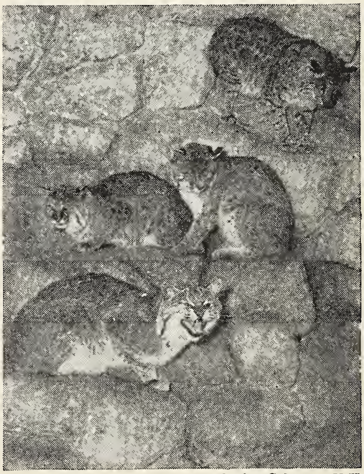
Globe Photos, Inc.

Black Bear

They live largely upon the hoofed animals, whose adaptations have been along the line of keen senses and swiftness to escape this very danger. The Carnivora have large, interlocking canine teeth, shear-cutting molars, very strong jaws, and enormous muscles attached to ridges on the skull. The skeleton is light and slender and the feet are usually provided with claws. These claws, in the cat family, can be withdrawn into sheaths, thus permitting noiseless approach. The claws of the dog family cannot be withdrawn, but serve to grip the ground firmly when they are running down their prey. The keenness of sight and smell of the Carnivora is especially adapted to their manner of life. Except for the dog and cat, none of the Carnivora is domesticated, and few of them are used for food. Their chief economic value is their fur.

The flat-footed Carnivora are represented in North America by both the bear and the raccoon. The black bear inhabits the northern and western states and at one time lived in much of eastern North America. These bears are not dangerous except when with young and, in many regions, may be seen perched high in trees. The grizzly bear lives in the Northwest and is especially abundant in the Yellowstone Park region. The grizzly is much larger than the black bear and much more dangerous in the wilds of the Rockies. The largest North American bears are the Alaskan brown bears. The polar bear is the most aquatic of the bears and inhabits the cold waters of the Arctic region. Few ever see the polar bear in its native haunts, although it is always a favorite subject in the zoological gardens.

The raccoon is widely distributed over North America especially near ponds and streams where they do their fishing. They feed on fish and clams, but often seize birds, mice, insects, and reptiles on land. The raccoon is an interesting animal to watch, and if captured young will



Ewing Galloway, N.Y.

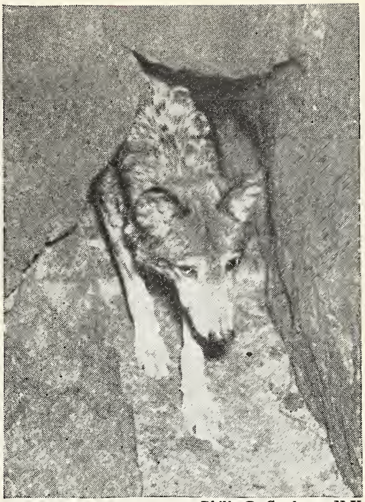
Bobcats in the Nashville, Tenn., Zoo

make a nice pet. They are widely sought by the hunter and the trapper for their fur value.

The dog and cat families are not as well represented in America as in other lands. Native cats include the mountain lion or puma and the bay lynx or bobcat and its larger cousin the Canada lynx. The mountain lion at one time inhabited much of North America, but has been driven to the remote regions of the Southwest. This puma or panther, as it is often called, is not as dangerous as supposed, and often seems to seek the friendship of man. Their chief danger is in the destruction of livestock. Both the bay lynx or bobcat and the Canada lynx are inhabitants of remote forests and are seldom seen by man.

The dog family is represented by the wolf, coyote, and fox. The gray wolf or timber wolf was once abundant on the western plains but with the advance of civilization has been forced to retreat into the northern forest regions. The coyote or prairie wolf has been much more successful in evading man than his larger cousin. Coyotes are still abundant on the western plains and do so much damage to stock that bounties are paid for their destruction. The red fox ranges over much of the United States, where it lives in dens in banks, and in hollow logs. It is very sly in its habits and an exceedingly fast runner for short distances. Color phases of the red fox include the black fox, cross fox, and silver fox, so highly esteemed for its fur value. The gray fox resembles the red fox but inhabits the warmer regions of the southern states.

The order Carnivora includes many smaller members, many with great fur value. The weasel and its winter color phase of the north, the ermine, cause extensive damage to poultry and small



Philip D. Gendreau, N.Y.

Timber Wolf Emerging from Den

animals with their bloodsucking habits. The skunk, badger, and otter are among the other smaller Carnivora with definite fur value.

Hoofed mammals — the Ungulates. The order *Ungulata,* usually called *Ungulates,* includes some of our most common domestic animals, such as the horse, pig, cow, sheep, and goat. Among its wild members are the deer, elk, moose, antelope, rhinoceros, hippopotamus, giraffe, camel, and zebra, most commonly seen in circuses and zoological gardens. All of these animals live on vegetable foods and have molars fitted for grinding. Most of them have a sidewise jaw motion which aids in this process. Their feet are encased in hoofs, and the limbs are never used for *prehension* (grasping), being adapted for swift locomotion.

The Ungulates are divided into two groups: *odd toed,* in which the weight is borne on one toe, though others may be present, and *even toed,* in which the

Philip D. Gendreau, N.Y.

American Bison or Buffalo

third and fourth toes bear the weight though two others are usually present. To the odd-toed Ungulates belong the horse and the rhinoceros, while the cow, pig, and sheep are examples of the even-toed forms. The even-toed Ungulates are further divided into two groups:

1. The non-ruminants (pig and hippopotamus)

2. The ruminants (cow, sheep, deer, etc.)

The *ruminants* [*room′in ants*] are so called from their habit of chewing their "cud." A cow, for example, first compresses its food into a ball, then swallows it into the first of the divisions of its four-chambered stomach where it is stored. Later it is forced back into the mouth, chewed thoroughly, and swallowed again but into another stomach, where the processes of digestion are continued. The advantage of this peculiar arrangement is that much food can be eaten hastily and stored. Then it is chewed later. For an animal which feeds in flocks or herds on bulky vegetable food this is of great importance, since it can crop its food in haste and chew at leisure.

The Ungulates are widely used for food and include most of our domestic animals. Wild Ungulates inhabit many regions of our land, although their numbers have been reduced by the changes brought about by civilization.

Bison herds, totaling several million members once roamed our western plains and, at one time, ranged as far east as New York state. They are now reduced to a few small herds, closely supervised in our western states. The deer family is still well represented in the white-tailed deer, the mule deer, the elk, the moose, and the caribou or reindeer. Prong-horned antelope still range the western plains, although their numbers are, likewise, much reduced. In the rocky summits of the western mountains, the mountain goat, really not a goat but an antelope, and the big horn sheep still hold forth, more secure in their environment than their cousins of the plains.

Erect mammals — the Primates. This order is rather strange in its distribution. None of its wild forms exist in the United States, although its highest type — man — is represented more than 120 million strong. While man is classed bi-

Philip D. Gendreau, N.Y.

Big-Horn Ram

A Young Gorilla

ologically as a *Primate,* he has the distinction of being placed in a family by himself, *Hominidae* [*home in′ id ee*], which sets him apart from the apes and monkeys. He belongs to the genus *Homo;* the species *sapiens.* His correct biological name is *Homo sapiens.*

The structural adaptations of the Primates do not compare with the other mammals, but superior brain development places them at the top of the entire animal kingdom. Primates have well-developed arms and hands with fingers for grasping. They walk erect or nearly so, and have fleshy lips. Most of the Primates live in South America, Africa, or Asia. Though probably more capable than any other mammal in adapting themselves to environment, all but man have remained in the warm regions of the earth.

The Primates of the world may be classified principally as follows:

1. The gorilla, the largest of the apes, inhabits Africa. It is erect, and is one of the most powerful of animals.

2. The chimpanzee is also found in Africa. It is much smaller than the gorilla and when trained reveals much intelligence.

3. The orangutan is a native of the East Indies. It is a droll animal with reddish hair.

4. The gibbon is a long-armed type found in Asia. The gibbon and the three preceding Primates are called anthropoid apes. They are not monkeys, though so called by many. Unlike the monkeys, they are erect and tailless.

5. The Old World monkeys and baboons of Asia and Africa have narrow noses and non-prehensile tails.

6. The New World monkey of South America has a wide, flat nose and prehensile tail.

7. The marmoset, found in Mexico and Brazil, and the lemur of Madagascar are small forms, quite different from both apes and monkeys.

Observing mammals. Mammals are much more difficult to observe in nature than most other forms because they have sufficient intelligence to avoid man. Frequently the observer must resort to tracking animals in order to get a look at them. The woodsman is well familiar with the tracks of the mammals of his region. In the snow, the task of tracking a mammal is much simplified.

Wild mammals are much more abundant than most people realize. The skilled observer can usually find many species in the woods and fields even near large cities. Did you know, for example, that in the edges of the country woods and even in fields in the city there is a country cousin of the common mouse with white feet, and big, inquisitive ears? Three more common rodents are rabbits and woodchucks of the field and muskrats of the ponds. Many of these wild animals are nocturnal and, hence, are seldom seen by one who hikes exclusively by day. In some areas of the country, wild Ungulates, especially deer, may be seen on hikes through the woods. Frequently, however, the nearest one comes to seeing a deer is its footprints in the path.

Among the Carnivora are many forms which are common enough but are seen only by a patient watcher. Mink scurry along the shore where the raccoon is washing its supper before eating it. Back in the woods the weasel is starting out on his nightly quest for blood. Though small, he is the killer of the woods. Foxes leave their dens to search for food, and on the western plains coyotes howl. Deep in the woods a bear settles down to sleep while the wildcat continues to stalk its prey. Bats of different kinds zigzag after evening insects, and opossums move through the trees. Moles burrow on and on.

All of these activities may be completely unknown except to the woodsman and the biologists. As you develop skill in observation, you may be able to enjoy watching the interesting activities of the mammals about you.

Summary

The mammals constitute the most highly developed group of vertebrate animals. The class Mammalia is composed of numerous smaller groups called orders, of which ten are most important.

Most common mammals are included in four orders, the rodents, the Carnivora or flesh eaters, the hoofed mammals, and the Primates, which include man.

Mammals are characteristic in bearing their young alive, nourishing them on milk produced by the mammary glands, in having a hairy body covering, highly developed cerebrum, diaphragm, two sets of teeth and fleshy lips, and high circulatory development. The orders of mammals are distinguished on the basis of numerous structural adaptations.

Mammals are extremely important to man and are his closest companions. Many forms are used for food, while others supply valuable furs for industry. Certain kinds, especially in the order Carnivora, do extensive damage to other animals which they kill for food.

Using Your Knowledge

1. What principal characteristic of the mammals has enabled them to gain superiority over other forms of life?

2. Name five structural characteristics which distinguish mammals from other animals.

3. Give an example of a mammal with limbs developed for each of the following

types of activity: swimming; running over hard ground; climbing, defense and food getting; flying; grasping objects.

4. In what principal respect are the duck-bill and spiny anteater distinct from all other mammals?

5. Name an order of mammals in which each of the following kinds of teeth are especially well developed: incisors; canines; molars.

6. Give examples of mammals which have body coverings other than the customary hair.

7. Account for the fact that the Carnivora are frequently dangerous and difficult to domesticate.

8. How are the characteristics of the feet of land-dwelling Carnivora used as a basis for dividing them into three groups?

9. Rodents, as a group, cause considerable harm. Name one way in which they are very valuable economically.

10. Name several regions of the earth where Primates other than man live as native species.

Expressing Your Knowledge

mammal	premolar	Ungulate
viviparous	molar	Carnivora
diaphragm	gnawing	Primate
flipper	foraging	tusk
incisor	prehension	ruminant
canine	rodent	non-ruminant

Applying Your Knowledge

1. Classify into their respective orders the animals usually found in the menagerie tent of a circus.

2. Make a list of the native North American Ungulates.

3. Prepare a report on the native rodents of your area, and include the habitat and economic importance of each.

4. Visit your zoological garden, if you have one in your vicinity, and prepare a list of the orders and species of animals included in the collection.

5. Enumerate the characteristics of your own body which place you into the class Mammalia.

Increasing Your Knowledge of This Unit

Allen, Arthur A. *The Book of Bird Life.* D. Van Nostrand Co., New York. 1930

Anthony, Harold E. *Field Book of North American Mammals.* G. P. Putnam's Sons, New York. 1928

Blanchan, Neltje. Birds. (The Nature Library) Doubleday Doran and Co., New York. 1926

Boardman, E. T. *Guide to Higher Aquarium Animals:* Cranbook Institute of Science, Bloomfield Hills, Michigan. 1944

Colbert, Edwin H. *The Dinosaur Book.* (Man and Nature Publications Handbook # 14) The American Museum of Natural History, New York. 1945

Curran, C. H. and Kaufield, Carl. *Snakes and Their Ways.* Harper and Brothers, Publishers, New York. 1937

Ditmars, Raymond L. *Snakes of the World.* The Macmillan Co., New York. 1931

Ditmars, Raymond L. *Reptiles of North America.* Doubleday Doran and Co., New York. 1936

Ditmars, Raymond L. *Reptiles of the World.* Revised Imperial Edition. The Macmillan Co., New York. 1937

Hegner, Robert. *Parade of the Animal Kingdom.* The Macmillan Co., New York. 1940

Hornaday, William T. *American Natural History*. 16th Ed. Revised. Charles Scribner's Sons, New York. 1935

Innes, William T. *Exotic Aquarium Fishes*. 3rd Edition. Innes Publishing Co., Philadelphia. 1938.

La Monte, Francesca. *North American Game Fishes*. Doubleday Doran and Co., New York. 1945

Moore, C. B. *The Book of Wild Pets*. G. P. Putnam's Sons, New York. 1937

Morris, Percy A. *They Hop and Crawl*. Jaques Cattell Press, Lancaster, Penn. 1945

Nelson, E. W. *Wild Animals of North America*. The National Geographic Society, Washington, D. C. 1930

Pearson, Gilbert, editor. *Birds of America*. Garden City Publishing Co., Garden City, New York. 1936

Peterson, Roger Tory. *Field Guide to the Eastern Birds*. Houghton, Mifflin Co., Boston. 1939

Peterson, Roger Tory. *Field Guide to the Western Birds*. Houghton, Mifflin Co., Boston. 1939

Pope, Clifford H. *Snakes Alive and How They Live*. Viking Press, New York. 1937

Pope, Clifford H. *Turtles of the United States and Canada*. Alfred A. Knopf, New York. 1939

Reed, Maxwell and Bronson, Wilfrid S. *The Sea for Sam*. Harcourt, Brace and Co., New York. 1935

Roberts, Thomas Sadler. *Bird Portraits in Color*. University of Minnesota Press, Minneapolis. 1934

Schmidt, Karl P. and Davis, D. Dwight. *Fieldbook of Snakes of the United States and Canada*. G. P. Putnam's Sons, New York. 1946

Shurtlef, Bertrand. *AWOL, K-9 Commando*. The Bobbs-Merrill Co., Indianapolis. 1944

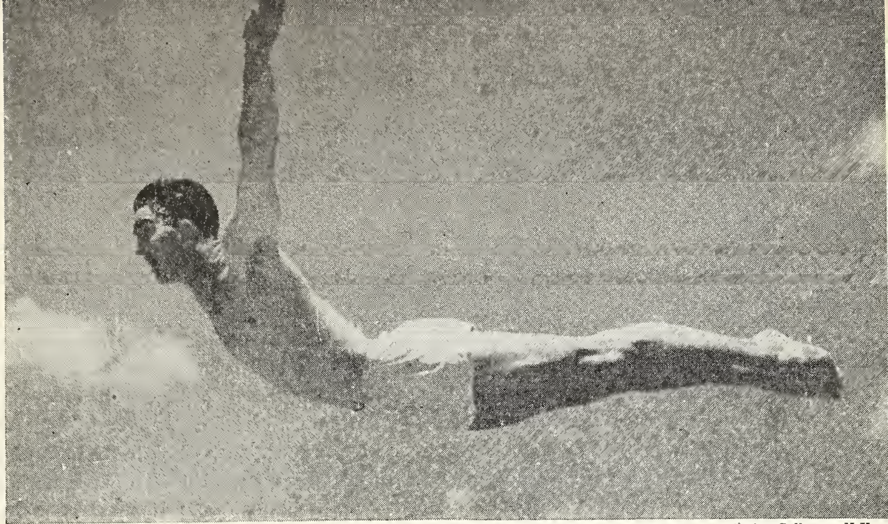
Smith, Hobart M. *Handbook of Lizards*. Comstock Publishing Co., Ithaca, New York. 1946

Weed, Clarence M. and Dearborn, Ned. *Birds in Their Relation to Man*. 3rd Edition Revised. J. B. Lippincott Co., Philadelphia. 1924

Williamson, Thames. *Opening Davey Jones's Locker*. Houghton, Mifflin Co., Boston. 1930

Wright, Anna Allen. *Handbook of Frogs and Toads*. Comstock Publishing Co., Ithaca, New York. 1933

Wood, L. N. *Raymond L. Ditmars*. Julian Messner, Inc., New York. 1944



Ewing Galloway, N.Y.

Unit 8 ---

How Biology Applies to Ourselves

Good health is the most priceless possession of man. No aspect of biology is more important than a knowledge of the human body. We can be familiar with the structure of plants and animals, but this information will not help us as biologists unless we also understand the way in which our own body functions, and know of what parts it is composed.

In order to maintain good health, we must know something about the framework of the body, the various systems comprising it, the way the various organs are related and how they co-operate, and the way in which food is used and waste products are given off.

Not only must we know something about the structure and function of our body, but we must also realize the importance of an adequate diet. We must be familiar with the different kinds of foods and what each contributes to good health.

Chapter 38

The General Structure of the Human Body

Primitive man knew nothing about his body. He lived where the food supply was abundant and, when that was exhausted, he moved elsewhere. When disease struck, or when an organ was incapacitated he succumbed to it, because he did not know how his body was organized or what to do when something went wrong.

Because man has a highly developed brain, he is more advanced than any other living organism. Even primitive man was more highly developed than any animal. But he had no biological knowledge, and so was totally unable to help himself in the event of disaster.

Today, modern science in all its branches has made it possible for us to keep our bodies healthy. The science of *anatomy* has given us the complex knowledge necessary to study the various parts of the human body.

This chapter will tell you something about these various parts, and will show you how cells, tissues, and organs are combined into a unified organism, more wonderful and more complex than that of any other form of living thing.

Man, the most complex form of life. Man belongs to the genus *Homo,* which includes both modern man (*Homo sapiens*) and some of his more primitive ancestors.

His highly developed brain is the one outstanding feature which makes man more complex than any other animal. The human brain is larger in proportion to body size than the brain of any other mammal, and is much more highly specialized. This brain has enabled man to form habits easier, to think out problems and to reach a satisfactory solution of them, to acquire skills by constant practice, and to achieve a much higher type of living than is achieved by animals.

Man and the vertebrates. Man is not structurally adapted, as are many vertebrate animals, for skill in climbing, running, flight, swimming, and strength. In fact, there is nothing that man can do, unaided by his intelligence, which many animals cannot do much better; but with his intelligence to direct him, there is no animal that can compete with him. Man has learned the use of tools, devised a spoken and written language, found a means of controlling fire, and developed mental faculties and social habits that place him in a position far above any of the animals.

Structurally, man resembles the higher apes. Almost every detail of their anatomy is similar — skeleton, muscles, teeth, position of eyes, structure of the hand, and even motions and facial expressions. There are, however, certain structural differences, such as the more erect position of man, his shorter arms, larger and better balanced skull, higher forehead, smaller canine teeth, and inability to use the big toe like a thumb for grasping.

These differences are utterly overshadowed by the one great difference, the human brain. The brain of all the

Ewing Galloway, N.Y.

NEANDERTHAL MAN. This prehistoric, primitive race differed widely from any modern human type of man.

Primates is large, but man's is about twice as large and heavy as the gorilla's, which most nearly approaches it in character.

It is worth while to note the factors that have contributed to man's development. The erect position freed the forelimbs from use in locomotion and permitted the development of the most wonderful organ of *prehension* in the world, the hand, which is man's one point of high structural adaptation.

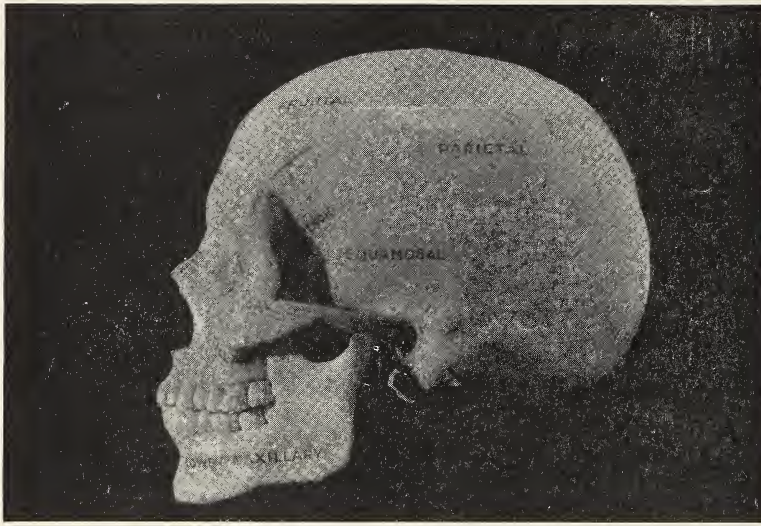
It is difficult to say whether the brain taught the hand, or the hand helped to develop the brain, but it is certain that these three factors — erect position, the hand, and the brain — have been essential in man's development.

As a consequence of his erect posture, man's hands are left free to grasp things. However, nature does not give something for nothing, and man has to pay for his upright position by certain disadvantages. In the first place, since only one pair of limbs is used in locomotion, he must balance upon two feet instead of four, and he has the center of weight high above the point of support. This necessitates the long and difficult process of "learning to walk" which other animals do not experience.

Placing the weight vertically on the hips instead of at right angles to them renders man more liable to hip, spinal, and foot diseases and deformities. The internal organs rest one upon another in a vertical pile instead of lying side by side, producing a tendency to pressure or displacement. When sick or tired, we instinctively lie down to relieve this strain.

The arteries of the human armpit, neck, and groin are now exposed toward the front, whereas in quadrupeds they face downward and are protected. In man, the trachea and appendix open upward, instead of forward, giving opportunity for the entrance of irritating substances. But all these difficulties are more than repaid by the advantage of the human hand, and the mental and social development which it has made possible.

It rests with the intelligence of man to overcome the natural difficulties of his structure by especial attention to correct



Skull of Modern Man. Note the large brain capacity, the high-brow type of forehead, the small jaw, the presence of a chin, and the delicate teeth.

posture, position of spinal column, and, occasionally, support for the arches of the feet. The strain on the internal organs can be met by proper exercise and breathing and by training the abdominal muscles to support their extra burden. All this is but a small price to pay for the human hand and brain.

Primitive man and his development. Primitive man apparently had a much smaller brain capacity than his modern descendants, a lower, sloping forehead, bony ridges over the eyes, heavy jaws, and a receding chin. Still he was obviously human and intellectually far superior to the other Primates.

His earliest home must have been in relatively warm climates where nature provided food and shelter. His food was fruit and nuts, and such animals as he could capture and eat without cooking. This restricted his flesh foods mainly to clams and oysters, to which the enormous shell deposits in many places in central Europe still bear testimony. But man soon devised weapons — clubs and spears, perhaps — and later bows and arrows. Then he became a wandering hunter having no fixed home and changing his abode whenever game became scarce in any one locality. At some unknown time man began to utilize fire as an ally, first discovered through results of lightning or burning lava from volcanoes.

With a widespread scarcity of game came the necessity of taming and raising food animals. Thus we have the herdsman wandering with his flocks from place to place, as pasturage and food were exhausted. Domestication of animals probably began with taming the wolf to aid him in the hunt, but the real progress was made when tame cattle, sheep, and goats partly took the place of wilder game.

A wonderful advance was made when man hit upon the idea of cultivating

SKULL OF PREHISTORIC PEKING MAN. Note the small brain capacity, the low-brow type of forehead, the large jaw, the absence of a chin, and the large, strong teeth.

food plants for his flocks and himself. This permitted a fixed habitation, and for the first time a real " home life " had a chance to develop, with all that it meant in comfort and social progress. Doubtless the house was but a cave or tree shelter, but when man settled to remain in one place, to cultivate and gather his simple crops, community life and society had their earliest beginnings.

Modern man. Modern man does not seem to have a body which is much, if any, improved over that of prehistoric man, except perhaps in the case of specialized athletes. Mentally, however, through being born in the progressive world of today, each new generation gets a better start than its ancestors. Instead of feeling superior on this account, it would seem wiser to appreciate the fact that our world of today, with all its scientific achievements, has been made possible only through the countless trials and experiments of millions of brave souls who have preceded us.

Modern civilization has completely changed the mode of living. We would not relish going back to the life of the cave dweller, yet we pay a penalty for our safer and easier methods of living. Primitive man, if he survived at all, was necessarily hardy, living out-of-doors, eating hard foods, having a sturdy and little-protected body, and literally " earning his bread by the sweat of his brow." Now we have so learned to control our environment that we live quiet, safe, indoor lives, protect our tender bodies with houses and clothes, and provide ourselves with soft and delicately cooked foods. On the other hand, we have developed our brain and nervous system so that it takes over the work previously done by muscle and brawn. Hence we are overworking our latest acquisition, our highly developed nervous system, at the expense of the rest of our bodies.

Is it any wonder then that we now have fat and flabby muscles, weak lungs, delicate skin, and degenerate teeth, combined with overworked nerves? If we are to develop to its highest efficiency the wonderful mind which has been given to us, we have to make special efforts to keep our bodies strong, even though physical strength is no longer the one essential in the struggle for existence.

Importance of knowledge of the body. If we have an automobile, we learn how it works, and how to care for it so that it will run well and last long. We select the gasoline and oil with care and employ a skilled mechanic to make repairs.

If we take such care of a car which can be replaced for a comparatively small sum, how much more ought we to learn to care for our bodies, on which our health and comfort depend and which cannot be replaced at any price.

Yet it is a fact that we treat our own organism as we would not think of treating our car. We overstrain its parts, we give it improper food, we deny it sufficient rest, and seldom have it overhauled by an expert. Even when we are sick, we are likely to resort to amateur treatment, instead of getting competent medical advice. Our bodies are marvelously constructed, yet a perfectly sound, healthy body is a rare possession.

Before we can intelligently care for our bodies, we must know how they work (function), and before the functioning of our bodies can be understood, some knowledge of body structure is essential.

The cellular structure of the human body. The body of man, like that of any other organism, is composed of cells. The cells which compose our bodies are essentially like those of any other organism. Each consists of an outer membrane, a mass of cytoplasm, and a nucleus. Like the cells of all other organisms, each human cell functions as a tiny unit, carrying on all of the processes of life. But while our cells are similar to those of other organisms, taken together, they compose a unit of life far surpassing all other living things.

The biologist cannot account for the marvelous abilities of man in terms of cells alone. Indeed, such phenomena of human life as intelligence, memory, and emotion lie beyond biological explanation. To some extent, however, the marvelous development of the human body is evident in the high degree of specialization of human cells, especially of the nervous system.

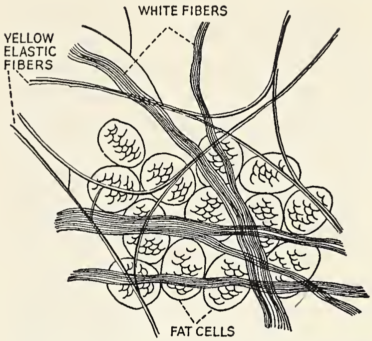
Cells which shift entirely for themselves never pass the protozoan stage in development. As animals become more complex, and, therefore, more efficient, their cells become more and more specialized. They become " experts " in performing one kind of activity for the organism as a whole. In becoming specialized, however, they become more dependent upon other cells for their existence. In the study of man we find this condition carried to an extreme. Nearly all of the millions of cells of our total make-up are highly specialized. They live in an extremely complicated society of interdependence. They express life in its highest form.

The study of the human body is a study of specialized cells. It is, also, a study of great numbers of similar *cells* functioning together to constitute a *tissue*. Various kinds of tissues are grouped into larger units called *organs*. The organs are, in turn, grouped into *systems*. Each system is specialized to perform certain processes with the highest degree of efficiency. The systems taken together constitute the *organism*. Thus, the study of the human body concerns the form and structure and the function of all of these units of organization.

Tissues of the human body. All of the cells which compose the human body may be grouped into nine principal kinds of tissues. These nine tissues may be classified into four distinct groups as follows:

1. Connective tissues
   (a) Bone
   (b) Cartilage
   (c) White fibrous tissue
   (d) Yellow elastic tissue
   (e) Adipose tissue (fat)
   (f) Liquid tissue (blood)
2. Muscular tissues
3. Nerve tissues
4. Epithelial tissues

The *connective tissues* are of numerous types and are widely distributed through the body organs. *Bone* is a peculiar tissue which forms deposits of mineral salts in its intercellular spaces, thus forming a framework for the body. *Cartilage* is commonly called *gristle* and serves, together with bone, as a supporting tissue. Various kinds of cartilage form a soft coating over the ends of the bones, compose part of the chest framework, and compose such strong but flexible body parts as the external ears, voice box, and *trachea* [*tray′ kee ah*] or windpipe. *White fibrous tissue* is a strong, pliable substance composed of white fibers arranged in bundles. Among the examples of white fibrous tissues in the body are the ligaments which hold the bones together, tendons which fasten muscles to bones, sheets which bind the muscle fibers together, and membranes which cover the heart, kidneys, and other organs. *Yellow elastic tissues* are composed of numerous yellowish fibers



Connective Tissue in the Human Body

which give it a tough yet pliable texture similar to rubber. They form the walls of blood vessels, especially arteries, the air passages within the lungs, and the discs between the vertebrae of the spine. *Adipose tissue*, commonly called fat, is composed of cells which become filled with stored food. Adipose tissues are found in various regions of the body, especially in layers beneath the skin, around the heart, kidneys, and other organs, and in the marrow of bones. The *liquid tissues* include blood and tissue fluid or lymph. These tissues are a peculiar combination of a liquid and living cells; they include the familiar blood corpuscles.

Muscular tissues produce movement in the body. Some are attached to bones and accomplish movement of the arms, legs, trunk, and neck. Other types of muscles form the heart, the diaphragm, the walls of the stomach and intestines, and the walls of arteries. The *nerve tissues* are perhaps the most amazing of all of the tissues because their activities are so little understood. They compose the numerous nerves of the body, the spinal cord and the various regions of the brain. The nerve tissues control the other tissues of the body and, because of their extremely high specialization, account for much of the superiority of man. The *epithelial* [*epi thee'lee al*] *tissues* compose the coverings of various parts of the body. *Skin* is the most familiar form. In addition, epithelial tissues include the *mucous membranes* which line the mouth, digestive system, respiratory system, and other body openings. Certain epithelial cells secrete mucus [*mew'kus*] which serves to lubricate membranes, while others secrete various digestive fluids and enzymes. Other epithelial tissues are called *serous membranes*. These membranes line all of the blood vessels, line the body cavities, and cover the internal organs. They serve to protect the organs and to prevent friction or pain during their movement.

The organization of tissues into organs. Several or many different kinds of tissues may be grouped together to perform some particular function. Such organized units are termed *organs*. Familiar examples of organs in the human body include the arms, legs, ears, eyes, heart, liver, and lungs. Each of these organs is specialized to perform a special function or a group of related functions involving several different tissues. The arms, for example, are composed of epithelial tissue, bone tissue, cartilage, muscle tissue, blood tissue, nerve tissue, and other tissues. All of these function together to perform such acts as grasping, writing, sewing, or playing a violin.

The human body contains many other equally marvelous organs. The eyes transmit impulses to the brain, resulting in the phenomenon of sight. The ears, likewise, are specialized for sensitivity, but are sensitive to sound waves. All of these organs depend upon the pumping action of the heart, the exchange of gases in the lungs, the digestion of food in the stomach and intestine — in fact, the activities of all other organs.

The systems of the human body. The functions of the complex organisms become too complicated for even a specialized organ to maintain. Several organs become involved in the same process. Thus, we find organs grouped together into functioning units called *systems*. Nine such systems compose the human body. Each of these systems becomes a specialized study in itself. You will learn about each one in the chapters which follow. For the present, we shall merely list the nine systems and state the general function of each in the organization of the human body.

The *skeletal system* serves as the body framework, giving the body a definite shape, and as a protection for the other organs. It includes all of the bones of the body. The *muscular system* includes the various kinds of muscles, all of which serve for movement of one kind or another. The *circulatory system* includes the heart, arteries, veins, and capillaries. It serves as the transportation system of the body, carrying food and oxygen and various secretions to the tissues and returning waste products to the places of elimination.

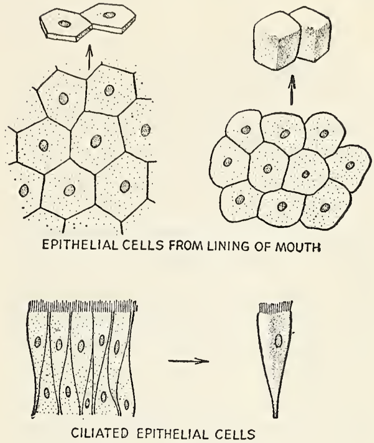
The *respiratory system* includes the lungs and *trachea* or windpipe, and certain tissues of the nose and throat. By providing for the entrance of oxygen into the body and release of carbon dioxide from the body, it performs the function which we call breathing. All cells of the body are completely dependent upon the breathing activity of these special organs for their individual respiration. The *digestive system* includes the stomach, intestines, and other organs such as the liver and gall bladder and the pancreas. Its duty is the digestion of food materials and the delivery of digested food through the intestine walls to the blood through the process of absorption. The life of all of the cells in the body depends constantly upon this system for the nourishment which they cannot otherwise obtain.

The *excretory system*, including the kidneys, and certain regions of the skin and digestive system, serves to eliminate waste materials from the body. These waste products include substances which cannot be digested as well as materials from cell activity. If allowed to accumulate, these waste substances soon poison the entire body.

The *endocrine* [*end' o krine*] *system* includes several glands which pour secretions into the blood stream. These secretions affect the activity of other organs. They are called *ductless* because they have no openings or ducts to carry their secretions to other organs as in the case of the digestive glands. Among the more familiar glands of the endocrine system are the *thyroid, adrenal* [*ad ree' nal*], and *pituitary* [*pit tu' it ary*] glands. The ductless glands are closely associated with the *nervous system,* which regulates the activity of the entire body. The nervous system ties all other systems together into a single functioning unit or organism. Its marvelous activities are accomplished by means of the brain as the center, the spinal cord as the main trunk, and the nerves, leading to and from all parts of the body. The *reproductive system* includes the organs of reproduction.

The body regions. All the systems united comprise the body as a whole. Their arrangement is such that they operate in harmony with each other.

The general form of the human body is similar to the other vertebrate animals. It includes the head, neck, trunk, and limbs in the form of arms and legs. The head includes the *cranial* [*krane' ee al*] *cavity*, formed by the bones of the skull.



Epithelial Cells

Within this protective layer, the brain lies safely encased. The head includes, also, the sense organs which are located close to the brain, to which they transmit impulses.

The *thoracic* [*thor ass' ick*] *cavity* is formed by the ribs, breastbone, and spine. It includes the lungs, trachea, heart, gullet, and other organs. A muscular partition, the *diaphragm* [*di' ah fram*], separates the thoracic cavity from the *abdominal cavity* which is included in the lower part of the trunk. Within the abdominal cavity are the stomach, liver, pancreas [*pan' kree as*], intestines, spleen, kidneys, and, in the case of the female, the ovaries. While the abdominal organs lack the bony protection of the cranial and thoracic cavities, they are protected by the spine along the back and by layers of skin and muscle on the front.

In your study of human systems, you will discover that the human body is essentially like all other vertebrates. It varies slightly from that of other animal bodies, but is an ideal climax for the study of the structure and activities of animal life.

Summary

The high development of the human nervous system has elevated man to a position of supremacy in the world of living things. His highly efficient brain has given him powers and abilities enjoyed by no other animal. Even primitive man had many advantages over his animal comrades. While he probably knew little more about his own body than they did, he was able to outwit his enemies and make better use of his surroundings.

Science has enabled modern man to understand his body and the manner in which it functions. Thus, modern man is able to make better use of his biological inheritance than was made by his primitive ancestors. In spite of knowledge of the body and the importance of its proper care, however, he all too often subjects it to severe mistreatment.

The human body, like that of other complex organisms, is composed of cells, tissues, organs, and systems. Division of labor among the systems is carried to a very high degree of efficiency. Specialized organs, grouped into systems, form a complete organism which is a smoothly operating, efficient machine. If given good care and proper treatment, it will respond with good health and long life.

Using Your Knowledge

1. Explain the manner in which man has developed to become the supreme form of life.
2. Explain the importance of intelligence and reasoning in the rise of modern man.
3. List examples of animals which surpass man in certain abilities.
4. Discuss the manner in which modern civilization has created health problems.
5. Why, do you think, modern man is more apt to suffer from a breakdown of the nervous system than any other system?
6. Discuss the importance of knowledge of the body in relation to good health.
7. How do the tissues, organs, and systems of the human body illustrate division of labor.
8. Name the three body cavities and certain of the organs contained in each.

Expressing Your Knowledge

Homo sapiens	liquid tissue	digestive system
prehistoric	muscular tissue	excretory system
connective tissue	nerve tissue	endocrine system
bone	epithelial tissue	nervous system
cartilage	skeletal system	cranial cavity
white fibrous tissue	muscular system	thoracic cavity
yellow elastic tissue	circulatory system	abdominal cavity
adipose tissue	respiratory system	diaphragm

Applying Your Knowledge

1. Prepare a report on one of the several races of early man. Include such phases of his life as his home, diet, methods of protection, and relation to his fellow men.
2. Make a list of the different kinds of abilities of man, such as intelligence and ability to reason, locomotion, sight, and hearing. Enumerate the abilities in which man is supreme, and those in which he is surpassed by other animals.

Chapter 39

The Body Framework

When a contractor builds a house, he starts with the framework. First he erects the main beams and joists, then the studding and rafters. Next come the walls and the roof, and finally the outer sheeting and the plaster. The strength of the entire structure depends upon the framework upon which all of the other parts are fastened.

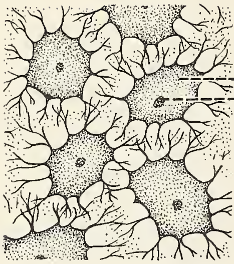
The human body is like a house in many ways. Most of its organs are soft and would lie in a shapeless mass were it not for a framework to give it definite form. But unlike the house, the body must have strong support and yet be able to move. The framework must be jointed so that its parts may be moved by muscles. Support and movement of the body involves two separate systems working in close harmony. The skeletal system alone can accomplish support but not movement. The muscular system, on the other hand, can produce movement, but cannot support the body. Together, they enable the individual to walk, run, swim, dance, and to perform many other body movements.

The proper operation of these two systems is essential to health. Just ask someone who has broken a leg or an arm, or who has sprained a wrist or an ankle, or who has wrenched a shoulder, how such an injury affects his life. When the injury is repaired, and the individual is again able to resume normal activity, he is inclined to have much more regard for those systems of his body which give him support and accomplish movement.

Skeletons of vertebrates and other animals. Animals lack the thick cell walls and supporting fibers which give strength to the tissues of plants. The cells of animals are soft and pliable, with only thin membranes surrounding the jelly-like cell contents. Consequently, all but the simplest animals require some sort of framework to support their soft tissues.

The study of different forms of animal life has revealed many ways in which support has been accomplished. The sponge consisted of a strange framework of mineral materials which supported two layers of soft, living matter. The coral formed an extensive apartment of limy matter containing numerous cavities to provide quarters for great communities of soft-bodied animals. The clam, oyster, and snail are examples of animals which encase their soft bodies in a strong shell. They carry their houses with them but never have an opportunity to get out of the house and see what is going on in the world. Even the insect and crayfish, while they enjoy the protection of an exoskeleton, are handicapped by the cumbersome covering which they must carry with them.

By far the most efficient system of support is illustrated in the internal or *endoskeleton* of man and the other vertebrates. Our bony framework gives great internal strength. This arrangement gives the greatest support with the least amount of weight. It permits movement far superior to any other type of frame-



BONE CELLS

work. The animal with an internal skeleton is, however, at one great disadvantage. Much of the protection afforded by an external skeleton is lost with the external exposure of the soft parts of the body. Consequently, the organism must rely upon its nervous system and sense organs for the protection which the skeleton does not provide.

Functions of the skeleton. The functions of the bones of the body may be classified principally as:

1. Support and form for the body
2. Levers for muscles
3. Protection for delicate organs

Many of the 206 bones which compose the human skeleton function for more than one purpose. For example, the vertebrae of the spine, the shoulder girdle, the hip girdle, the bones of the legs, and those of the arms support the body and give it definite form, although the arms have ceased, to a great extent, to serve as organs of support. The bones of the legs and arms serve, likewise, as levers for muscles to produce many types of body movement. Certain delicate organs lie beneath special protective bones as, for example, the brain which is encased in the cranial bones, the heart which lies beneath the breastbone, and the lungs which are protected by the ribs.

Bone, a living tissue. We commonly use the expression, " dry as a bone " and assume that living bone is like the dried-out bones we see lying around. Actually, bone is far from dry, either from the standpoint of texture or as a subject for biological study. It is moist and active and requires nourishment the same as any other living tissue. True, part of what we call bone is nonliving, for bone tissue is a peculiar combination of living cells and mineral deposits.

Composition of bone. The formation of bone involves not only bone substances but *cartilage* as well. In some of the primitive vertebrates the skeleton is composed entirely of cartilage, which has a tough, elastic texture. Such animals as the shark which have a skeleton of cartilage have internal support, but not to the extent of the higher vertebrates which have a skeleton of true bone.

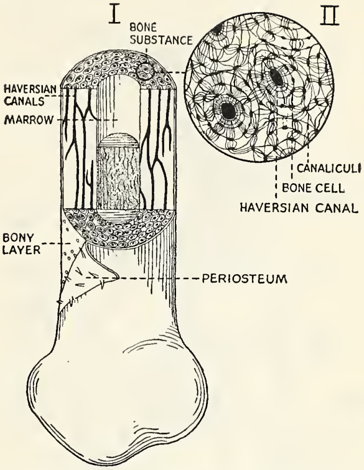
In the early stages of the development of the human embryo, the skeleton is composed entirely of cartilage. After about the second month of development, however, certain of the cartilage cells disappear and are replaced by other cells which deposit minerals in the form of *calcium phosphate* and *calcium carbonate* in the spaces between them. This process is called *ossification*, and occurs throughout childhood and, at a reduced rate, until maturity.

The amount of cartilage in the bones of children is, therefore, much greater than in the bones of adults. Hence, they are more flexible and less liable to be fractured under strain. Furthermore, the rapid rate of ossification permits rapid repair in case of fractures, a process which requires a much greater period of time in adults and is almost impossible in old age. The flexibility of young bones, however, permits them to be forced out of shape easily. For this reason, young people should be extremely careful in selecting shoes and clothing which fit properly and in maintaining good posture.

The mineral and cartilage portion of a bone may be determined easily by means of simple experiments. If a bone, such as a chicken drumstick, is placed into twenty per cent hydrochloric acid for several days most of the mineral matter will be removed, leaving only the cartilage. Though the general appearance of the bone will not be changed, it will have no rigidity and can be bent without breaking. If, on the other hand, such a bone is thoroughly burned, the cartilage portion will be removed and the mineral portion will not be greatly changed. Again, the shape is not much altered, but the bone has become brittle and has no elasticity.

Factors controlling mineral deposit in bone. Ossification involves the deposit of calcium compounds between the bone cells and increases the strength of the bone. Naturally, this deposition cannot occur unless the proper minerals are present. Calcium compounds enter the body with food and are carried to the bone tissues by means of the blood. The diet therefore governs mineral deposition in bone. Especially in childhood, the diet must be controlled carefully to be sure that the bone tissues are receiving proper mineral supply. Milk, the natural food of all young mammals, is the most ideal source of these calcium compounds.

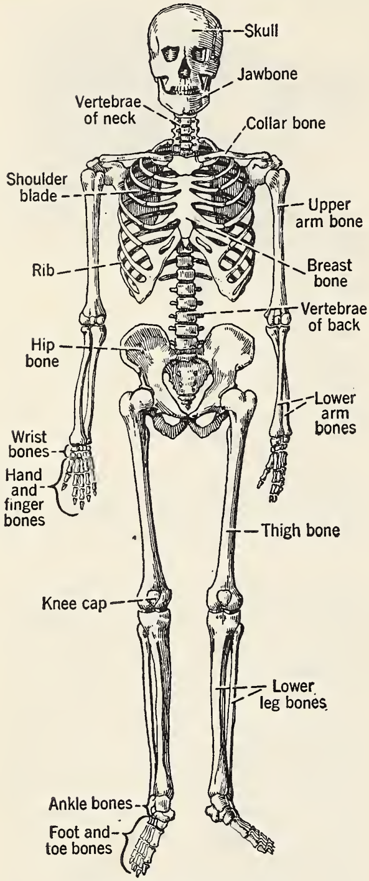
Another important factor, other than diet alone, has been found to be of vital importance in mineral deposition. Certain vitamins, especially Vitamin D, are necessary for normal bone activity. When this vitamin is lacking in the diet, mineral deposition does not occur properly and the individual suffers from soft bones. Frequently the legs become bowed and the joints grow abnormally.



INTERNAL STRUCTURE OF A BONE. I: longitudinal section of a bone; II: microscopic view of bone in cross section.

Such a condition, referred to as *rickets*, can be avoided by supplying sufficient quantities of Vitamin D. The amount of the vitamin in the normal diet may be supplemented by taking special preparations of a concentrated extract such as cod liver oil, haliver oil, or other sources of abundant supply. The body itself seems to produce Vitamin D upon exposure to sunshine.

Structure of a bone. If a long bone, such as a bone from the leg or arm, is sectioned lengthwise, several distinct regions will appear. The outer covering is a tough membrane called the *periosteum* [*peri os'tee um*]. This membrane aids in nourishing the bone and in repairing injuries and provides a slick outer covering. Within the periosteum is a hard *bony layer*, containing the deposits of mineral matter. This layer may vary from an extremely hard to a spongy texture, depending upon its location in the bone. The bony layer is very hard through the shank, or mid-region but



THE HUMAN SKELETON

becomes porous and spongy at the joint ends. In this way the weight of the bone tends to be equal at all points regardless of the size of the region. The spongy texture of the enlarged ends of the bone prevents the joints from being heavy.

The bony layer is penetrated by numerous channels, the *Haversian* [*hav er'shan*] *canals*, which form a network extending throughout the region. These canals are necessary to conduct nourishment to the living cells of the bony layer. The blood vessels of the Haversian canals connect with those of the outer membrane from which nourishment is received.

The larger bones are hollow within and contain a soft tissue called *marrow*. The marrow is richly supplied with nerves and blood vessels. There are two distinct types of marrow, red and yellow. The red marrow is found especially near the joint ends of bones and gives rise to the red corpuscles of the blood stream. The yellow marrow fills the central cavity of the bone and extends into the Haversian canals of the bony layer. It is believed that white corpuscles originate in the cells of the yellow marrow.

The smaller bones are solid rather than hollow and vary considerably in the amount of spongy bone tissue present. Though they are solid, however, they are completely penetrated with blood vessels which provide nourishment for growth and repair.

The bones of the human body. The human skeleton is composed of 206 separate bones. The number would be even greater if certain bones which are fused together to form single structures were counted separately. Some are united by flexible joints, while others are joined firmly by layers of cartilage or bone tissue. You will find the bones illustrated in the diagram of the skeleton which is shown on this page.

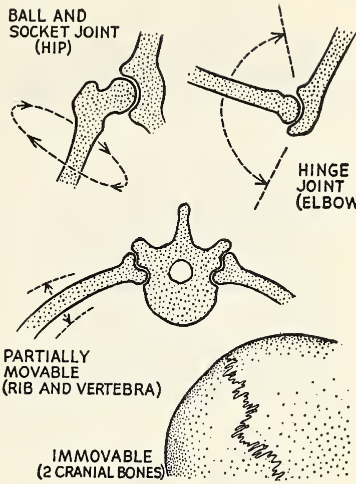
Permanent cartilage. Certain parts of the body are supported by cartilage rather than bone. Such *permanent cartilage* remains as such and is not replaced by bone as in the case of *temporary cartilage*. Permanent cartilage forms such structures as the end of the nose, the external ears, and the walls of the *larynx* [*lar'inks*] and *trachea*. The inner faces of the joints, likewise, are covered with layers of cartilage, thus permitting free and frictionless movement. A secretion of the cartilage, called *synovial* [*sin ov' ee al*] *fluid*, serves to lubricate the joints.

Joints of the body. The point at which two separate bones are fastened is called a *joint*. The various bones of the human body are united in several different kinds of joints.

The elbow is an example of a *hinge joint*. Such a joint moves as a hinge in one plane only, but has the advantage of giving great power because there is little danger of twisting. When the muscles of the upper arm contract, the lower arm is pulled upward only. The knee is another example of a hinge joint. The hip and shoulder joints are examples of *ball and socket joints*. Here, the bone of the upper arm ends in a ball which fits into a socket of the shoulder girdle. Such a joint has the advantage of universal movement, or movement in any direction. The hip joint is similar, with a ball on the end of the femur or thigh bone fitting into a socket of the pelvic girdle. Theoretically, the leg may may be moved as freely as the arm. Actually, however, the fact that man supports his entire body on the legs has resulted in enlargement of the leg muscles and strengthening of the hip joint, thus reducing freedom of motion of the hip joint.

Ball and socket and hinge joints are held in place by tough strands of connective tissue called *ligaments*. Ligaments may be stretched with exercise, thus "loosening" joints and permitting more free movement.

The ribs fasten to the *vertebrae* [*vert' ah bree*] of the spine in joints which are only *partially movable*. The joints are held securely by layers of cartilage which stretch to allow movement. Long strands of cartilage attach the ribs to the breast-

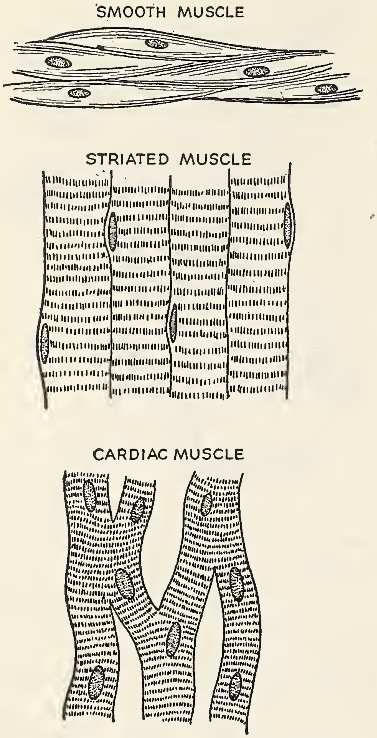


Four Types of Joints

bone in front so as to allow for chest expansion during breathing. Some joints, such as those of the skull bones, are *immovable*. The bones may be held together by cartilage or may be entirely fused by ossification. The skull bones of the infant are held together by cartilage and are somewhat movable. After a few years, however, they become securely fused.

Muscles and the production of movement. Bones, even in a living body, have no power to move themselves because their hard layers of calcium prevent contraction. Energy release must therefore come from soft structures which can contract easily. Muscles accomplish this function admirably. We can better understand how important motion and action are to the human organism when we realize that there are about four hundred different muscles, comprising approximately one half of the body by weight.

The fact that we can move our arms when we want to shows that certain muscles are under the control of the will.



Different Kinds of Muscle Cells. In each of these three types, note the differences in the shapes of cells, and in the number and position of the nuclei.

Such muscles are called *voluntary* muscles. There are many other muscles which assist in the operation of our digestive, respiratory, circulatory, and excretory systems which are never controlled by our will, and are therefore called *involuntary* muscles. Some muscles are both voluntary and involuntary, as, for instance, those that operate the eyelids.

A voluntary muscle is usually spindle-shaped. At each end it loses itself in a tough, white structure called a tendon. This inelastic tendon attaches the muscle to a bone.

The microscope reveals three kinds of muscle cells:

1. *Striated* or skeletal: fibers with bands and many nuclei (voluntary)

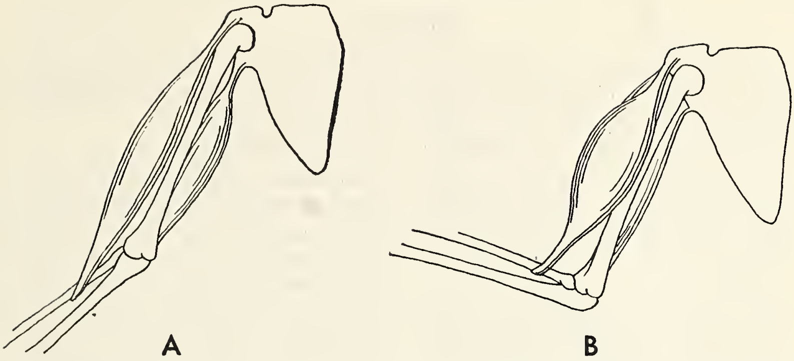
2. *Unstriated* or smooth: spindle-shaped with one nucleus (involuntary)

3. *Cardiac*: branched, striated fibers (heart muscles)

Muscles have the power of shortening. This is called contraction. How it is done cannot easily be told. Nerves are necessary to produce a stimulus. Blood vessels must supply oxygen and food for the release of energy through oxidation. The blood must also take away waste products or fatigue of the muscle rapidly takes place. A period of *relaxation* of the muscle, however brief, must follow a normal contraction.

The large voluntary muscles are always arranged in pairs which in action oppose each other. For instance, if you bend your arm rigidly, the upper arm region enlarges. This swelling is due to the contraction of the *biceps* muscle which has contracted and pulled the arm up toward the body. To straighten the arm, the *triceps* muscle on the under side of the upper arm contracts and pulls the lower arm out straight. Those muscles which, like the biceps, bend a joint, thus bringing a part closer to the body, are called *flexors*. A muscle which straightens a joint or extends a limb is called an *extensor*. While it is true that the skeleton supports the muscles, it is also a fact that both flexor and extensor muscles assist greatly in supporting the skeleton.

Unstriated and cardiac muscles. The *unstriated* or *smooth muscles* differ in their arrangement from striated or skeletal muscles. Their cells are arranged, usually, in two layers. When the muscle contracts, the entire layer draws up. Layers of smooth muscle form the walls

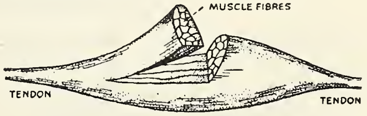


MOVEMENTS OF MUSCLES OF UPPER ARM. A: The arm is straightened by the contraction of the triceps muscle on the under side. This is therefore an extensor muscle for the arm. In this movement, the biceps muscle, on the upper side of the arm, is relaxed. B: The arm is flexed by the contraction of the biceps muscle, a flexor for the arm. The triceps muscle is now relaxed.

of many internal organs. The stomach and intestine walls contain such layers and may contract in waves to churn food or pass it along through the digestive tract. Artery walls, likewise, contain layers of smooth muscle. Due to impulses from the nervous system, the artery walls may constrict and raise the blood pressure during periods of danger or emotional upset. All action of smooth muscle is controlled by parts of the nervous system over which we have no conscious control.

The *cardiac* or *heart* muscle differs both in form and operation from the other muscles. The individual cells are more or less rectangular and are joined end to end. They are striped, but not as distinctly as the skeletal muscles. Heart muscle must contract at regular intervals throughout life, for the heart has no rest except between beats. Such continuous operation without rest would soon exhaust any of the other muscles.

Muscular co-ordination. The skeletal muscles, like all other muscles, contract as a result of impulses from the nervous system. Any body activity involves many impulses and many muscles. The combined action of muscles to produce a movement is called *co-ordination*. The skill with which movement is produced depends upon the co-ordination of nerve impulses and muscular contractions. To a great extent, muscles may be trained to produce a particular kind of movement by means of practice. One must learn to play tennis, drive a golf ball, or dribble a basketball. As his nervous system and muscles become accustomed to the activity, a skill is developed. The athlete, the musician — anyone who requires a particular muscular skill — must practice long hours to attain perfection. Needless to say, any influence such as alcohol or narcotics, improper diet, or insufficient rest will affect both the nervous system and the muscular system and will greatly reduce muscular co-ordination and efficiency.



STRUCTURE OF A SKELETAL MUSCLE

Summary

The body framework consists of an internal skeleton composed of bones which give the body form, act as levers for muscles, and protect the more delicate organs. Bone is a living tissue whose cells deposit mineral matter consisting chiefly of phosphate and carbonate of calcium.

A bone consists of three general regions; an outer membrane or periosteum, a bony layer, and an internal cavity filled with marrow. The bone is nourished by blood vessels which penetrate the marrow and Haversian canals of the bony layer.

Cartilage tissue is closely associated with bone as a supporting tissue of the body. Temporary cartilage is replaced by bone during ossification. Permanent cartilage gives form and flexibility to such body parts as the tip of the nose, the external ears, and the walls of the trachea and voice box.

Muscles produce movement in the body. Those which attach to bones by means of tendons are called skeletal or striated muscles. They contract to bend joints. Smooth or unstriated muscles form layers in the walls of such internal organs as the stomach, intestines, and the arteries. Cardiac or heart muscle differs both in structure and function from other muscles. Its cells are more or less rectangular and can function a lifetime with no prolonged rest period.

The operation of muscles in close harmony during movement is called co-ordination. Muscular co-ordination depends upon co-ordination of nerve impulses.

Using Your Knowledge

1. What is the principal advantage of an internal skeleton over an external skeleton like the grasshopper or a limy covering like the mollusk forms around its body?
2. Explain why an internal skeleton necessitates a highly developed brain and nervous system.
3. Enumerate the principal functions of bones and give an example of a bone serving each purpose.
4. Account for the fact that " dry as a bone " is a familiar expression.
5. Explain the general process of ossification.
6. Explain the relation between diet and mineral deposition in bone formation.
7. Name the regions and state the function of each region.
8. Explain the necessity of the Haversian canals in the bony region.
9. Enumerate the four kinds of joints found in the body.
10. Distinguish between permanent and temporary cartilage.
11. Explain how muscles may be classified upon the basis of muscular control.
12. How are muscles classified according to cellular and fiber makeup?
13. Explain why movable joints require two muscles for operation.
14. Explain what is meant by muscular co-ordination.

Expressing Your Knowledge

endoskeleton	muscular co-ordination	red marrow
cartilage	rickets	yellow marrow
ossification	periosteum	spongy end
calcium phosphate	bony layer	permanent cartilage
calcium carbonate	Haversian canals	temporary cartilage

synovial fluid	voluntary	cardiac
hinge joint	involuntary	relaxation
ball and socket joint	striated	flexor
ligament	unstriated	extensor

Applying Your Knowledge

1. Obtain a large bone from your butcher and saw it lengthwise so as to show the various regions of a bone.

2. If possible, obtain a joint, including the attached ends of two large bones. Clean off all of the muscle tissue so as to expose the ligaments holding the joint in place.

3. Place a chicken leg bone into a hydrochloric acid solution for several days. Observe the texture after treatment. Using a similar bone, heat it in a flame until it becomes red hot and no more smoke and vapor come off. Cool it and observe the texture. Is it different than the first?

4. Prepare a report on rickets. Include the cause of the disease, the nature of the symptoms, and the prevalence in America.

5. Make a list of muscular skills of a special nature which you have developed through practice. Such a list might include bicycle riding, piano playing, and tennis.

6. Interview an athletic coach in your school. Find out the scientific basis for the training program athletes are required to follow.

7. Using the diagram of the human skeleton on page 430, locate the bones in your own body and name them.

Chapter 40

The Nature of Foods

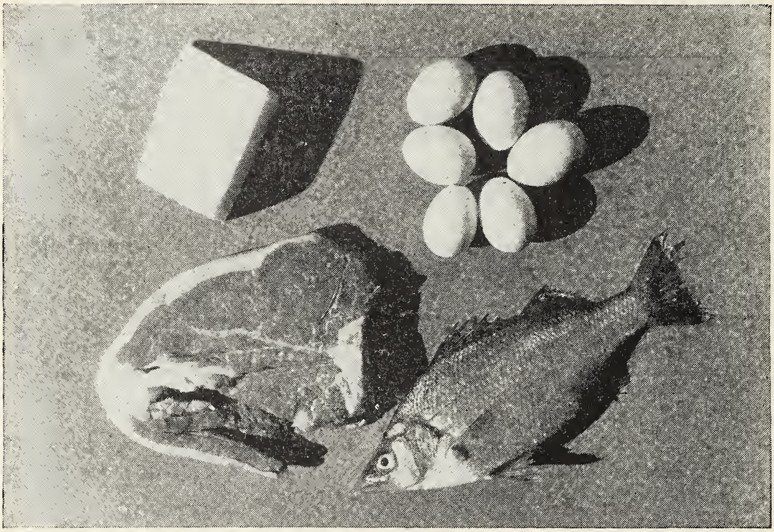
All living things require energy. This energy depends in part upon oxidation, which involves the union of oxygen with food and tissues. The process destroys the substance oxidized and necessitates the replacement of oxidized tissue. Replacement of tissue means that more food must be taken in, a vital necessity to all living organisms.

If food is assimilated faster than it is used, growth or storage of the excess will result. In plants little energy is required, and growth may be continuous. But in animals a point is reached where oxidation balances assimilation, and true growth practically ceases.

Today we know much more about food, nutrients, and those all important substances called vitamins, than we did fifty years ago. Proper diet can accomplish wonders in the maintenance of good health.

What is food? *Food* may be defined as any substance which, when taken into a living organism, yields material valuable for the production of energy, the building of tissue, and the regulation of the life processes, without harming the organism. The energy is necessary for life activities, the tissue building for repair and growth.

The general classes of foodstuffs (nutrients) have been mentioned in Chapter 4, where their composition and properties are discussed. We shall now take up the special uses of nutrients in relation to



PROTEIN FOODS

the life and growth of animals, including man.

Water. About 60 per cent of all animal tissue is water. It is an essential part of protoplasm, a necessity to plants in starch making, and in both plants and animals transports and dissolves other foods. Though not oxidized in the body, it is an essential part of all foods, as blood and other body foods are largely composed of water. Water is especially valuable as a solvent for waste matter in perspiration and urine.

Mineral salts. *Mineral salts,* of which table salt, phosphate of lime, and various compounds are examples, compose about five per cent of all animal tissue. Not only do mineral salts furnish elements for some of our body tissues, but they aid digestion, and are essential to the proper functioning of the blood and nerves. Phosphates, which are found in whole cereals, meats, fish, and milk, aid in the formation of protoplasm and bone and nerve tissue. Iron compounds, which are obtained from green vegetables, prunes, meats, etc., are necessary in the formation of red blood corpuscles and aid in carrying oxygen. Calcium compounds are important in bone formation, are concerned with blood platelets, and, together with magnesium compounds, help to regulate nerve and heart action. In fact, mineral compounds are sometimes called " regulating foods " because of their importance in this matter.

Proteins. These are the only foodstuffs containing *nitrogen*, and are therefore essential in production of living tissue. They include some of man's most valuable foods, such as lean meat, white of egg, cheese, gluten in wheat, legumin in peas and beans. Protein compounds constitute about 18 per cent of the weight of man's body. Proteins furnish material to build and repair muscle and tendon, bone, cartilage, skin, and the corpuscles of the blood. Proteins may also be oxidized directly and thus furnish energy. While this actually takes place to some extent, it would be an expensive source of fuel and it would also put too great a strain upon the excretory organs if energy were primarily sought from this class of foods.

The following is a list of protein foods in the order of their cost, those giving most building and repair material for the money heading the list:

Fats. *Fats* are the chief energy producers. Fats occur in meat, butter, fish, and eggs, and in olive and cotton-seed oils, nuts, corn, and cocoa. Much of the energy of the body comes from the oxidation of fat, either in the form of fat tissue which constitutes about 15 per cent of the human body, or from digested fat before it is organized into tissue. Excess fat is stored in tissue under the skin.

Carbohydrates. *Carbohydrates* (starches and sugars) comprise the bulk of man's food. They are found in all vegetable foods, grains, potatoes, fruits, and nuts. Milk furnishes an important animal sugar. Though occupying so large a place in our menu, carbohydrates compose hardly 1 per cent of the body's weight. This is because they are easily

Beans, dried white	Bread, graham	Milk (whole)
Dried peas	Salt cod	Beef, lean round
Oatmeal	Milk, skimmed	Lamb, leg
Cornmeal	Cheese, American	Eggs (second grade)
Beans, dried lima	Peanuts	Halibut
Bread	Macaroni	Porterhouse steak
Bread, whole wheat	Mutton, leg	Eggs (first grade)
	Beef, lean rump	Almonds, shelled

Wide World Photos

BUTTER — A TYPICAL FATTY FOOD

Philip D. Gendreau, N.Y.

Carbohydrate Foods

oxidized, furnishing much heat and bodily energy. If any excess is taken, it is likely to be changed into fat and stored as such.

Thus it is seen that while proteins, fats, and carbohydrates may all supply energy, the proteins alone supply animals with nitrogen, thus functioning in growth and repair of tissue. The fats and carbohydrates are more easily oxidized; thus the valuable proteins, in general, are saved for their chief function of tissue building.

Fuel foods, the great foundation foods of the diet, supply energy for muscular work. There are three groups of fuel foods. They are arranged in the table at the bottom of the page in the order of their cost, those giving most energy for the money heading the list.

Vitamins. In 1911, Funk coined the word " vitamine " (now " vitamin ") to identify certain substances which were found to exist in certain foods and which appeared to be necessary for the prevention of certain maladies, later called deficiency diseases.

The term vitamin may be applied to certain substances normally found in foods that are indispensable for normal

1. Starchy Foods

Cornmeal	Oatmeal	Macaroni	Dried lima beans	Bread
Hominy	Flour	Spaghetti	Split peas, yellow	Potatoes
Broken rice	Rice	Cornstarch	Dried navy beans	Bananas

2. Sugars

Sugar	Candy
Sorghum syrup	Molasses
Corn syrup	Most fruits
Maple syrup	Figs
Dates	Honey

3. Fats

Drippings	Peanut butter
Lard	Milk
Salt pork	Bacon
Oleomargarine	Butter
Nutmargarine	Cream

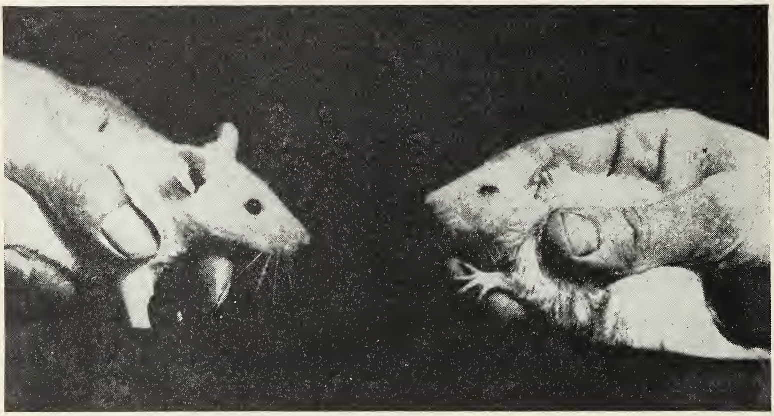
SUMMARY OF NUTRIENTS

Nutrients	Composition	Function	Foods containing
Proteins	C, H, O, N, S, P, K, Ca, Cl, Fe (proportions vary)	Changed into protoplasm Some energy	Lean meats, eggs, beans, peas, milk
Carbohydrates	C, H, O (in varying proportions)	Energy Stored as fat	Sugar, cereals, bread, corn meal
Fats and oils	C, H, O (in varying proportions)	Energy Stored as fat	Butter, lard, milk, cheese, olive oil, nuts
Vitamins	(?)	Regulate body functions	Green vegetables Fruits Milk products
Water	H_2O	60% tissue Blood, fluids Transporter	In all vegetables, fruits, all foods
MINERAL SALTS			
Phosphates	H_3PO_4	Bone Protoplasm Aid digestion	Grains (whole), meats, fish, milk
Salt	NaCl	Essential in blood Appetizer	Used in almost all food
Iron compounds	$FeCO_3$	Oxyhemoglobin (Oxygen carrier)	Spinach, lettuce, green foods, prunes, meats
Potassium compounds	K_2SO_4	Essential in blood	Vegetables
Calcium and magnesium compounds	Ca, Mg	Regulate nerve and heart action	Grains (whole) Vegetables

growth, good health, and the prevention of specific diseases.

Vitamins were first distinguished by the letters A, B, C, etc. Now the name of their chief chemical ingredient is also used. Today there are ten important vitamins which are recognized. They are vitamins A, B_1 (*thiamine* [*thy'ah min*]), B_2 (G or *riboflavin* [*rib oh flav' in*]), B_6 (*pyridoxine* [*pir re dox'in*]), P-P (*nicotinic* [*nick oh tin'ick*] *acid*), C (*ascorbic* [*as kor'bick*] *acid*), D, (*calciferol* [*kal see fer'ol*] and *cholesterol* [*ko les'ter ol*]), E (*tocopherol* [*to ko fer'ol*]), K, and *pantothenic* [*pant oh then'ick*] *acid*. Of these, however, the functions of two, vitamin B_6, and pantothenic acid, are not well known. Also many other substances which appear to be vitamins are being considered. The results of vitamin experimentation, begun first in 1897 by Eijkman, have contributed enormously to bodily development and general health.

Vitamins are as essential to the body as nutrients, but in very much smaller



Vitamin A Is Necessary. Left: Normal rat with adequate vitamin A in its diet. Right: Opthalmia has developed in this rat because of a lack of vitamin A in its diet.

amounts. Unlike nutrients, vitamins are destroyed by heat and oxidation.

Vitamins A, D, E, and K are called "fat-soluble," since they are dissolved by oils. Vitamins B, C, G, and nicotinic and pantothenic acids are water-soluble. Cooking tends to destroy vitamins A, B, C, P-P, and K. Plants are the chief source of vitamins. The more important vitamins are:

Vitamin A prevents night blindness and dry-eye disease, and increases resistance to infections. It occurs in great abundance in cod-, shark-, and halibut-liver oil. It is abundant also in milk, butter, and other dairy products, liver, yolk of egg, spinach, yellow corn, green leafy vegetables, and especially escarole, carrot, sweet potato, etc. Vitamin A is produced in the liver from carotene (the yellow pigment of certain vegetables like yellow corn and carrot). The body is able to store up this vitamin to a considerable extent for future needs. Vitamin A is destroyed by cooking and by continued exposure to air.

Vitamin B_1, the first vitamin studied, is especially important to the nervous system and prevents neuritis. It also increases the appetite, regulates digestion and stimulates growth. It prevents inflammation of the nerves and a nervous disease called beriberi, common in eastern countries to eaters of polished rice. Its lack has been proven to impair intelligence in animals. Vitamin B_1 is found abundantly in yeast, corn meal, and wheat germ; also in nuts, fruits, green vegetables, milk, red meats, and liver.

Since this vitamin, unlike vitamin A, cannot be stored for long in the body, it is important for health to include vitamin B_1 in our daily diet. The average person does not get enough vitamin B_1. It is especially important in youth. Cooking impairs this vitamin only slightly, though soda added to the food during cooking breaks down the vitamin. Vitamin B_1 is soluble in water. Hence, the water in which vegetables containing vitamin B_1 are cooked should not be thrown away.

Vitamin C is necessary for normal condition of the capillaries. It aids in bodily growth, makes firmer gums and

VITAMINS ARE NECESSARY. Left: Rat whose diet lacked all vitamins. Right: Normal rat whose diet contained adequate amounts of all vitamins. Both rats are the same age.

sounder teeth, and increases resistance to disease. Its use especially prevents scurvy, a curious illness affecting monkeys, guinea pigs, and man and in which there is a breaking down of the capillary blood vessel system. Lack of vitamin C causes the cells that form the dentine of the teeth to degenerate rapidly. Dr. Elmer McCollum of Johns Hopkins University, a noted authority, says: "Many people may have wrought permanent injury to their teeth by running short of this vitamin for periods of two or three weeks or longer." Vitamin C is abundant only in plant products, especially citrus fruits (oranges, lemons, grapefruits, etc.), raw or canned tomatoes, cranberries, paprika, and green, leafy vegtables, especially cabbage and lettuce. Green peppers contain four times as much vitamin C as do oranges or lemons. A substance called *vitapric,* produced from the juice of ripened paprika fruits, contains about six times the amount of vitamin C normally found in oranges and lemons. A daily supply of vitamin C is important since the body cannot store it. Cooking destroys vitamin C and exposure to the air oxidizes it.

Vitamin P-P (nicotinic acid) prevents and cures pellagra, a deficiency disease attacking the alimentary canal. Vitamin P-P is found in yeast, wheat germ, egg yolk, buttermilk, and meats.

Vitamin D prevents rickets (soft bone formation), builds and maintains better teeth, increases resistance to certain diseases, and strengthens the bones. It is necessary for the proper utilization and ratios of calcium and phosphorus in the body. Lack of vitamin D eventually softens the teeth and definitely increases the possibility of decay. Dr. McCollum states that "growing children particularly need this sunshine vitamin, but all of us can benefit from its good effects." It is the scarcest in foods of all the known vitamins, and yet it is probably the most essential. Its best natural source is cod-liver oil, which has a high percentage of vitamin D. Traces of this vitamin are found in butter, egg yolk, and milk. Exposure to sunlight produces vitamin D in the skin. Today vitamin D is being added commercially to many foods, such as bread, yeast, and milk.

Vitamin E seems to be necessary for fertility and normal reproduction. Unless this vitamin is present in the foods

TESTING FOODS FOR VITAMIN CONTENT. This instrument is used in the chemical determination of vitamins in foods.

of the mother animal, the embryo may begin to develop but dies in about two weeks. This antisterility vitamin is found chiefly in wheat germ and its oil. It is also present to a slight extent in beef muscle and fat, egg yolk, and milk. There is usually no lack of this vitamin in the average diet.

Riboflavin, also called flavin, B_2 and G, furnishes protection against a special kind of skin inflammation and a skin disease called *cheilitis* [*ki ly'tis*]. It is also valuable in digestion and in the growth of infants. Foods containing riboflavin are yeast, wheat germ, whole-grain cereals, spinach, eggs, milk, and liver. The potency of this vitamin is affected by exposure to light.

Vitamin K increases the clotting power of the blood. It is destroyed by light. Vitamin K is present in spinach, kale, alfalfa, tomatoes, and oat sprouts.

Vitamin B_6 is thought to prevent certain skin conditions and to aid in the synthesis of hemoglobin. This vitamin is found in yeast, wheat germ, whole-grain cereals, rice, bran, and liver. It is destroyed by light.

Pantothenic acid is thought to be associated with the functions of riboflavin. It is found in yeast, whole-grain cereals, milk, egg yolk, kidney, and liver.

Lipoid. All body cells contain *lipoid,* which is derived from fat in the diet. It is affected by alcohol, anesthetics, and poisons, and may be the means by which these act upon the body.

Measurement of food values. There is no way of measuring the tissue-building value of foods. But the heat value may easily be measured. The unit of measurement is the *Calorie* [*kal' oh ree*] which is the amount of heat required to raise the temperature of four pounds (pints) of water one degree Fahrenheit. Careful experiments have shown that a

TABLE I

DAILY CALORIE NEEDS (APPROXIMATELY)

1. For child under 2 years	1,000	Calories
2. For child from 2 to 5 years	1,300	"
3. For child from 6 to 9 years	1,700	"
4. For child from 10 to 12 years, woman (not working)	2,000	"
5. For girl from 12 to 14 years, woman (light work)	2,200	"
6. For boy (12–14), girl (15–16), man (sedentary)	2,600	"
7. For boy (15–20), man (light work)	3,000	"
8. For man (moderately active)	3,200	"
9. For farmer (busy season)	3,500 to 4,500	"
10. For excavator, ditchdigger, etc.	4,000 to 5,000	"
11. For lumberman (winter)	5,000 to 8,000	"

man in an average day's work needs food enough to produce 3,000 to 3,300 Calories of energy.

The amount of energy (number of Calories) required varies with age and occupation as shown in Table I.

The energy required for various degrees of exercise is shown below. One can compute the number of Calories used per day by multiplying the Calories per hour by the hours of each kind of exercise per day. Do this and see how near it comes to the estimate in Table I for a person of your age.

Food proportions. In order that the body may have tissue-building foods and fuel foods in healthful proportions, we ought to eat from two to three ounces of protein per day, and enough fats and carbohydrates to make up the number of calories which we may require as indicated above.

Since the fuel value of carbohydrates is only one-half to one-third that of fats, our diet should have two or three times as much carbohydrate, especially in warm weather, when the concentrated fuel of the fats is less needed. Still another way of reaching the same result is to take 1/80 ounce of protein for each pound of our weight, and enough of the fuel foods (fats and carbohydrates) to make up the required number of Calories for energy production. This makes a diet rather low in protein especially for growing children, but our usual mistake is to use too much rather than too little protein, and one good authority sets the amounts even lower.

A safe proportion for growing boys and girls would be about 2 or 2½ ounces of protein per day, and enough fuel foods to supply the required energy, which will depend upon the age and activity as already stated.

The carbohydrates ought always to be more abundant than the fats, because of the much greater amount of energy produced by the latter. This is especially true in warm weather, when the proportion of four times as much carbohydrates is about right.

If the above proportions are followed for all three foodstuffs, the ratio for all will be approximately as follows:

protein, 1: fat, 1: carbohydrate, 4.

Not only should these proportions be maintained, but the foods should be so selected as to include plenty of green vegetables, fruits, and uncooked foods to supply the essential vitamins and mineral salts. Without these no diet can be considered well balanced and healthful.

Need of mixed diet. We require proteins, fats, and carbohydrates in about the proportions 1:1:4, but there is no one food that contains these nutrients in these proportions, so it is evident that a mixed diet is necessary. When foods are properly selected, so that the above pro-

TABLE II

AVERAGE NORMAL OUTPUT OF HEAT FROM THE BODY

Conditions of Muscular Activity	Average Calories per Hour
Man at rest, sleeping	65 Calories
Man at rest, awake, sitting up	100 "
Man at light muscular exercise	170 "
Man at moderately active muscular exercise	290 "
Man at severe muscular exercise	450 "
Man at very severe muscular exercise	600 "

A Proper Daily Diet. Adequate daily requirements of carbohydrates, fats, and proteins are contained in these foods.

portion is obtained, we have what is known as a "balanced ration."

If we use a diet largely of lean meat, we have too high a percentage of protein. This excess is thrown off by the kidneys and intestines as waste. It overtaxes these organs seriously and is an expensive and unnecessary form of diet. In the same way an excess of fat much above the given proportion, such as would come from a diet rich in fat meats and butter, merely wastes the extra energy or stores it as unnecessary fat tissue in the body.

A strict vegetarian diet is almost sure to be too rich in carbohydrates and, as with a diet too rich in fats, fuel is wasted, too little tissue material is provided, and fat tissue may accumulate from the starches, transformed and stored in this form.

Cost of foods. Not only must our diet be selected with reference to proper amounts of the nutrients and ease of digestibility, but also with regard to the cost in money. This is affected by three things: the actual price of the food, the amount of water and waste, and the expense of preparation. It is more and more important that we shall be informed as to the composition and cost of foods, and for this purpose the government has published many bulletins, which can be had free of cost, by application to the Department of Agriculture at Washington. Lists of all publications will be sent on application. Americans eat more food than is required and they have an idea that the most expensive foods are the most nutritious. These are serious mistakes, overtaxing both the digestive system and the pocketbook.

Right and wrong diets. We are all too apt to let our artificial "tastes" and the demands of fashionable customs overrule our natural instincts and better judgment in the selection of foods. Costly, highly seasoned, stimulating, and unnatural substances are frequent invaders

Philip D. Gendreau, N.Y.

A High School Cafeteria. Well planned meals, containing the necessary vitamins and minerals, are served in this cafeteria. Do you select your food carefully, and include a balanced ration?

of our digestive apparatus, to the detriment both of our bodies and our bank accounts. For the majority of people in normal health, meats, fish, eggs, milk, butter, cheese, sugar, flour, meal, potatoes, and other vegetables make a fitting and sufficiently varied diet — the main point being to use them in proportions suited to the actual needs of the body and not according to acquired whims of the appetite.

Another fact that is often misunderstood, even after a study of nutrients, is the necessity of mineral salts — especially iron, calcium, and potash compounds — which we obtain from green vegetables. As shown by the Summary of Nutrients on page 439, these mineral compounds are a necessary part of every properly balanced diet. Many foods, especially of vegetable origin, contain considerable indigestible matter such as cellulose, or connective tissue, and supply a certain *bulk* required to keep the digestive apparatus properly filled and active.

If phosphorus compounds are lacking, the nerves will suffer; if protein is absent, our muscle tissue might feel the lack; but in a balanced diet this is never the case. An excess of any element, above what is normally used in the body, does not develop any special part, but is merely wasted. Extra protein is not needed for extra work; it is the fuel food that supplies the energy, the protein requirement being almost constant for all grown persons and varying only slightly for younger people.

If energy were all that is required of food we could get our 2,500 Calories from about twenty ounces of sugar or white of egg, or half that amount of clear butter. Both our instinct and experience teach us that this would not support a healthful life, though instinct is not to be generally trusted in the matter of selecting food.

A diet could be made up of highly concentrated and pre-digested foods which, though giving all necessary nutrients, would be very harmful, because of relieving the digestive organs of the work for which they have become adapted, and without which they will not remain healthy.

Cooking of foods. Cooking of food performs three functions: first, it changes the mechanical and chemical condition so as to make it more easily digestible; second, it makes food more appetizing in appearance or flavor, and this quickens the flow of digestive fluids and actually aids digestion; third, the high temperature kills any dangerous bacteria, organisms, or parasites that the food may contain. This is extremely important.

Cooking meat develops its pleasing taste and odor, softens connective tissue, and makes it tender, though too high temperature may harden the proteins of the lean portions.

Milk, if heated to boiling, is made less valuable as food, partly because the vitamins are destroyed. When pasteurized, the heat is regulated so as to kill most bacteria, but not to reach a point high enough to impair its food value so seriously. When vegetable foods are cooked the changes are chiefly the softening of the cellulose and the swelling of the starch in the hot water or steam, which bursts the walls around the starch grains and exposes them to digestive fluids when eaten.

In baking all flour foods, the aim is to make the material "light" and porous so as to be more easily broken up and digested in the alimentary canal. This lightness may be secured by the mere expansion of steam in the dough, but it is usually caused by use of yeast or baking powder, which produce carbon dioxide within the batter. The gluten (protein), always present in flour, is sticky enough to retain the gas, which expands with the heat of cooking, filling the loaf with countless bubbles and making it porous. Finally the heat stiffens the gluten and starch and drives out much of the enclosed gas and we have the "light," porous, and digestible bread or pastry, instead of an indigestible paste of uncooked flour and water.

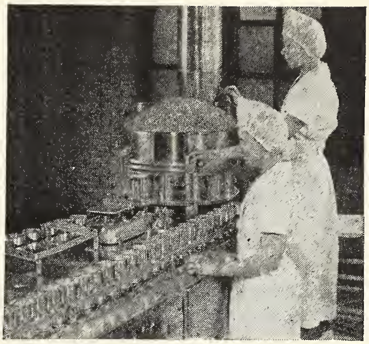
Special foods. There are no special foods for special organs. Fish is not a brain food, nor celery a nerve food, nor meat a muscle food. If eating strong muscle made us strong, we ought to have a diet of the toughest meat possible. The savage eats the heart of his fallen foe to absorb his courage, but we ought to be beyond that stage. If we use a properly balanced diet our cells will select what they need in proportion as we use them. The only way to increase the brain power is to use the brain — not by eating foods rich in phosphorus, simply because phosphorus is an element of brain tissue.

Fruits and vegetables are important for another reason. They produce alkaline substances when digested and these neutralize harmful acids formed by the digestion of proteins. They are also an important source of vitamins and cannot be safely omitted from the dietary, even though their Calorie value is not always very high.

Food preservation. Food for man and his domestic animals is also food for bacteria and other organisms. It is subject to oxidation and decay, like other organic matter, and must be protected if it is to serve man as food. Bacteria require moisture and warmth for growth and are killed by heat and certain chemical substances. Foods are preserved by utilizing these facts.

Moisture may be removed, i.e., the food is "dried." This method produces hay, cereals, and dried fruits. Bacteria do not thrive unless warm, hence cold storage and refrigerators are used to preserve meats, eggs, fish, and milk products.

Heat kills bacteria. Therefore, if foods can be sterilized by heat and then sealed so that no more bacteria can gain entrance, they will keep fresh almost indefinitely. The enormous canning industry is based on this process.



Canning Beans. In this cannery utmost precaution is taken to see that the conditions under which the workers perform their duties are sanitary.

Salt and substances produced by smoke are preservatives which hinder bacterial growth but do not harm the food. Much meat and fish is preserved by smoking and salting or by salt alone. Other preservatives, such as benzoate of soda, may be used, possibly without harm to the consumer, but they might make possible the canning of partially decayed foods. Use of such preservatives must be stated on the label. The quick freezing of foods is a new development in preservation methods. These foods are to be had at many retail outlets.

Allergy. Children sometimes complain that they do not like this or that food. Unless there are actual symptoms of itching, breaking out of the skin, or nausea, it will generally be safe to consider such objections imaginary or unimportant. Some persons, however, find that certain protein foods or other substances actually do produce the discomforts just referred to, or even illnesses. A distressing reaction to a protein introduced into the body by eating or breathing is called an *allergy,* and the person who suffers is said to be *allergic.* This condition is also referred to as *anaphylaxis* and as protein sensitivity.

Asthma, hay fever, serum sensitivity, and other similar conditions, such as reactions from certain foods, are caused by this hypersensitivity to one or more proteins. Inhaled pollens seem to be the primary cause of hay fever. Typical asthma (difficulty in breathing) may be due to the same cause or to extreme sensitivity to certain foods.

If there is any doubt about the causal agent, a minute quantity of the questionable food is injected under the skin by a specialist. If the person is allergic to that food, the region around the injection becomes red and somewhat inflamed. Repeated injections of very minute amounts of the offending protein may produce a temporary immunity lasting several months.

Summary

Food is any substance which when taken into a living organism yields material essential for the production of energy, the building of tissue, and the regulation of the life processes.

The three chief classes of foods are

proteins, fats, and carbohydrates. Proteins are the only foods containing nitrogen and are therefore necessary for the building of living tissue. Fats are the chief energy producers. Carbohydrates also produce energy but are important too because they comprise the bulk of man's food.

Vitamins are not foods, but are special substances normally found in foods. They are essential for normal body activities.

A mixed diet of proteins, fats, and carbohydrates in the proportion of 1:1:4 is necessary for the maintenance of good health.

Using Your Knowledge

1. Enumerate uses made of the mineral salts of the diet.

2. Why are proteins termed body building foods?

3. Inhabitants of the polar regions have little opportunity to obtain carbohydrates because of the scarcity of plants in the region. What sorts of foods make up for the absence of these fuel foods?

4. Explain the method used by science in measuring the energy value of food.

5. Explain what is meant by a balanced diet.

6. Discuss the relation of cooking of foods to problems in digestion.

7. What is gained and what is lost by pasteurizing milk?

8. Discuss various methods of preserving foods.

9. What do we mean when we say that a person is allergic to certain types of food? Describe a test for allergy.

Expressing Your Knowledge

mineral salt	nicotinic acid	lipoid
protein	ascorbic acid	Calorie
fat	calciferol	allergy
carbohydrate	cholesterol	scurvy
vitamin	tocopherol	beriberi
thiamine	pantothenic acid	citrus
riboflavin	cheilitis	antisterility
pyridoxine	fat soluble	pellagra

Applying Your Knowledge

1. Prepare a vitamin table listing the name of each, its source, and the disease resulting from its deficiency in the diet.

2. Prepare several different balanced diets for growing young people of high school age including the proper amounts of proteins, fats, carbohydrates, and minerals.

3. Obtain several small white rats and cage them separately. Feed them on different diets for several weeks, making accurate records of the kind and amount of food consumed, the weight increase, and other important data. One diet should be balanced with milk included, one without milk, etc. It might be interesting to feed one on soft drinks and pastry for a few weeks to check the value of common soda fountain luncheons.

Chapter 41

Nutrition

At a recent scientific meeting, one of the audience asked the speaker, who was a distinguished biologist, to explain the difference between food and nutrition. "They are really quite different," he said, "food, as you know, is merely one or many substances — raw materials, you might say, for the building of tissues. *Nutrition,* on the other hand, is a term including all of the body processes by which food is obtained, changed by digestion, and eventually oxidized and built into body tissues. Food is only the beginning of nutrition. Without it there can be no such thing as nutrition."

In the lowest animals such as the *Amoeba,* or in the lowest plants such as the bacteria, nutrition is a very simple process. Such one-celled organisms are able to get food from the immediate surroundings, to digest and circulate this food in the cell, to obtain energy by oxidizing some of the food, and to convert the remainder into protoplasm, rejecting from the cell what is not used.

Man, as you will see from this and the following chapters, has complicated structural adaptations and systems for dealing with food. Yet he uses the same primary functions as the lowest organisms, that is, eating, digestion, absorption or diffusion (because in his body digested food or excretions pass through many cells), circulation, assimilation, respiration, oxidation, and excretion.

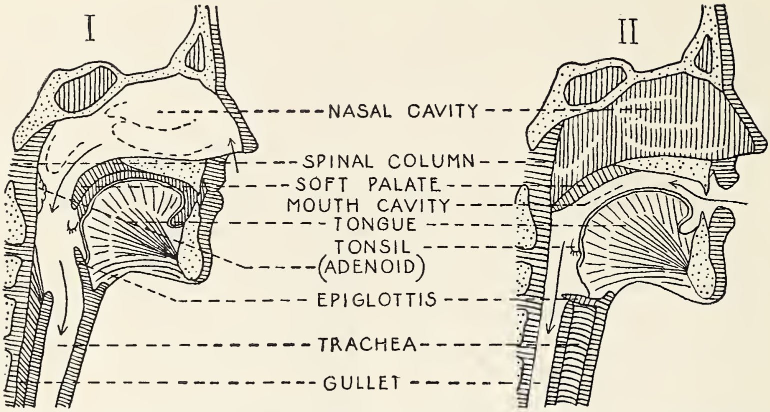
What is digestion? Digestion produces two important changes in foods. First, it makes them soluble, allowing transfer by osmosis; second, it changes them chemically, permitting them to be assimilated. These changes are brought about in two ways: first, *mechanically,* by the teeth and the motion of the stomach and intestinal walls; second, *chemically,* by active substances in the digestive fluids called *enzymes* or *ferments.* The latter process is true digestion. There are several kinds of enzymes, each acting on a particular foodstuff and each secreted by different glands in various parts of the digestive system.

Experiments referred to in Chapter 11 show the necessity of changing foods into liquids which will pass through living membranes such as intestinal walls, blood vessels, and cells.

The digestive organs. The digestive tract or alimentary canal is practically a continuous tube with many glands opening into it to furnish digestive fluids, also with a rich blood supply to provide for its activities and to remove digested foods. This food tube consists of four general regions whose structure and functions will be studied in order: the mouth, the gullet, the stomach, and the intestines.

In the simpler animals (Protozoa) the digestive canal may be lacking, or almost straight and uniform in size (worms), but in the higher animals and man it is much coiled to provide greater surface for secretion and absorption. It also varies much in diameter, to permit the carrying out of special functions in various parts.

The mouth. So far as digestion is concerned, the mouth performs two func-



THE MOUTH, NOSE, AND THROAT. I: the relative positions of these organs in breathing; II: their relative positions in eating.

tions. In it the food is crushed or cut into smaller portions and at the same time it is mixed with saliva, one of the digestive fluids. The mouth cavity is limited above by the palate, below by the tongue, and at the front and sides by the teeth, lips, and cheeks. There are six openings into this cavity, from within, namely:

1. Two *nasal openings,* behind the palate and connecting with the nostrils, above.

2. Two *Eustachian* [*you stay'shun*] *tubes,* also far back, high up at the sides, and connecting with the ears.

3. The *trachea* and *gullet* below; the former in front and connecting with the lungs, and the latter behind it and communicating with the stomach.

Other organs are immediately connected with the mouth cavity, most of which can be seen by studying your own mouth with a mirror or by looking into a friend's mouth with a small electric light. The " roof of the mouth " or hard palate can be easily recognized. Back of it is a downward projecting sheet of muscle, the soft palate; at either side rounded projections may be seen, which are the *tonsils.*

Abnormal growths called *adenoids* [*ad'e noids*] sometimes appear behind the soft palate and near the opening into the nasal cavity. These may obstruct the breathing and should be removed if present. The tonsils sometimes become enlarged and act as places for bacterial growth, necessitating their removal.

The openings of the Eustachian tubes are protected by their high location and are usually closed. The trachea is protected by the base of the tongue and the *epiglottis,* which is a doorlike organ that covers the trachea during swallowing.

The tongue. The *tongue* is easily studied, but few of us really know its shape, size, or structure. The best way to find out is to look at it. It is a large muscular organ, nearly filling the front part of the mouth cavity when the jaws are closed. It has great freedom of motion and performs the following functions:

1. It is the organ of taste — a sense which aids in selecting foods and in promoting their digestion.

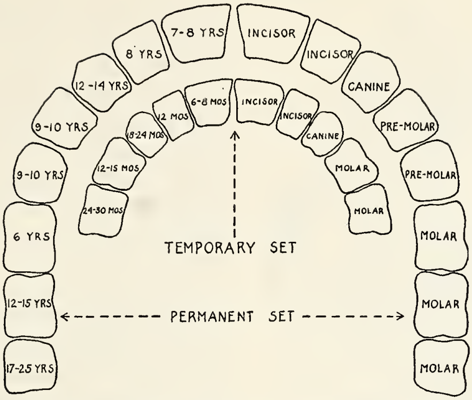


CHART SHOWING THE KINDS OF TEETH. The order of succession is shown, and also the time of appearance of both sets of teeth.

2. It aids in chewing by keeping the food between the teeth.

3. It is concerned in the process of swallowing, since it rolls the food into proper shape, pushes it back toward the gullet, and partly closes the trachea.

4. It helps to keep clean the inner surface of the teeth.

5. It is the chief organ concerned in producing speech.

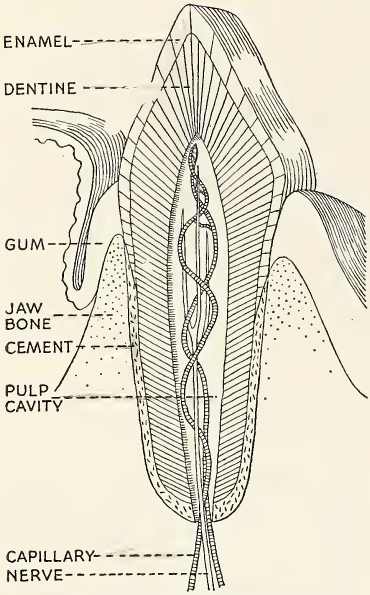
The teeth. The *teeth* are familiar and important organs. Each consists of three parts: (1) the crown or exposed portion, (2) the neck, a slight narrowing at the edge of the gum, and (3) the root or roots, which are attached to the jaw.

A section cut lengthwise through a tooth shows that the crown is covered by a very hard substance called *enamel,* which protects the exposed parts. The bulk of the tooth consists of *dentine,* a softer and more porous substance. The center is occupied by the *pulp,* which contains the nerves and blood vessels of the tooth. The root is covered by a bonelike coating, the *cement,* and through the very tip is the opening by which the nerves and blood vessels find entrance.

The number and kinds of teeth. There are four kinds of teeth, though all may not appear till the twentieth year or later.

In the full set there are thirty-two, sixteen on each jaw, arranged as follows: In front are eight *incisors* with sharp edges, whose function is to cut the food. Next on each side is one *canine,* or four in all, which are pointed and which the lower animals use for tearing food. In man they assist the incisors. Behind these on each side come two *premolars* and three *molars,* all with rough, flat crowns used to crush the food. The first or "milk" teeth lack the premolars and one set of molars, and so number but twenty in all. Having two sets seems to allow for the necessary growth of the jaw. Hence, if the first teeth are allowed to decay and are pulled too soon, the jaw never gets its proper shape and the later teeth are crowded and irregular. At the right times the roots of the first teeth are absorbed, and make way easily for the permanent teeth.

The numbers of teeth are often expressed in fractional form, and are easily remembered in this way. Beginning at



VERTICAL SECTION THROUGH A CANINE TOOTH

the front in the middle of the jaw and putting the upper teeth above and the lower teeth below, we have the "dental formula" for the adult and for the first sets as follows:

	Incisors	Canines	Pre-molars	Molars
First set (20)	2/2	1/1	0/0	2/2
Permanent set (32)	2/2	1/1	2/2	3/3

The last pair of molars, the "wisdom teeth," may not appear until about the twentieth year.

Among other animals the teeth vary a great deal in size and number, but there is none that has a greater variety of kinds. Horses and cattle have molars greatly developed, cats and dogs have canines long and sharp, while rats and squirrels develop the incisors excessively for gnawing. Vegetable foods require broad grinding teeth, while animal food needs sharp canines and shear-cutting premolars. Man, being adapted for a mixed diet, has all forms moderately developed. Chewing is one of the mechanical processes which prepares the food for chemical action by the digestive fluids.

The glands. Digestive fluids are secreted by organs called *glands*. A gland consists of a group of cells adapted for producing a fluid secretion. These cells are developed on the inner walls of a cavity which usually opens into some other organ by way of a tube called a *duct*.

These cavities may be simple and very small like the mucous glands that moisten all the digestive tract, or they may be very large and complex like the liver. In either case they must have a rich blood supply and nerves to control the action of the gland. A gland, then, consists of secreting cells, the gland cavity, the duct, and the blood and nerve supply to it.

The salivary glands. The principal glands of the mouth are the salivary glands of which there are three pairs. The largest pair, the *parotid* [*par ot′id*] glands, is located beneath the ears on each side of the head and the ducts open opposite the second upper molar. Inflammation of these glands causes the mumps. The *submaxillary* glands lie within the angles of the lower jaw, and the *sublingual* [*sub ling′gwal*] pair is below the tongue, beneath the floor of the mouth. Ducts from both of these glands open under the middle of the tongue.

Saliva. *Saliva* is a thin alkaline fluid containing the enzyme *ptyalin* [*ty′ah lin*] which changes starch to soluble sugar, though this action is slight since the food remains so short a time in the mouth. The other functions of saliva, however, make it important that it be thoroughly mixed with the food since its presence in the stomach stimulates the gastric glands. It also permits food to be tasted, since only when in solution will the food affect the nerves of taste. Furthermore, saliva aids in chewing and is indispensable in swallowing food, so that its digestive function is only one of several functions. The quantity secreted is much greater than one might suppose, being about three pints per day.

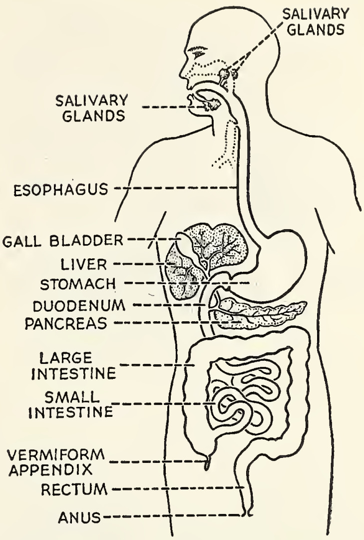
The steps of the digestive process in the mouth, then, are:

1. Food mechanically crushed
2. Food moistened for tasting and swallowing
3. Some starch changed to sugar by saliva
4. Some soluble mineral matter dissolved

Demonstration of salivary digestion. The action of digestive fluids can easily be shown experimentally. Starch paste is put into each of two tubes. Saliva is added to the one and water to the other. Both tubes are kept at about body temperature (98.6° F.) for a few minutes. If Fehling's test is applied,* the tube with the starch and saliva will now yield a sugar test, showing the digestive change wrought by the saliva. The tube with no saliva shows no sugar, as the starch remains unchanged.

The stomach. Passing from the mouth, the food enters the gullet, which at a distance of about nine inches enlarges into the stomach. This organ is located just beneath the diaphragm with the inlet at the left and close to the heart. Except when fully distended, it is not the smooth, pear-shaped organ usually

* The saliva used should also be tested for the presence of sugar.

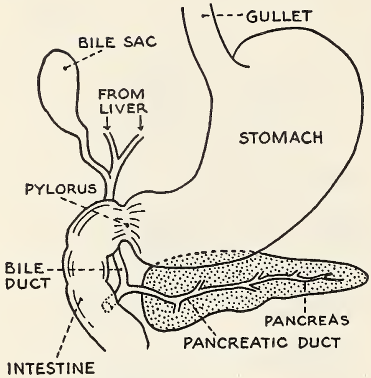


THE HUMAN DIGESTIVE SYSTEM

pictured, but may be collapsed and empty, or almost any irregular shape, depending on its contents and muscular movements.

Its function is largely to churn and finely divide the food. We usually eat at one time enough food to last for several hours. This food must be held somewhere, and the stomach provides the place. Also, chewing has only partly divided the food, so a second function of the stomach is to furnish the mechanical separation of the food particles by the churning motion of its muscular walls, an action called *peristalsis* [*peri stall′sis*]. The walls are also provided with millions of simple glands which secrete the gastric fluid at the rate of five to ten quarts a day.

Gastic fluid. The *gastic juice* contains hydrochloric acid and two enzymes, *rennin* and *pepsin*. The rennin acts on the casein (milk protein), changing it to curd, in which form it is more easily digested by other ferments.



THE STOMACH AND PANCREAS

(Note: Rennin is used in the production of cheese and junket tablets.)

Pepsin, acting only in the presence of an acid, changes some proteins to partly soluble products called *peptones* and also dissolves much connective tissue, thus exposing a greatly increased food surface for digestion in the intestine. Do not get the idea that all or even a great deal of protein food is completely digested in the stomach; in fact, as fast as they are finely divided, many proteins are discharged into the intestines where the pancreatic fluid completes protein digestion.

The stomach performs six functions, namely:

1. It acts as a reservoir for food until partly digested.

2. It mechanically divides and separates food particles.

3. Rennin curdles casein.

4. Pepsin acts on some protein and connective tissue.

5. Hydrochloric acid dissolves insoluble mineral matters.

6. Hydrochloric acid kills many bacteria.

The food, as it is discharged into the intestines, is called *chyme* [*kime*] and consists of:

1. The fats unchanged

2. Most of the carbohydrates

3. A large portion of the proteins

4. Some sugars, peptones, and water, which were not absorbed in the stomach.

It is evident that, so far, the food has been mainly prepared *for* digestion rather than digested. Digestion is chiefly accomplished in the small intestine.

Protein digestion. This may be shown by the same method as in testing for starch. Use cooked white of egg instead of starch, and a solution of pepsin in place of saliva. The egg in the pepsin tube will become soluble after a few hours and will yield a peptone test, showing that it is digested. The egg in the water of the other test tube remains unchanged and constitutes a check or control.

The intestine. The stomach connects with the *small intestine* by way of a muscular valve (the *pylorus* [*py lor′us*]) which prevents the food from passing through before it is thoroughly broken up in the stomach.

The intestine is the most important portion of the digestive tract, and consists of a coiled tube about twenty-nine feet in length. The part next to the stomach is about twenty-three feet long, over one inch in diameter and is called the *small intestine*, while the remaining five and one-half feet are over two to three inches in diameter and constitute the *large intestine*.

The small intestine joins the large at the lower right side of the abdomen, and at this point is the location of the appendix. Inflammation of this organ is called *appendicitis*.

Adaptations for increase of surface. To allow secretion of fluids and absorption of food to go on, much surface is needed.

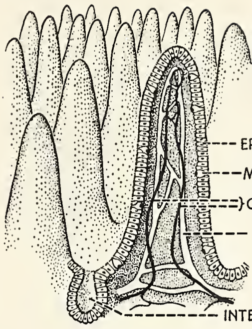
For this increase of surface, the intestine is adapted in three ways:

1. Its great length and coiled position in the body

2. Its inner lining projecting in creases and folds

3. Its lining (the small intestine) thickly covered with microscopic projections called *villi*

The villi are so fine and so numerous that, under a lens, the intestinal lining looks like velvet. By this means the absorbing surface is increased five times, so that the total area of the intestine is approximately twenty-five square feet or about twice that of the skin.



A Sectioned Villus

A layer of involuntary muscle in the intestinal walls contracts and expands continuously. This action, called *peristalsis*, has two functions.

1. It mixes and separates the food, thus constantly exposing it to digestive action.

2. It keeps the food moving slowly through the digestive canal.

The efficiency of digestion and absorption depends as much upon these muscular movements as upon the chemical action of the digestive fluids themselves. To provide the fluids for intestinal digestion there are three kinds of glands: (1) the intestinal glands, (2) the liver, (3) the pancreas.

Digestion in the intestine. Increased acidity of the food mass in the stomach causes the pylorus to open. Yet this same acidity in the small intestine causes the pylorus to close and is the signal for intestinal digestion.

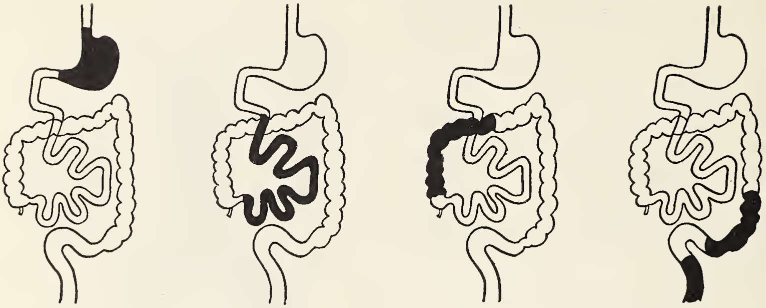
This action was long a mystery. Now we know that it is caused by a hormone called *secretin* produced by the cells of the lining of the small intestine. The moment an acid substance comes into the small intestine, these cells pass off secretin into the blood. The circulation soon brings it to the *pancreas* where it acts as a sort of physiological alarm clock to stimulate immediate secretion by the pancreas, the liver, and the intestinal glands.

The pancreatic juice secreted by the pancreas, the bile secreted by the liver, and the intestinal juice secreted by the intestinal gland are the three digestive juices which are found in the small intestine and which complete the process of digestion. All of these digestive juices are strongly alkaline and their enzymes will not operate in an acid medium.

Pancreatic fluid. The *pancreas*, whose secretion is by far the most important in producing the chemical changes of digestion, lies between the lower side of the stomach and the first fold of the intestine. The pancreatic fluid contains three strong enzymes: *trypsin* [*trip′sin*], *amylopsin* [*am ee lop′sin*], and *steapsin* [*ste ap′ sin*].

The trypsin acts like pepsin and completes the digestion of the proteins and peptones, changing them into *amino acids*. The amylopsin (like the pytalin of saliva) reduces starch to maltose sugar. The steapsin, by a process of emulsification, transforms fats to fatty acids and glycerine. The pancreatic fluid acts on any food except insoluble mineral matter.

The digestion of fat. Partial digestion of fat (*emulsification*) is shown by using



X-ray Diagrams of Food. The time required for an average meal to pass through the digestive tract depends upon the digestibility of the food eaten. When bismuth subnitrate is mixed with the food the mass appears black under the X ray.

olive oil or any other oil and a weak alkaline solution, such as sodium hydroxide or ammonia. Sodium carbonate produces an emulsion lasting indefinitely. The check tube this time should be prepared with oil and water. Shake the test tubes thoroughly. The oil and alkaline mixture will turn white and remain that way a long time, whereas in the other test tube, the oil will soon separate from the water, rising to a yellow ring at the top.

The bile. The *liver* is the largest gland in the body. It is located between the diaphragm and stomach, thus being the uppermost of the abdominal organs. The secretion of the liver is called *bile* and is a thick brown liquid, of which about one quart is produced daily. This is stored temporarily in a sac called the *gall* or *bile sac*. Bile has several important functions, as follows:

1. Bile is, itself, partly waste substance, removed from the blood.

2. It aids in digestion and absorption of fats.

3. It stimulates the action of the intestine.

4. It tends to prevent decay of intestinal contents.

The chief digestive action of the bile is on the fats, which it makes into a milk-like emulsion to be absorbed by the lacteals. If bile is prevented from entering the intestine, over half of the fats eaten are not absorbed.

Another important function of the liver is the storage of excess carbohydrate in the form of *glycogen* [*gly'ko jen*] or liver starch which the body may draw upon as a source of energy in emergencies. The liver, then, excretes waste, secretes a digestive fluid, and stores food.

The intestinal juice. The intestinal glands are small, simple, and numerous, located in the lining among the villi and secreting a strongly alkaline fluid containing sodium carbonate. The intestinal juice contains four enzymes, three of which act on carbohydrates and one which digests protein. *Maltase*, *sucrase*, and *lactase* are the enzymes which transform complex sugars to glucose. *Erepsin* [*ee rep'sin*] is a very important enzyme which is even more effective than trypsin of the pancreatic juice in producing amino acids from peptones. The final digestion of food, then, takes place in the small intestine, after the food has undergone the preliminary steps of (1) chewing, (2) salivary digestion, (3) gastric separation, and (4) gastric digestion.

Absorption. The general purpose of digestion is to put the foods in a soluble form so that they may pass through the body's membranes by absorption.

Absorption is the name given to the passage of digested food materials from the digestive tract to the blood or lymph. Absorption may take place (1) directly into the blood capillaries which richly supply the walls of the stomach and intestine, or (2) indirectly, by way of the lymph capillaries of the villi (lacteals) which also eventually empty into the blood circulation.

The capillaries of the gastric vein in the stomach walls absorb some water, and still less sugar, but the principal region of absorption is in the villi of the small intestine. Here the thin walls and enormous surface bring the digested foods close to the blood and lymph capillaries. Amino acids, sugar, salts, fatty acids, and water are passed into the blood stream, while the fats that have been emulsified are taken up by the lymph capillaries (*lacteals*) and carried by the lymphatic circulation to the *thoracic* duct and finally emptied into the general circulation, near the left jugular vein.

Assimilation. All the steps of digestion and absorption lead to the final processes of assimilation and oxidation, i.e., building up cells or using food as fuel. For this purpose the blood carries the absorbed foods to the tissues. These foods pass as *lymph* (by osmosis) from the capillaries to the lymph spaces which surround every living cell, and there the assimilation occurs. Every cell of the body is practically an island, bathed on every side by lymph, which brings *from* the blood the digested foodstuffs (and oxygen as well) and removes *to* the blood stream the waste matters produced by the cells' activities.

A comparison of plant and animal nutrition. The food that animals consume is either plants themselves or animal tissue made directly from plants. Therefore, without green plants no animal life would be possible. From raw

Digestion and Absorption

	Glands	Secretion	Enzymes	Changes	Absorption
Mouth	Salivary	Saliva (alkaline)	Ptyalin	Starch to maltose sugar	
Gullet	Mucous	Mucus		Lubricant	
Stomach	Gastric	Gastric fluid (acid)	Pepsin	Proteins to peptones	
			Rennin	Coagulates casein	Water, Salts } by capillaries of gastric vein
	Acid glands	Hydrochloric acid		Stimulates glands Dissolves insoluble mineral matter	
Intestine	Liver	Bile (alkaline)		Emulsifies fats	Fats by lacteals
	Pancreas	Pancreatic fluid (alkaline)	Trypsin Amylopsin Steapsin	Protein to amino acids Starch to maltose sugar Fats to fatty acids and glycerin	Amino acids, Salts, Sugars, Water } by mesenteric capillaries
	Intestinal	Intestinal fluid (alkaline)	Maltase Sucrase Lactase Erepsin	Maltose to glucose Cane sugar to glucose Lactose to glucose Peptones to amino acids	

materials plants produce carbohydrates in the form of starch, sugars, and cellulose; proteins such as the gluten of wheat, legumin of beans and peas, and zein of corn; fats found in the coconut; and oils from peanut, olive, and cotton seed. Most of this food formation takes place in the leaves of plants.

Plants do not have digestive organs. However, they secrete enzymes similar to those in animals. In plants *diastase* digests starch, *protease* digests protein, and *lipase* digests fats and oils. *Zymase* of yeast changes glucose to alcohol and carbon dioxide. Enzymes are not living, though produced by protoplasm. They are killed by high temperatures. A few plants like the Venus'-flytrap, sundew, and bladderwort capture insects and other protein food and digest them.

In plants the digestion of food is followed by the oxidation of a small amount of such food for the release of energy and by the assimilation of the remainder of the digested food into protoplasm. It should be noted that new protoplasm in both plants and animals can only be produced by protoplasm already formed. Nutrients have been prepared in the laboratory. In fact, during World War I, German scientists succeeded in producing fat synthetically. Any nutrient can be thoroughly digested inside glass dishes with prepared digestive juices. Yet the mysterious substance called protoplasm or "living matter" comes only by assimilation in living plants and animals. "Vivum ex vivo" (life from life). Plant protoplasm does not seem to be particularly different from animal protoplasm except for the differences in substances found in the cells of green plants and the cells of typical animals, as taken up in Chapter 3. After protoplasm has been formed in plants, some of it is broken down and changed into specific substances or secretions which are stored in different cells of the plant. Many such by-products of plant nutrition are useful to man for industrial or other requirements. Some of them are: resins, gums, drugs, narcotics, perfumed oils, cellulose, and vitamins.

Summary

Digestion, which is the most important phase of nutrition, makes food soluble so that it can be transferred to all cells of the body by osmosis, and changes it chemically so that it can be assimilated by these cells.

In order for food to be digested in man, it must first be ground and chewed. This function is performed by the teeth. While the food is being chewed it is mixed with saliva which partially digests certain foods, particularly starches. The tongue then pushes the chewed food into the gullet where it passes directly into the stomach.

In the stomach the food is mixed with gastric juice which continues the digestive process. Then the intestine receives the still undigested mass of food. Here it is further acted on by the pancreatic fluid and various other intestinal juices.

Finally it is entirely digested in the intestine, absorbed into the blood stream directly or due to the activity of the villi, carried to the various cells of the body by the blood, and assimilated and oxidized by them.

Plant nutrition differs from animal nutrition in several ways, but chiefly in the fact that plants do not possess specific digestive organs. Digestion occurs in each individual cell.

Using Your Knowledge

1. Interpret in detail the meaning of the statement, " The roots of the first teeth are absorbed." Mention several cases in connection with lower animals.

2. Many animals never chew their food and yet do not seem to suffer any ill effects therefrom. Can you explain why young people, then, are constantly urged to develop the habit of thorough mastication?

3. If gastric juice will digest protein and there is a considerable amount of protein in the walls of the stomach, why does not the stomach digest itself?

4. Can you trace any relationship between sugar stored or in circulation and insulin or adrenin?

5. Can you trace a spoonful of butter from the time it is eaten to the time when it is being oxidized for energy in the body, mentioning all changes and the agencies affecting same?

6. What is the source of the different enzymes secreted by the digestive gland — that is, where do the glands obtain the enzymes?

7. The digestive system has been likened to well-adjusted machinery. What power would you regard as the engineer?

Expressing Your Knowledge

enzymes	ptyalin	amino acid
palate	diastase	emulsification
tonsil	protease	bile
adenoids	pylorus	glycogen
gums	peristalsis	maltase
crown	rennin	sucrase
cement	pepsin	lactase
pulp	peptone	erepsin
enamel	chyme	fatty acid
dentine	alimentary	lacteal
gland	secretin	lymph
parotid	trypsin	lymphatic
submaxillary	amylopsin	lipase
sublingual	steapsin	zymase

Applying Your Knowledge

1. Place a small amount of starchy food into a test tube and test for sugar with Fehling's solution. Your test should be negative. Now obtain some saliva and add it to the food. Mix thoroughly. Now test for sugar and explain your results.

2. Obtain some prepared gastric fluid and pancreatic fluid. Test the action of each upon different foods. Your teacher will help you outline experiments.

3. Obtain a section of small intestine from a slaughter house and section it lengthwise. Place a portion under a lens and see if you can find the villi.

Chapter 42

The Release of Energy in the Body

Breathing is a word correctly applied to the physical means by which oxygen or air containing oxygen is brought into an organism, and by which waste gases, the chief of which is carbon dioxide, are given off. There are no distinct breathing organs in plants or in low forms of animal life, because the exchange of oxygen and carbon dioxide takes place constantly through the cell walls from the atmosphere.

Respiration, on the other hand, includes the process by which each living cell in the body takes in oxygen, uses it in oxidation, and gives off oxides, mainly carbon dioxide, water, and urea. Life depends upon respiration. Cells that cannot get oxygen die and may cause the death of the entire organism.

In many-celled animals, respiration would be impossible in parts distant from the breathing organs if it were not for the circulatory system which carries the oxygen to the cells and the waste products away from the cells to the excretory organs. In a human being, no more actual respiration (cell oxidation) goes on in the lungs than in any other active tissue of the body; but, as in all animals possessing organs of breathing, the lungs supply oxygen to the blood and receive carbon dioxide and water from the blood.

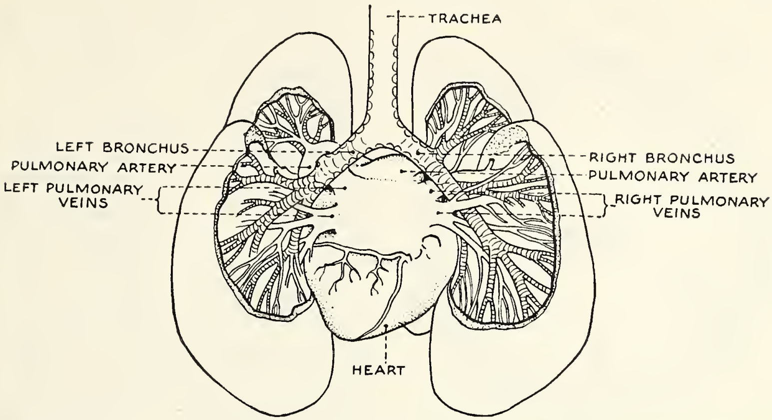
Respiration in the lower animals. Respiration in Protozoa takes place by direct contact of each cell with the air dissolved in the water. In the worms the blood circulates in the skin and obtains its oxygen direct from the air. In still higher forms, like crayfish or fish, gills are developed with great extent of surface to absorb the dissolved oxygen in the water. Insects take their air directly into the tissues and blood by way of their numerous complicated air tubes and so get along with a simple circulation. In amphibians, gills — temporary or permanent — lungs, and skin share in breathing. In birds, most reptiles, and mammals, the air comes to one place only (the lungs), while a complex circulation carries the oxygen to all parts of the body.

The organs of breathing. The organs concerned with breathing motions can be placed in two groups: (1) those concerned with holding and carrying the air, and (2) those which change the size of the chest cavity, causing the air to circulate.

The nose. The breathing system begins with the nose, which is adapted as an entrance for air (1) by the hairs and moist mucus to catch dust, (2) by the sense of smell to guard against bad air, (3) by its long moist passages which warm and moisten the air.

The mouth was not intended as a breathing organ except in emergencies, and habitual mouth breathers lose all the advantages mentioned above.

The trachea. Passing from the nasal cavity to the back of the mouth, the air enters the *trachea.* This is a large tube which opens into the throat at the back of the tongue, so that the food passes over it when we swallow. Its upper end is therefore protected by the base of the



THE HEART AND LUNGS. Pulmonary arteries bring deoxygenated blood to the lungs. Pulmonary veins take away blood laden with oxygen.

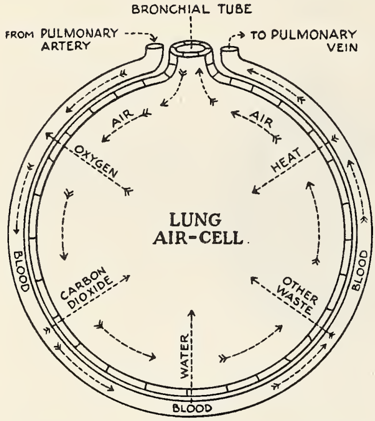
tongue and by a sort of self-acting lid (*epiglottis*) which closes when food is passing on its way to the gullet, situated farther back in the mouth cavity. The enlarged upper end of the trachea is the *larynx,* seen externally as the " Adam's apple," in which are situated the *vocal* (*speech*) *organs.* The walls of the trachea are supported by rings of cartilage, which hold it open for free passage of air.

The trachea and its branches are lined with cilia somewhat like those on *Paramecium.* These are in constant waving motion, and carry up toward the mouth any dust or dirt taken in with the air. This dust mixed with mucus is removed when we cough or " clear our throat." The nasal passages are also lined with cilia for the same purpose.

With the hand on the larynx, swallow a mouthful of food and notice two things: (1) how it rises and contracts inward to meet the epiglottis, (2) how the very base of the tongue moves back and down over the opening. Both movements are to allow the food to pass *over* the top of the trachea and *into* the gullet.

The bronchi and air cells. At its lower end the trachea divides into two branches (*bronchi*), one extending to each lung, where they subdivide into countless minute bronchial tubes. These finally terminate in thin-walled, elastic air cells of which the lung tissue is largely made. Thus there is provided in one organ (the lungs) enough surface to supply air (via blood) for the needs of the millions of body cells that have no direct access to air. The total area of the air cells in the lungs is about the same as the floor area of a room forty-four feet square or almost two thousand square feet.

The lungs. The lungs fill most of the body cavity from the shoulders to the diaphragm, except the space occupied by the heart and blood vessels. They are spongy, consisting mainly of the air tubes and cells and an extensive network of blood vessels and capillaries, all held together by connective tissue and covered on the outside by a double *pleural membrane.* Their shape is the same as the chest cavity, the upper part of which they completely fill. Between them is



RELATION OF BLOOD AND AIR IN THE LUNGS

the heart and below is the diaphragm, a muscular partition curving upward so that the lower lung surface is sharply concave. The *pleural membrane* that covers the lungs and lines the chest cavity is constantly moist and permits free motion of the lungs within the chest for breathing. *Pleurisy* is an inflamed condition of these membranes which makes breathing very painful and difficult.

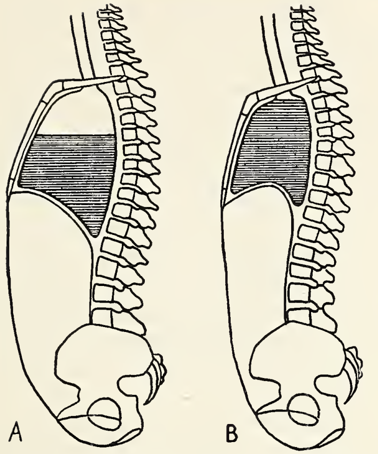
The blood supply. The pulmonary artery brings the dark (deoxygenated) blood to the lungs. There it divides into an extensive network of capillaries, completely surrounding each air cell. The thin, moist walls of both cell and capillary make easy the gaseous exchange of oxygen from air to blood and of carbon dioxide and water from blood to air, so that the pulmonary vein returns its blood to the heart, purified and laden with oxygen for the tissues. Carbon dioxide in the lung capillaries has a higher concentration than that in the connecting air cells. Hence, carbon dioxide diffuses outward into the area of lower concentration in the air cells. Water passes out of the blood for the same reason. By applying the same principle, see if you can explain how oxygen passes from the air sacs through the capillary walls into the blood, then into the hemoglobin of the red blood cells.

Air capacity of the lungs. The total capacity of the lungs is about 350 cubic inches, of which our ordinary breathing utilizes about 30. By an effort we can take in and force out an extra hundred or more, while there is about another hundred cubic inches which we cannot get out at any one breath. When we realize the great importance of oxygen to the tissues these facts ought to be an argument for fresh air, deep breathing, and loose clothing. We use little enough of our lungs at best, and so every effort ought to be made to increase their activity. The one-third of the air which cannot be forced out of the lungs provides for constant diffusion. Breathing is an intermittent process, but the blood's supply of air has to be continuous, hence the need for air always in the lungs. A reason for deep breathing is to mix as much fresh air with this " residual air " as is possible at each breath.

Breathing movements. The process of getting air into and out from the lungs is rather complicated and consists of two sets of operations: *inspiration* (breathing in) and *expiration* (breathing out), which we somewhat wrongly call the acts of respiration.

The diaphragm. The chief breathing organ is the *diaphragm,* a muscle (not a mere partition) which extends across the body, curving upward, as a floor to the lung cavity. When its muscles contract it tends to pull down straighter across the body, thus giving the lungs more room but compressing the abdominal organs beneath it at the same time.

The rib muscles. Second in importance are muscles between the ribs which lift them up and outward. This enlarges the



BREATHING MOVEMENTS. A: position of the diaphragm during inhalation. B: position during exhalation. The shaded part indicates the stationary air.

lung cavity but, what is more important, bends the elastic rib cartilages, which tend to spring the ribs back in place. Another set of rib muscles helps to pull the ribs downward.

Air pressure. The third important factor in inspiration is the pressure of the outside air which rushes in to occupy the extra space thus provided and, by so doing, expands the elastic tissue of the lungs. Inspiration, then, consists of (1) depression of diaphragm and compression of abdominal organs, (2) raising the ribs and bending the rib cartilages, (3) air pressure, expanding the lung tissue.

Expiration. Expiration is merely the springing back of the organs that have been compressed by the movements of inspiration. It consists of the following steps: (1) the elastic reaction of the compressed abdominal organs, (2) the springing back of the rib cartilages, (3) the contraction of the elastic lung tissue.

All of these tend to make the lung capacity less and force out the air, against its own pressure. The change of position of the ribs, diaphragm, and abdominal organs can be felt in our own bodies.

The rate of breathing. This double process takes place from 16 to 24 times per minute, depending upon activity, position, and age. The more oxygen the tissues need, the more rapidly the lungs have to operate to supply the blood with it, to be carried to the tissues. This is automatically regulated by the amount of oxygen or carbon dioxide which is in the blood. When there is too much carbon dioxide present, it stimulates the respiratory centers in the brain and they produce more rapid breathing. Too much oxygen has the opposite effect. An injection of CO_2 will quickly increase the rate of breathing.

Air changes in breathing. Air contains only about 20 per cent of oxygen. Of this, only about one-fourth is absorbed in the lungs by the *hemoglobin* [*heem' oh globe in*] of the blood. In the circulation, the hemoglobin can give out only about one-half the oxygen it contains, so, unless we breathe deeply and keep our breathing apparatus in healthy working order, the tissues may receive too little oxygen. Since oxidation (union of oxygen with tissue) is the only source of physical energy, this matter is of great importance. Muscular energy appears to come from a complicated series of chemical changes in the muscles in which glycogen, glucose, or some similar digested sugar is changed into lactic acid. This liberates ample energy for the activity of the body.

Oxidation is necessary to remove part of the lactic acid by converting it into carbon dioxide and water in the usual oxidation reaction. This partial oxidation appears to change the remaining lactic acid back into glycogen again, which can be used over by the muscles. This is the modern view of the function of oxidation in the muscles.

If oxygen is lacking, lactic acid accumulates and produces "fatigue," which stops muscular action unless it is removed by oxidation. It is thus apparent that oxidation is essential to muscle action, but in a different way from what was formerly supposed.

Expired air has lost about one-fourth of its oxygen, but receives from the tissues 100 times as much carbon dioxide as it had when taken in, also a large amount of water vapor and heat, together with a very little organic waste matter.

The following table is taken from Howell's *Physiology*.

	Nitrogen	Oxygen	Carbon Dioxide
Inspired air	79	20.96	0.04
Expired air	79	16.02	4.38

Respiration. The term "respiration" is often used incorrectly to refer to the acts of inspiration and expiration which constitute breathing. True, breathing is an important step in respiration, but it is only a part of the total process. We might consider it *external respiration* since breathing involves the organism and the atmosphere without. True respiration is, however, a cell process. It is just as important that bone, nerve, and muscle cells carry on respiration as the cells which compose the lungs. Cell, or internal, respiration concerns the exchange of gases between the cell protoplasm and the blood. The blood, in turn, must move constantly as a medium of transportation between the lungs and the cells.

Oxidation. *Oxidation* is a chemical process occurring in all living matter. *Respiration*, on the other hand, is the physical exchange of gases between living matter and its environment, whether it is the outside atmosphere or the body fluid. During respiration, oxygen enters the protoplasm where it reacts chemically with food substances and lactic acid and releases energy for cell activity. Carbon dioxide forms during these chemical processes and must be removed as it is formed. The removal of the waste resulting from oxidation is a part of respiration.

Metabolism. Respiration and oxidation are part of a complex series of body processes which are included in *metabolism*. All processes, both physical and chemical, which are concerned with the activity, maintenance, and growth of an organism constitute metabolism.

Growth and maintenance concern the assimilation of food. During assimilation, food substances are reorganized in the tissues to form new protoplasm. In some strange way, the new protoplasm is given the power of life from the protoplasm which organized it. Growth and maintenance processes, like all other types of protoplasmic activity, require energy. This energy must come from food and must be released through the process of oxidation. Thus, the energy relations between food and living matter constitute another important phase of metabolism. The rate of respiration affects the rate of oxidation, while the amount of energy released is governed directly by the rate of oxidation. All three are regulated by the activity of the body.

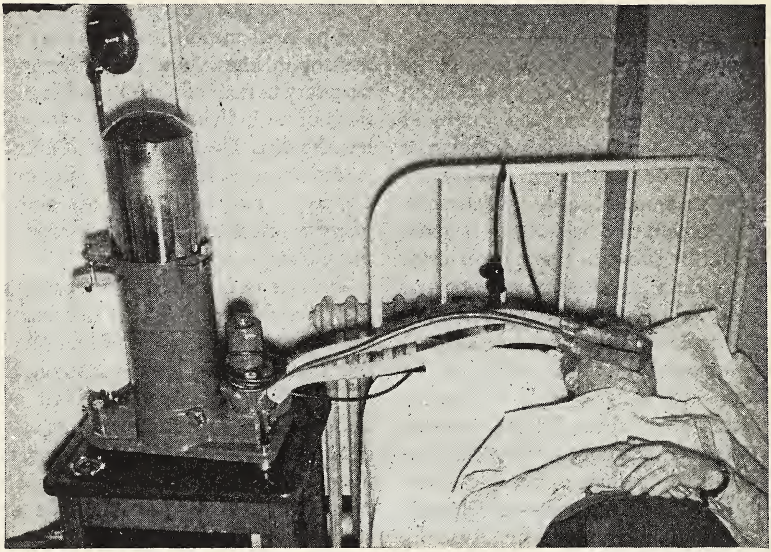
Body oxidation and its measurement. The rate of oxygen intake, respiration, and energy release are increased in proportion to the activity of the body. This activity may be muscular, as in the case of walking, running, or some other form of exertion, or it may be mental. Other factors governing the rate of oxidation include exposure to cold and activity of the digestive organs during digestion of food. The rate of oxidation in the body may be measured directly by determining the amount of heat which is given off from its surfaces. Energy loss from the body may be measured by means of a device called a *calorimeter*. The individual to be tested is placed in a closed compartment which is equipped to measure accurately all of the heat which is given off by his body. The patient may lie quietly in bed during the process, or he may sit in a chair or exercise vigorously by pedaling a stationary bicycle within the chamber, depending upon the nature of the activity to be tested. The amount of heat energy given off during each type of activity is a direct indication of the rate of oxidation in the body tissues. Calorimeter tests are important in determining the energy needs of various individuals in order to adjust a diet to their specific requirements.

Basal metabolism and its measurement. Even when the body seems completely inactive as in sleep, respiration, oxidation, and energy release are continuing. With the cessation of muscular and, to a great extent, nervous activity, the rate of oxidation is greatly reduced. The activities required to maintain the body and to supply energy necessary to support the basic life processes are included in the term, *basal metabolism*. Individuals vary greatly in their rates of basal metabolism. Perhaps you know certain people who are naturally quite nervous tend to run a slight temperature, and eat rather heavily without storing food. Those individuals likely have a high rate of basal metabolism. The opposite symptoms may indicate a low rate of basal metabolism. It is very important to know how much energy is necessary to maintain the basic life functions of an individual in order to regulate the diet. The basal metabolism rate is important in determining, also, overactivity or underactivity of the *thyroid gland* which has a direct effect upon the metabolic processes.

The rate of basal metabolism may be determined by means of the calorimeter. During the measurement of heat loss in the course of the determination, the patient must be at complete rest and must not have food in the process of digestion. During the calorimeter test, the use of energy to maintain body temperature is avoided by providing the test chamber with body temperature. In the calorimeter test, the amount of heat given off is expressed in terms of Calories per hour. This figure, in turn, is used to determine the basal metabolism rate.

Another method, widely used in hospitals, measures the amount of oxygen consumed in a measured period. The patient rests for at least one hour prior to the test. The tests are usually run in the morning and the patient is instructed to eat no food until after the test is completed. After the rest period, intended to relax the body, the patient lies quietly. The nose is plugged to avoid breathing from the atmosphere. A mouthpiece connected to a tank of oxygen is fitted into the mouth. During a period of several minutes, all oxygen consumed is from the measured tank. Oxygen consumption is recorded on a graph. From the amount of oxygen consumed during a given period, the rate of oxidation during basal metabolism may be calculated.

External influences upon breathing and respiration. In addition to the effect of body processes upon the rate of



Monkmeyer Press Photo Service.

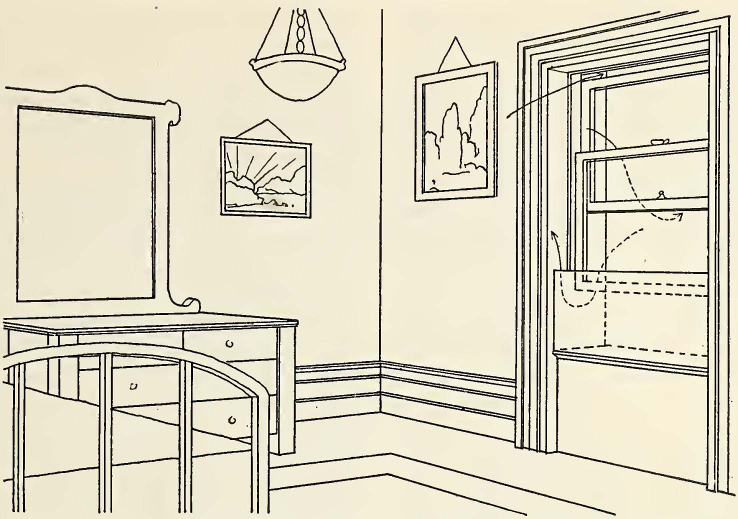
BASAL METABOLISM TEST

breathing and respiration, certain external factors have an important influence. These external influences are of tremendous importance. Increase in the rate of breathing may compensate for many unfavorable external conditions, but under extreme conditions, the entire activity of the body may be affected. In some cases, death may result from lowering of respiration below the point necessary to maintain life. One of the most important external factors influencing breathing and internal respiration is *ventilation*.

Ventilation. The fact that air in a "close" room becomes unfit to breathe is due mainly to the excess moisture and heat, and not to the carbon dioxide, or lack of oxygen, as was formerly supposed.

The carbon dioxide in expired air was produced by the union of oxygen and the carbon of tissues, or lactic acid. The water was produced by oxidation of the hydrogen, and the heat was the result of both oxidation processes. We use annually about 10,000 pounds of air (28.7 pounds per day) from which we take about 650 pounds of oxygen and give off about 740 pounds of carbon dioxide. We breathe out about 9 ounces of water every day, half a pint in liquid form. These figures will give some idea of the amount of work done by the respiratory organs and their importance to life.

Proper ventilation is concerned, not only with supplying fresh air, but with the removal of water vapor, heat, and, least important of all, carbon dioxide. Circulation of air in a room will often relieve breathing conditions by lowering the body temperature and removing excess water vapor from the vicinity of the body. We usually have oxygen enough in any ordinary air supply, and seldom



Efficient Ventilation. Can you explain the air currents as indicated by the arrows?

does the carbon dioxide cause trouble, but very often the temperature and amount of water vapor produce unpleasant and even dangerous results.

"Keeping cool" consists not in *keeping* heat out but in *getting* it out. We get rid of about 100 Calories per hour, which is somewhere near the amount of heat given off by four ordinary electric lights. To evaporate a quart of water requires 500 Calories. If the air conditions permit rapid evaporation, our perspiration will remove heat at this rate and keep the body comfortable. If the air already has much moisture in it, evaporation is hindered and our temperature rises — unless heat is eliminated in some other way.

Heat tends to "run down hill." If the air is cooler than our body temperature (98.6 degrees), we lose more or less heat, depending on the difference. If the air is much cooler, we use clothing to hinder the flow of heat from body to air. If the air is warmer, we cannot easily get rid of our bodily heat, and suffer in consequence.

It is thus evident that ventilation has to do with moisture and temperature of the air, even more than with its composition. A recent report of the New York State Commission on Ventilation proved that temperature and amount of moisture in the air were more important than the proportions of oxygen or carbon dioxide. The following facts are based on this report.

A temperature of 68 degrees or less, with sufficient change of air to remove odors without creating drafts, was found to be best. Excess moisture, especially in hot air, causes great discomfort. The heart action and breathing increase and symptoms like fever develop. There is a tendency to closure of the nasal passages and an increase in liability to take cold when going out into cold air.

These same conditions are felt on hot and "humid" days in summer. So much moisture is in the air that the body cannot readily get rid of the perspiration. This interferes with its heat regulation, and discomfort or dangerous overheating may ensue. Extra moisture is less troublesome if the air is cool, and if the air is in motion the bodily heat is carried off better. Hence a fan does promote comfort though it may not cause any change in the composition of the air.

"Fresh" air is refreshing not so much because of less carbon dioxide or more oxygen as because it is usually cooler and less laden with moisture. Hot, moist, fresh air is about as bad as stale air from indoors, though really stale or ill-smelling air reduces ability to work and interferes with the appetite.

Window ventilation, using muslin screens to prevent drafts, is a satisfactory plan in many cases. In large buildings forced draft has to be used, and moisture and temperature must be carefully watched. In homes, windows, doors, and fireplaces provide plenty of fresh air if the temperature, moisture, and circulation are looked after. Air moisteners in furnace-heated houses will prevent the air from becoming too dry. In schools and crowded rooms the danger is from too much moisture and too high a temperature. There is no special value in extremely cold air except in the treatment of tuberculosis or similar diseases.

Respiratory diseases. Colds, catarrh, bronchitis, influenza, pneumonia, and tuberculosis are infections of the respiratory tract. Specifics and serums have been developed for some of these diseases, but none as yet can be entirely relied upon. It is quite probable that a filterable virus will be found to be the offending agent in the case of colds and influenza.

Many theories and methods for the prevention and cure of colds are advanced by their advocates. Some of them seem to be successful with certain individuals. In general it may be said that the best kind of protection is normal and rational living. This means accustoming the body to fresh air, out of doors and indoors, drinking plenty of water and fruit juices, eating and exercising moderately, resting sufficiently, and facing each day with a tranquil mind and a zest for living.

The steady decline in the death rate from tuberculosis, which Dr. Logan Clendenning thinks has been going on for at least the past seventy-five years, is one of the cheering things of civilized life. Among the undoubted factors are better distribution of food and better housing conditions. The treatment for tuberculosis no longer calls for drugs, but rather for rest, fresh air, nourishing food, and peace of mind. One of our worst enemies is fear and discouragement. All authorities agree that almost everyone "gets" tuberculosis in some degree at some time in life. In practically all cases the tuberculosis germs are overwhelmed by the body defenses and are either killed or walled up. Overwork or undernourishment may produce a fresh outbreak of the germs, but if discovered in time such attacks can be controlled.

A comparison of plant and animal respiration. All living things get energy for their functions and activities from the oxidation of protoplasm or food. In animals, cellular respiration takes place, as you know, in all living cells of the body, though probably to a greater degree in the lungs and muscles than elsewhere. In plants, the parts most nearly corresponding to the lungs are the leaves, into which air containing oxygen can easily enter through the stomates and penetrate the intercellular spaces in the interior of the leaf. Yet, everyone knows that leaves do not draw air into the plant. In all animals except Protozoa, there are special ways of bringing the oxygen to the distant cells of the body. Usually the blood is the carrying agent, though in insects air is brought directly to the body cells by special tracheal tubes. All living plant cells, as well as animal cells, must be able to get oxygen, but there are no special tubes to carry it through the plant. Stems that appear solid have lenticel openings; roots absorb oxygen from the ground. Once inside the plant, air containing oxygen penetrates into the spaces between cells. Also, when oxygen has been absorbed by the cell sap of one cell, it can pass by diffusion to the next cell until consumed. Doubtless a considerable quantity of oxygen is dissolved in the liquids that circulate through the plant. Probably carbon dioxide is eliminated from the plant in the same way, being dissolved in circulating liquids and thus being brought near to the surface or near stomates and lenticels.

Summary

Respiration is the exchange of gases between living matter and its surroundings. In the simplest animals it takes place directly between the cell and its environment. In the more complex forms, blood is necessary as a conducting medium between the cells and the outer environment. Air tubes of insects, gills of fish, and lungs of higher land animals are special devices which provide the blood with oxygen to be carried to the cells and to remove cell wastes from the organism.

The organs of breathing in man include the nose and throat, trachea, bronchi, and the air passages of the lungs. Breathing movements are accomplished by action of the ribs and diaphragm. Air enters the lungs during inspiration and is expelled, with carbon dioxide and water delivered from the blood, during expiration. Inspired air contains more oxygen and less carbon dioxide than expired air.

Respiration, oxidation, and energy release are closely associated in living things. These processes, together with growth and repair processes constitute metabolism. Basal metabolism is the activity necessary to maintain the fundamental life processes without any special activity. It is measured in terms of oxidation and energy release. Ventilation is important in relation to respiration as an environmental influence.

Using Your Knowledge

1. Explain the importance of the lashing cilia which line the trachea and bronchial tubes.

2. Do you take air into your lungs because the chest cavity gets larger, or does the chest enlarge because it is forced to expand by the in-rushing air?

3. Explain why determination of the rate of basal metabolism and metabolism under various forms of exertion are important in determining the Calorie needs of an individual.

4. Describe the method by which energy loss from the body may be measured.

5. Explain the mechanics of artificial respiration.

6. Explain the relation between breathing rate and body activity.

7. Compare plant and animal respiration. Do plants " breathe "?

Expressing Your Knowledge

respiration	epiglottis	pleurisy
oxidation	larynx	residual air
breathing	bronchus	metabolism
inspiration	bronchial tubes	basal metabolism
expiration	diaphragm	calorimeter
trachea	pleural membrane	ventilation

Applying Your Knowledge

1. Have each member of the class check his breathing rate per minute. Tabulate all results and determine the average for the entire class.

2. Check your own rate of breathing under different conditions such as resting, walking, climbing stairs, and running.

3. Prepare an artificial apparatus to demonstrate breathing. Use a bell jar to represent the chest, a rubber sheet fastened over the open end to represent the diaphragm, a Y tube inserted through a rubber stopper at the top to represent the trachea and bronchi, and a pair of balloons fastened to the Y tube to represent the lungs. Raise and lower the rubber sheet and see what happens.

4. Consult a doctor or a nurse for a detailed account of the method used in determining the rate of basal metabolism. Report your findings to the class.

5. Learn and demonstrate the procedure in performing artificial respiration.

Chapter 43

Circulation

The lower animals and plants are so minute that no special system is necessary to carry substances from place to place within the organism. A system of transportation, however, is set up as soon as the organism develops to a many-celled stage and thus has division of labor. If food is taken in at a certain place and digested in a certain place, how shall distant parts of the organism be fed? How shall internal cells which are not near the surface get rid of wastes? The cells of the breathing organs are "lucky" enough to get plenty of oxygen, but not so the distant cells. One of the primary problems of all the higher animals is this one of transportation of food, oxygen, and wastes and the equalization of heat. The blood is the carrier, the blood vessels are the tubes, and the heart is the pump.

Circulation in lower animals. A circulatory system is not found in simple animals like protozoans, sponges, and *Hydra,* because they have so few cells that each can obtain its own food and oxygen and throw off its waste without the need of a set of special circulatory organs. We do not find a transportation system within our own home, nor even in a small village, for each individual does his own carrying. In larger cities street railways or busses are necessary, while to care for a whole state numerous highways, railroads, and canals are required.

It is the same in animal structure. The simple forms have no circulatory transportation; in higher types (earthworm) there are simple circulatory organs. In still more complicated organisms (crayfish) a heart and blood vessels are required, while in the vertebrates, especially birds and mammals with their highly specialized organs, there is needed a complete and complex transportation system in order that each cell may be supplied.

Now we may carry our comparison between cell functions and life on Crusoe's island a step further and find another result of specialization. Like the one-celled protozoan, Crusoe had to perform for himself all the functions of life, such as preparing his food, making his clothes and building his home. The higher forms of life are like small communities where one man may build the houses or another specialize in making clothes. This would correspond to the first steps in specialization, as shown by sponges, *Hydra,* etc. As the communities grow, many men work together at one trade to supply all, and this would illustrate the grouping of specialized cells into tissues, each performing its cooperative function for the whole animal. Then in larger communities the wants are more numerous, more groups of men specialize in different trades and supply others at a distance with their products. This is the stage represented by the higher animals, where a transportation (circulatory) system is required. In man this is accomplished by the blood, which is kept in motion by the heart, and flows through arteries, veins, and capillaries.

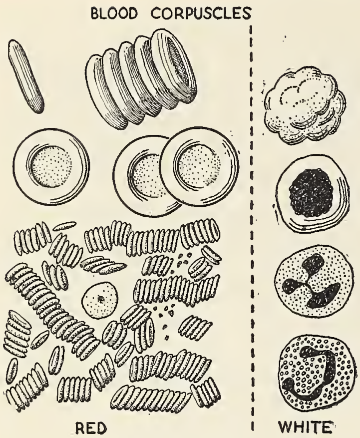
In warm-blooded animals, such as man and the other mammals, and the birds, the circulation is rapid. In the other vertebrates and the insects, all of which are "cold-blooded," the circulation is sluggish, especially in low temperatures. In a hibernating frog the heart hardly beats.

The blood. The blood is a fluid tissue, 80 per cent of which is water, and which constitutes about one-thirteenth of the weight of the body. It consists of a liq-

The Function of the Blood

TRANSPORTATION

Transportation of	From	To	For the purpose of
Digested food	Digestive organs	Tissues	Supplying energy Building new tissues Rebuilding used tissues
Waste	Active tissues	Lungs Skin Kidneys	Removing harmful or useless substances, such as urea, carbon dioxide, water, etc.
Oxygen	Lungs	Tissues	Releasing energy by oxidation
Heat	Active tissues	Skin	Equalizing temperature at 98.6° F.
Secretions	Ductless glands	Various organs	Regulates growth

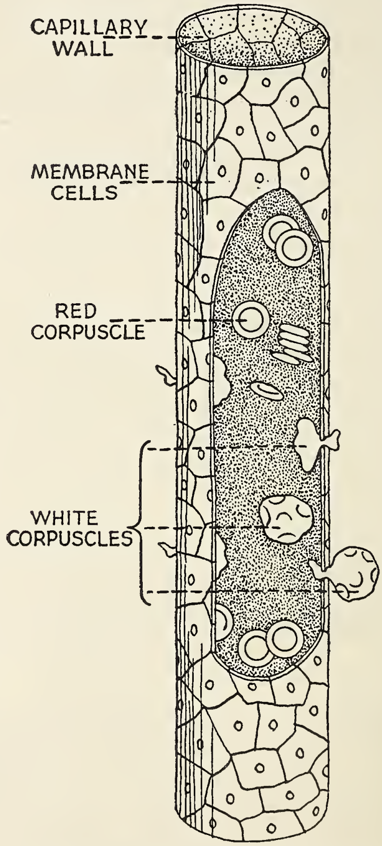


Blood Corpuscles

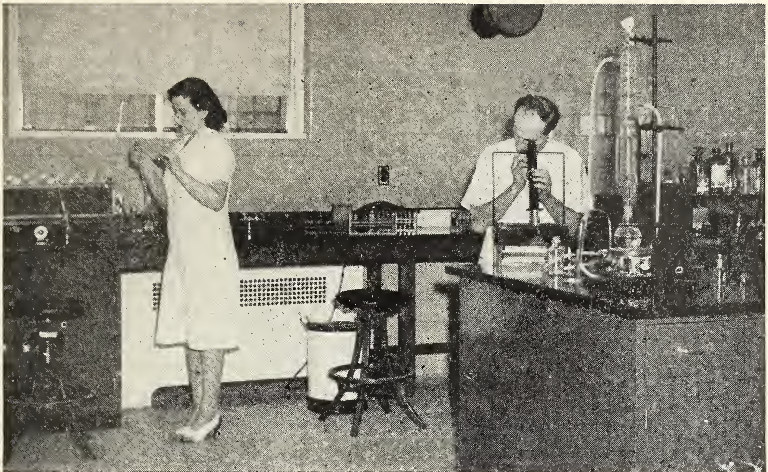
uid portion called *plasma,* nine-tenths of which is water, and solid portions called *corpuscles* or *blood cells.* The plasma constitutes the bulk of the blood and consists of a liquid (*serum*) which carries the food and waste products, and a protein substance (*fibrinogen* [*fibe rin'oh jen*]), which when exposed to air aids in forming a clot to stop bleeding. The corpuscles are of two sorts, red and white; the former much more numerous, thus giving the red color to the blood.

The red corpuscles are minute, disc-shaped blood cells, so small that ten million can be spread on a square inch, yet so numerous that there are enough in the average body to form a row four times around the equator. They are formed in the red marrow of the bones. Their red color is due to a complex iron compound (*hemoglobin* [*heem'oh globe in*]) which easily unites with oxygen and forms a compound called *oxyhemoglobin* [*ox'ee heem oh globe in*]. Oxygen is thus carried from the lungs to the tissues where oxyhemoglobin gives up its surplus oxygen. When laden with oxygen red corpuscles are bright red, but become darker when the oxygen is removed, causing the difference in color of the blood on going *to* and coming *from* the tissues.

The white corpuscles or *leucocytes* [*lu'ko sites*] are almost colorless and can change their shape much like the *Amoeba.* Unlike the non-nucleated red blood cells, each has from one to five nuclei. They are larger and fewer than the red corpuscles, the average number



Section Through a Capillary. Note the movement of the white corpuscles through the capillary wall.



Ewing Galloway, N.Y.

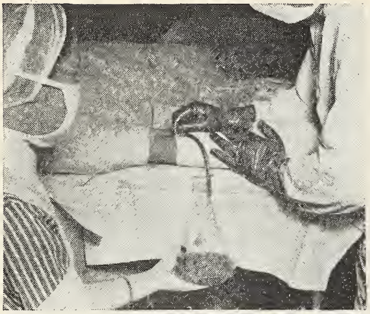
Typing Blood. These laboratory technicians are analyzing blood tests and typing blood.

being about one white blood cell to every one thousand of the red blood cells. There are several kinds and their functions differ, but seem to be concerned in aiding the absorption of fats and in destroying disease germs in the body. They are formed in the lymph glands and bone marrow. They have the power to penetrate the capillary walls and wander through the lymph spaces; they collect at wounds and points of infection and oppose the entrance and attack of disease germs.

Blood *platelets* are the smallest organized bodies found in the blood. They are only one-third as large as the red blood cells. They easily disintegrate and in some way, not yet entirely known, aid in clotting by changing fibrinogen to *fibrin*.

Hemophilia. Some individuals seem to lack the necessary ingredients in the blood to form a clot. This dangerous condition or disease is called *hemophilia* [*heem oh feel′eeah*]. Its victims, always males, may bleed extensively from even slight wounds. Unfortunately, this unusual disease is hereditary and is transmitted from mother to son, though strangely enough no woman has ever been known to suffer from it.

Healing a wound. In the healing of a cut there are several processes set at work by the blood. First, as the blood oozes out, fibrinogen is exposed to the air, and due to the action of an enzyme in the blood hardens to fibrin. This entangles the corpuscles, and a clot or scab forms. Then the blood supply is automatically increased to rebuild new tissue and bring extra white corpuscles valuable to oppose infection. This causes the redness (inflammation) usually noticed. As the fibrin forms, it contracts, causing the puckering of a scar and, as fast as new tissue is built, the clot or scab is shed. A slight scratch or blister often lets only the plasma through, while a "black and blue" bruise is in part due to breakage of capillary walls and consequent clotting of blood under the skin.



Ewing Galloway, N.Y.

DONATING BLOOD. This patient is giving his blood to be used in a blood transfusion to another patient.

Normal changes in composition of blood. The composition of the blood is constantly changing as it receives and distributes its various substances. This is shown in the table on page 475.

Probably the blood is actually " purest " when leaving the kidneys, though it is still dark colored, due to lack of oxygen. It is therefore not correct to speak of " dark blood " as always being " impure blood."

Abnormal changes in composition of blood. When there is considerable loss of blood through *hemorrhage,* there is an immediate lowering of the number of red blood cells. Under normal conditions the body will have made good this loss in a month or two. When the number of red corpuscles or the quantity of hemoglobin is reduced through disease this condition is called *anemia* [*an eem'ee ah*]. A diet rich in liver has been found to be of great benefit in such cases. Sometimes blood transfusion from a healthy person having the same type of blood also aids. The diagnosis of anemia is made by making a blood count of a diluted sample of blood under the microscope, using a slide accurately ruled into squares for that purpose.

Blood plasma. Conditions such as hemorrhage, surgical and wound shock, and severe burns have long been treated by means of whole blood transfusions. Blood so transferred to a patient replenishes not only the necessary liquid or plasma but also the blood cells. The problem in this transfer, however, is to match the blood of the donor with that of the patient. This is difficult because there are four distinct types of human blood. These are designated as the A, B, O, and AB types. Use of wrong types may result in the death of the recipient. Later it was found that, in the majority of cases requiring blood transfusion, whole blood is not necessary since the main need of the individual is for volume of liquid in the blood stream. The human body normally possesses an adequate reserve supply of red blood cells. Consequently plasma has replaced whole blood in most cases of blood transfusion. Certain definite advantages are gained through the use of plasma. The necessity for selection of one of the four types of whole blood is eliminated. Furthermore, we are now able to dry the plasma which facilitates its storage and distribution. When a transfusion is needed, powdered plasma is dissolved in distilled water and used. During World War II, thousands of donors donated their blood to " blood banks " enabling transfusions of whole blood and plasma which saved the lives of countless servicemen and civilians.

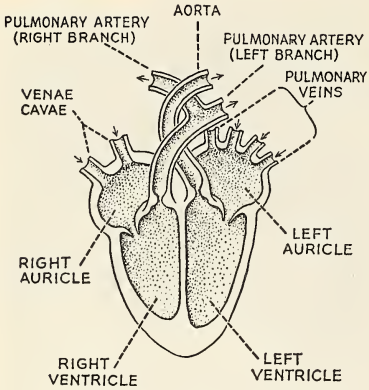
The heart. The heart is a hollow, cone-shaped muscular organ, located behind the breastbone, between the lungs, nearly on the center line of the body; the point is downward and lies between the fifth and sixth ribs a little to the left. Since the beat is strongest near the tip, it has given the false idea that the whole heart is on the left side. The heart consists of

Changes in Composition of Blood

Where	Blood loses	Blood receives
In all active tissues	Materials for growth, repair, and energy	Wastes of oxidation Carbon dioxide, water, and urea
In walls of digestive organs	Materials for making digestive fluids and for growth, activity, and repair of the digestive organs	Digested nutrients
In the lungs	Carbon dioxide and water	Oxygen
In the kidneys and skin	Water and urea	Traces of carbon dioxide
In the ductless glands	Materials for making hormones	Hormones; wastes
In the spleen	Functioning red blood cells Functioning white blood cells	Broken down red blood cells Broken down white blood cells
In the bones (marrow)	Nutrients	White blood cells Red blood cells
In the liver	Glycogen and amino acids, to be stored	Fibrinogen Urea Glycogen to be oxidized Amino acids to be assimilated or oxidized

two halves, right and left, each of which consists of a thin-walled *auricle,* and a thick muscular *ventricle.* The auricles act as reservoirs for the incoming blood, permitting a steady flow, and their contraction aids the rapid filling of the ventricles. The ventricles, by alternate expansion and contraction, force the blood into the arteries and so around the body. Between each auricle and its ventricle are *valves* which allow blood to enter the ventricle but prevent its exit except by the arteries, and at the base of each artery are valves preventing the blood from flowing back into the ventricles.

The action of the heart. The right auricle receives deoxygenated blood from the veins through which it has been collected from the whole body. This passes through the valve into the right ventricle, which, when it contracts, forces it to the lungs, via the pulmonary arteries. In the lungs, the blood receives a new load of oxygen, unloads some carbon dioxide and water, and returns via the pulmonary veins to the left auricle. From here it passes through the valves into the left ventricle and is thence forced out through the aorta to all parts of the body. The ventricles contract and expand together so there are two waves of blood sent out at each beat, one to the lungs and one to the general circulation. While the ventricles are contracting and forcing *out* their blood, both auricles have been filling so there is no stop in the flow. The heart is more powerful, in proportion to its weight, than a locomo-



THE HUMAN HEART

tive; more accurate in its action than a watch. It rests only between beats, and it repairs its own wear — a truly wonderful organ, but one that we take for granted and often abuse by overwork or improper habits.

Systemic circulation. The left ventricle has thicker walls than the right ventricle because it has more work to do. When it contracts, the blood it contains is forced out between valves into the largest blood vessel of the body, the *aorta.* This branches, and blood is thus carried all over the body. By means of smaller divisions called *capillaries,* the blood is enabled to come close enough to cells to discharge food and oxygen to them, taking up wastes in return. It then flows into small veins leading back to the heart. During the systemic circulation, the blood passes through the kidneys where it eliminates urea, and through the intestinal walls where it gains a fresh supply of food.

Portal circulation. The passage of venous blood from the stomach and the intestine through the liver requires special blood vessels comprised in the portal system. By passing through the liver, the carbohydrate content of the blood is kept uniform.

Pulmonary circulation. When the venous blood reaches the heart it enters the right auricle on the side opposite to that from which it started out on the journey through the body. It is received by the right auricle from which it passes into the right ventricle. When this contracts blood is forced through the pulmonary arteries to the lungs, where it gives up its load of CO_2 and receives oxygen. Having been oxygenated it returns through the pulmonary veins to the left auricle and ventricle from which it starts out again on a trip around the body, a journey completed in about thirty seconds, unless diverted.

The rate of beat. The rate of heartbeat is normally 72 times per minute in men, 80 in women, much higher in young children and in very old persons, reaching the average at about twenty years of age. Naturally, the amount of blood needed is affected by exercise, temperature, food, excitement, pain, etc., and so all these automatically change the rate of heartbeat. When we run upstairs (a bad habit, by the way) we use more energy, hence oxidize more tissue,

Ewing Galloway, N.Y.

A BLOOD TRANSFUSION. This student nurse is pouring blood, which has been donated, into the flask. It was kept in a refrigerator until the nurse needed it for this patient.

hence need more oxygen to be brought by the blood, and produce more waste, which must be carried off.

With the body at rest, the heart pumps about five pints of blood per minute. Walking raises the amount to twenty pints and running upstairs increases it to thirty-five pints per minute.

The total amount of blood in the body is about 8.8 pints, hence the left ventricle handles all the blood about four times per minute. When we realize that the actual muscle used in the ventricle weighs only about a quarter of a pound and is only half an inch thick, we can get some idea of the efficiency of the heart as a pump. In twelve hours the heart does enough work to raise a 150-pound man the height of the Woolworth Building.

Fear, anger, worry, and mental states in general also affect the action of the heart and influence other bodily functions. If the heart is to operate properly, the state of mind ought to be carefully controlled, instead of blaming a bad temper on heredity.

The blood vessels. These are tissues which vary in size and which carry blood to or away from the heart. The three kinds are (1) *arteries,* (2) *capillaries,* and (3) *veins.*

The arteries. All the vessels that carry blood away from the heart are *arteries* regardless of whether they carry red (oxygenated) or dark (deoxygenated) blood. Arteries have elastic muscular walls and very smooth linings. Their function is to assist and to regulate blood flow. Since they are elastic they expand when blood is forced into them, and as the valves prevent it from returning to the heart, their elastic contraction carries the pressure from the ventricles clear to the capillaries.

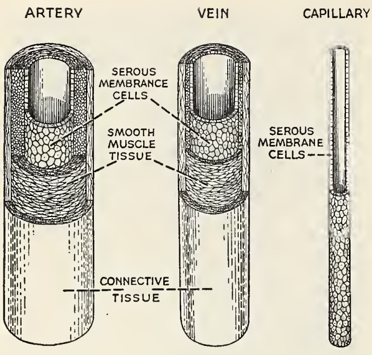
Ewing Galloway, N.Y.

Measuring Blood Pressure. The nurse records the patient's blood pressure as read by the doctor.

If it were not for this elasticity, which is greatest in the large arteries, the circulation would be unsteady and the arteries themselves in danger of bursting under the sudden strain, when the ventricles contract. In "hardening of the arteries" this elasticity is lost and produces serious results.

In general the arteries are protected by location beneath thick muscles, but at the wrist and neck some large ones come near the surface. Their elastic wave of expansion can be felt, and is known as the *pulse.*

The pulse is most easily felt at the wrist. Place the fingertips on top of the wrist, on the thumb side and press gently into the groove between the outer armbone and the tendon or "cord" next to it. The throb of the pulse can be plainly felt and its rate counted. Count your own or a friend's pulse rate and see how it compares with normal rate for your age. Do a few minutes of active exercise and count the pulse again, noting the change in rate. It is a good plan to become accustomed to finding and counting the pulse rate, in order to be prepared for emergencies.



THE THREE TYPES OF BLOOD VESSELS

The muscles in the artery walls perform the important function of regulating the amount of blood that reaches a given organ. By a complicated system of nerve control, these muscles expand when more blood is required and contract when the supply is not needed.

The capillaries. As the arteries leave the heart they divide again and again, becoming smaller and thinner-walled till they develop into microscopic tubes with a wall of only one layer of cells. These tiny blood vessels are the *capillaries* ("hairlike"), and are so numerous that they reach every living tissue of the body. Their large area and thin walls permit diffusion to go on readily. By means of diffusion from the capillaries food actually reaches the body cells. Absorption of food in the digestive tract and excretion of waste from tissues in lungs, skin, and kidneys are also accomplished by these important blood vessels. Capillaries in the web of a frog's foot can be seen under the microscope and the flow of the blood corpuscles is easily visible.

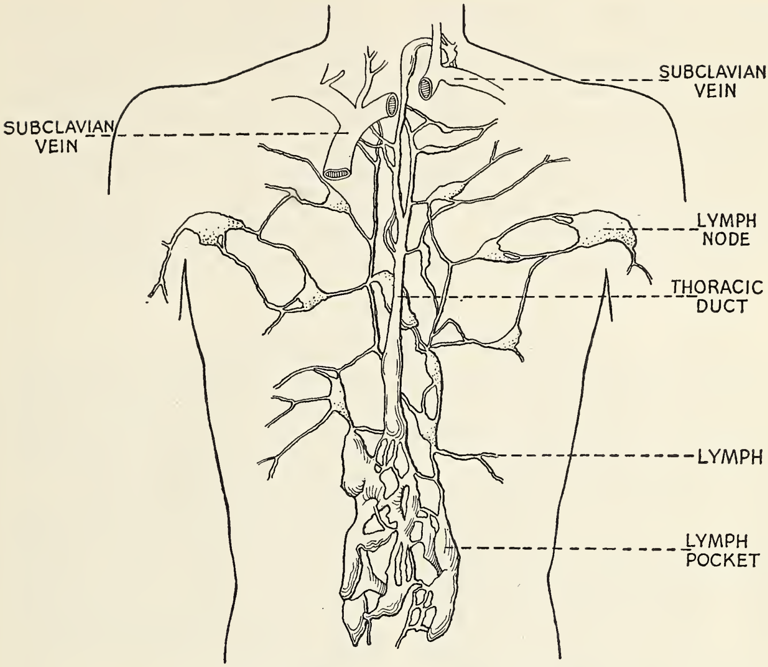
The veins. On leaving an organ the capillaries unite to form veins, which grow larger as they approach the heart, and always carry blood *toward* this organ. Their walls are thinner than the arteries, having little elastic or muscular tissue. Many of the larger veins are provided with cuplike valves to prevent backward flow of blood. Veins are often just beneath the skin and can be easily seen on the back of the hand where the dark color of their blood is conspicuous; enlargements show the location of the valves.

Let your arm hang downward for a moment, then place your finger firmly on the middle vein in the back of your hand. With another finger press up along the vein. The blood will be forced up through the vein which will then lie collapsed. The valves will prevent any blood from coming back into this vein and the finger pressed firmly keeps out the blood which would normally enter.

Veins have no pulse wave and the blood pressure is lower than in the arteries. Except for the pulmonary veins, their blood is dark (deoxygenated) as compared with the redder, arterial blood. However, this is of little use in deciding whether a wound has cut a vein or artery, as blood on exposure to air absorbs oxygen and brightens in color.

Bleeding from an artery, if large enough to be serious, is in pulselike spurts, while the flow from veins is steady. This and the location of the wound are the best means of distinguishing the source of blood flow.

Lymph circulation. Between different body cells there are usually spaces something like narrow yards around houses. When blood plasma diffuses through the thin-walled capillaries, it usually gets into these intercellular spaces. It is a colorless liquid because no red blood cells can penetrate even capillary walls. As it flows through the intercellular spaces, it bathes the adjacent cells, giving up to these cells nutrients and oxy-



THE CENTRAL PARTS OF THE LYMPHATIC SYSTEM

gen carried to this point by the red blood cells. It receives waste from the cells.

This fluid, somewhat more watery than blood, lacks red blood cells and contains less food and much more waste than true blood. It is called lymph. Special tubes, called *lymph tubes,* conduct lymph slowly back to a larger tube called the thoracic duct which also carries digested fat. The thoracic duct finally empties its contents into the *subclavian veins* in the neck.

Pressure from contracting muscles keeps the lymph circulating and valves in lymph tubes prevent backward flow. There are many enlargements of the lymph tubes (lymphatics), which are called *lymph nodes.* They catch bacteria, which are then eaten by white blood cells, always present in lymph.

Most cells in the body, then, are practically islands surrounded by narrow moats of slowly moving lymph.

White corpuscles may pass through the walls of the capillaries and thus get into the lymph spaces, from whence they may pass out with the returning lymph, by way of the lymph capillaries, to rejoin the blood through the lymph system. Lymph thus stands between the blood stream in the capillaries and the living cells of the body. Blood leaves the heart by one route, the arteries, and returns part way by two, the veins and the lymph system. These unite before reaching the heart again.

A comparison of plant and animal circulation. The need in animals for a heart and a circulatory system containing blood is self-evident. In plants there is no such need. Oxygen is not being rapidly used up by hard-working muscle cells; distant cells are not in need of food to replace nutrients and protoplasm oxidized in long-continued exercise. In fact, you might have difficulty in proving to a visitor from Mars, who was seeing green plants for the first time, that they were really living organisms.

Yet plant cells do require both oxygen and food, though little at a time. Since plants manufacture food rapidly, they need efficient circulation to bring water absorbed from the soil to the leaves, to transport newly-formed food from the leaves to storage regions, such as the roots, seeds, and the middle of the stem, and freshly-digested food from storage regions to growing points. Enzymes and secretions are also transported.

Summary

A circulatory system is found in all the higher animals. This functions in transporting oxygen, carbon dioxide, and digested food materials to the cells, and carries way waste products.

In man this system comprises the blood, the heart, and the blood vessels. The blood consists of a fluid portion, the plasma, and red and white corpuscles. The red corpuscles contain hemoglobin which unites with oxygen and forms oxyhemoglobin. The white corpuscles are colorless and aid in the absorption of fats and in the destruction of germs.

The heart is a muscular organ consisting of two auricles and two ventricles. To these the blood vessels are attached so that blood is pumped from the heart where it leaves by the arteries, and returns to the heart by the veins.

Besides arteries and veins, another kind of blood vessel is present. These are the minute capillaries which are located at the ends of the veins and arteries. They reach every living cell, and it is through them that diffusion to and from the cells occurs.

Using Your Knowledge

1. Explain the origin of red and white corpuscles.

2. The fish, whose body may be larger than ours, has only a two-chambered heart. Explain why the fish requires but two chambers whereas man requires four.

3. Explain the relation of fibrinogen to blood clotting.

4. How does the disease, anemia, alter the composition of the blood?

5. Why is separated plasma a better substance for blood transfusions than whole blood?

6. Name, in order, the chambers of the heart through which a drop of blood passes on its journey from the body into the heart and back to the body.

7. Explain the work of heart valves in maintaining blood pressure.

8. Name several factors which may influence the rate of beat of the heart.

9. Explain why a pulse may be felt in an artery but not in a vein.

10. Where would you locate a tourniquet in relation to a wound if a vein were cut? An artery?

11. How does lymph differ in composition from whole blood?

12. Explain how lymph is returned to the blood stream.

13. If you drink twice as much water as usual, will the density of your blood be affected? If you drink less water, do you think your blood will be thinner?

14. Briefly compare plant and animal circulation.

Expressing Your Knowledge

circulation	platelet	systemic
cold-blooded	hemoglobin	artery
warm-blooded	anemia	vein
plasma	hemorrhage	capillary
fibrinogen	blood bank	portal
fibrin	transfusion	pulmonary
hemophilia	auricle	pulse
oxyhemoglobin	ventricle	deoxygenated
red corpuscle	valve	lymph
white corpuscle	aorta	lymphatic

Applying Your Knowledge

1. Obtain a portion of an artery and a vein from your butcher. Compare their structure carefully.

2. If possible, obtain a hog heart or beef heart and section it lengthwise. Locate the four chambers and the valves which lie between the auricles and the ventricles and at the base of the two great arteries leaving the heart.

3. Consult your local Red Cross and find out how blood banks operated during World War II. Report your findings to the class.

4. Prepare a report on the measurement of blood pressure and factors which may cause high blood pressure and low blood pressure.

5. Place a drop of blood on a microscope slide and stain it with Wright's blood stain. Examine it and locate the red and white corpuscles.

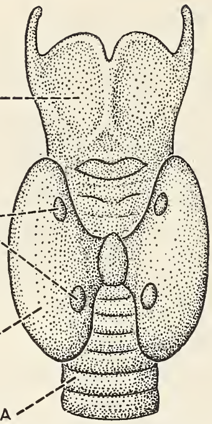
6. Find out how blood counts are made and the significance of the blood count in indicating a normal or abnormal condition in the body.

7. Consult a doctor or nurse and find out how blood may be typed as belonging to group A, B, O, or AB.

Chapter 44

The Body Regulators

Suppose that you were asked to name the most important cell in the body. Perhaps such a question could not be answered, because any organ undoubtedly could continue to exist if deprived of only one of its cells. Therefore no cell in the body is of the utmost importance. But when it comes to organs, that is another matter. There are several large organs, as you know, such as the heart, liver, lungs, etc., which are essential for carrying on the daily work of the body. These organs, however, are matched in importance by eight other organs, most of them insignificant in size, scattered in various parts of the body. Without these more or less obscure organs, all of them glands, normal development of body and mind would not take place. Their work seems mysterious and magical.



THYROID GLAND. Note the position of this gland in relation to the trachea. Note also the four parathyroid glands.

They are glands, to be sure, but they differ from the digestive glands in that they have no duct or visible exit tube. They are therefore called ductless glands. From the food supplied to them by the blood they manufacture chemical substances which they discharge into the blood and which vitally affect the whole of the body.

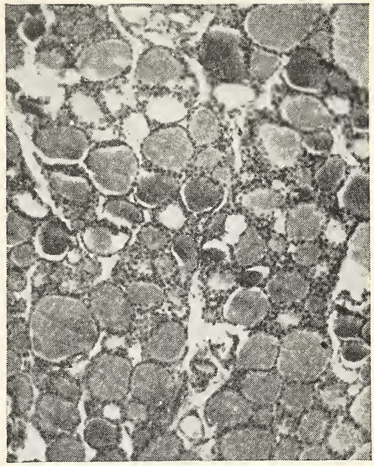
Kinds of ductless glands. The ductless glands are often referred to as *endocrine glands* or glands of internal secretion. Their secretions are termed *hormones,* which means "exciters." The characteristic of hormones is that they stimulate activity in a part of the body away from the place where they are produced. They are, then, in a sense, chemical messengers which are carried in the blood stream from the glands where they are made to other parts of the body where they produce their effects. Hormones are normally produced within the body. They are thus to be distinguished from vitamins, which are substances mainly supplied to the body in food. The organs of the body which are considered ductless glands are the thyroid, thymus, and parathyroids in the neck; the pituitary and pineal in the head; and in the abdominal cavity the adrenals, pancreas, interstitials of the testes, the ovaries, and possibly others. Some organs, like the spleen and the liver are also suspected of producing ductless secretions. There is definite evidence that certain glands in the stomach and in the small intestine also belong to this group. Some examples of ductless glands will be discussed in the following paragraphs.

The thyroid gland. This organ is located right in the front of the trachea in the neck. It is made of two parts. The hormone of the thyroid is called *thyroxine* [*thy rox'in*]. Its structure and chemical composition have now become so well known that it is possible to manufacture this substance artificially. One of the peculiarities of thyroxine is that a large portion of it (65%) is made of iodine. The effect of thyroxine is best noted in individuals suffering from a disturbance of this glandular secretion.

When thyroid deficiency occurs, a general sluggishness of metabolic processes results. Oxidation is reduced, the heartbeat is slow, and a general physical apathy and mental dullness follow. There is a tendency for the tissues to degenerate, and a kind of fatness and general loss of shape are observed. This condition is known as *myxedema* [*mix ee deem'ah*]. If thyroid deficiency occurs from infancy, a disorder known as *cretinism* results. In this disorder neither mental nor physical normalcy is attained. The individual grows into a misshapen and mentally defective dwarf. The administration of thyroxine is now taking an important place in the treatment of patients suffering from thyroid deficiency. Even cretinism has been successfully treated by this method. Of course, where the thyroid is permanently deficient, artificial administration of thyroxine may have to be continued permanently. Thyroxine is obtained from sheep, cows, and other animals; but a large proportion of it is now manufactured in laboratories. It appears to be the only hormone which produces its effects even when introduced into the body by swallowing.

The thyroid gland is perhaps best known through a condition called *goiter* when the gland becomes enlarged and very prominent in the neck. It is only natural that this disorder should have been the first thyroid disease to receive any attention. Goiter may be produced by overactivity of the thyroid gland, but a very large proportion of goiters are caused by underactivity. This latter condition, which is known as simple or endemic goiter, is more prevalent in some parts of the world than in others. It is rare on seacoasts but frequent in mountain regions such as the Alps in Europe and the Himalaya Mountains in Asia. In this country it is found in the Great Lakes region and in the upper Mississippi Valley. There appears to be some connection between this disease and the lack of iodine in the soil of the region. Where attention is being given to this condition, the addition of iodine to the water supply or to the diet seems a successful approach.

In some cases, goiter is a sign of overactivity of the thyroid. The symptoms of overactivity are just the reverse of those of deficiency of the gland. Oxidation, heartbeat, respiration, and the general metabolism of the body are increased. There is a general speeding up of the functions of the organs of the body with a resulting nervousness and a diseased condition which may become very serious and even fatal.



THYROID CELLS. Seen under the microscope and magnified 100 times.

In general, then, as one author says, the thyroid gland " regulates the speed of living." It is sort of timer for setting the pace for the other organs of the body.

The parathyroid glands. Attached to the thyroid gland are small glands, usually four, called *parathyroids* [*para thy′ roids*]. Their secretion, *parathormone,* enables the body to utilize calcium, thereby affecting bone growth. Parathyroids are essential for life.

The pituitary gland. The *pituitary* [*pit u′it ary*] gland is a small organ, little larger than a pea, located beneath the brain. It consists of two lobes. The anterior lobe produces the *somotropic* [*so mo troh′pic*] *hormone,* which regulates the growth of the skeleton. Sometimes abnormal amounts of this hormone are secreted. Too much makes a giant; too little makes a dwarf. The giants and dwarfs that we sometimes see in the circus owe their unusual sizes to the activity of the pituitary. The pituitary dwarf differs markedly from the thyroid dwarf. He is nicely built, well

Culver Service

GIANT AND DWARF. This eight-foot giant and the two-and-one-half-foot dwarf are striking examples of glandular disturbance. Explain, referring to the gland and the secretions concerned.

proportioned, mentally normal. He is really a man in miniature. Among the giants have been men measuring as much as 9 feet 2 inches, weighing over 300 pounds, and wearing size 30 shoes. Sometimes in middle life, symptoms of increased growth of the skeleton appear, especially in the face, arms, and legs. This condition is known as *acromegaly* [*ack roh meg'ally*]. The anterior lobe of the pituitary also produces other hormones. *Prolactin* [*pro lack'tin*] stimulates the production of milk in a mother mammal. The *ketogenic* [*kett oh jeen'ick*] *hormone* helps the body to utilize fat. The posterior lobe of the pituitary produces two hormones. *Pitressin* [*pit tress'in*] regulates the amount of water in the blood and also the blood pressure. *Pitocin* [*pit'oh sin*] stimulates smooth muscle. This hormone is now used clinically to check bleeding and as a means to aid muscular contraction.

The pituitary gland seems to be the master ductless gland. It not only has profound effects upon the development of the body; its hormones directly stimulate the other ductless glands.

The thymus gland. The thymus is a gland forming two large masses near the heart behind the breastbone. It disappears after childhood. Most authorities are doubtful as to whether it is a true ductless gland. No hormone has ever been isolated from the thymus, but it seems to have a retarding influence on sexual maturity. When it disappears, sexual development begins, induced by true hormones. Its supposed secretion has been called a *chalone* [*kal'ohn*]: "opposed to hormone."

The adrenal glands. Near the kidneys are located the *adrenal* [*ad dreen'al*] glands, whose hormone, *adrenalin* [*ad dren'ah lin*], affects the flow and pressure of the blood and also releases sugar stored in the liver for immediate use in energy production. In this way the adrenals are valuable in emergencies when extra energy is needed to escape danger. Adrenalin, discharged into the blood, reaches the liver and causes that gland to release some of its stored sugar. This provides extra fuel to be oxidized and furnishes energy for the critical moment.

The late Professor Walter B. Cannon of Harvard University made some interesting experiments on animals in which he ably proved that the dispersal of adrenalin occurs in response to certain emotions. He withdrew blood from animals that had been excited, from cats, for example, that had been barked at by a dog. He found a large amount of adrenalin in the blood of such animals. In animals that had not been excited, there was no evidence of the presence of this substance. This and other experiments and observations led to the conclusion that under violent emotions, such as hate, fear, love, and anxiety, the adrenals become active and pour their hormone into the blood stream. This results in making available large quantities of sugar for oxidation and yields greater oxidation. The adrenals have been nicknamed the glands of emergency; sometimes they are called the " glands of combat " because they come to our assistance by giving us greater strength for the moment. The " strength of desperation " can be explained in terms of adrenalin. The substance adrenalin, which can be extracted from other animals and is also manufactured, is used in surgery and medicine. Its use in stimulating the heart has received much publicity. It is also used in surgery to contract blood vessels and thus reduce bleeding. Only the inner portion of the adrenal, the *medulla* [*med dull'ah*], manufactures adrenalin. The outer part of the gland, the cortex, produces a substance now known as *cortin* [*kor'tin*]. Many symptoms of adrenal deficiency, fatigue and lethargy, are corrected by the use of this substance. Addison's disease, which was formerly thought to be due to a lack of adrenalin, is now found to yield to treatment with cortin. Oversecretion of cortin produces a disorder in which male characteristics become accentuated. Perhaps the " bearded lady " of the circus and the boy who smokes a cigar are to be understood through this secretion.

The pancreas. The *pancreas* [*pan' kree as*], although possessing a duct through which an important secretion passes off, has an internal secretion also. This contains a hormone, *insulin* [*in' su lin*], which enables the liver to store up sugar and also regulates its oxidation in the muscles. When a person lacks this hormone, he cannot store or oxidize sugar, which then accumulates in the body or is thrown off by the kidneys. This condition is the disease called *diabetes* [*dia beet'eeze*] and can be relieved by injections of insulin obtained from the pancreas of sheep.

The pineal gland. The *pineal* [*pin'ee al*] gland is a tiny organ situated in the brain. Its secretion and complete function have not yet been determined, but it helps to regulate early growth.

The table on page 486 summarizes the activities of most of the internal secretions of the body. The fact that question marks still remain in the table is a challenge to modern biology.

The ovaries and testes. These organs, the ovaries in the female and the testes in the male, have a dual function. We think of them primarily as organs for the manufacture of sex cells, the eggs in the female and the sperms in the male. In addition, however, the follicular cells of the ovaries and the interstitial cells of the testes serve as ductless glands. Their secretions are important in developing those traits which we think of as essentially masculine or feminine. Examples of these " secondary sex characteristics " are the comb of the rooster, the brightly colored plumage of most male birds, the fiery disposition of the bull, the horns of the stag, and the beard of the man. These characteristics are definitely interfered with upon removal of the sex organs.

Removal of the testes (*castration*) results not only in sterility but in complete change of personality, particularly if done early in life. There is a loss of mental acuteness, an increase in fat, and great sluggishness. Roosters are so treated because the fat tender-fleshed capon thus produced brings a better market price than the tough and skinny rooster. The stupid ox is a castrated bull.

THE GLANDS OF INTERNAL SECRETION

Gland	Location	Hormone	Functions and Reactions
Pituitary 1. Anterior lobe	Underside of brain	Somotropic Prolactin Ketogenic Others	Regulates growth — size, proportions; giantism, dwarfism Stimulates production of milk Influences fat metabolism Stimulate other ductless glands
2. Posterior lobe	Underside of brain	Pitressin Pitocin	Regulates amount of water in blood and blood pressure Stimulates smooth muscle
Thyroid	Neck	Thyroxine	Regulates rate of oxidation; lack from birth is cretinism; enlargement known as goiter
Parathyroid	Near thyroid	Parathormone	Utilization of calcium
Adrenal 1. Medulla	Above each kidney	Adrenalin or epinephrine	Meets emergencies by releasing sugar; regulates blood flow; excess is high blood pressure; deficiency is weakness
2. Cortex		Cortin	Regulates use of water and salt; excess is marked maleness; lack is Addison's disease
Pancreas Islands of Langerhans	Near junction of stomach and intestine	Insulin	Regulates sugar absorption and oxidation; lack is diabetes
Ovary Follicular Cells	Pelvis	Oestrin	Produces female secondary sex characteristics
Testis Interstitial Cells	Below pelvis	Testosterone	Produces male secondary sex characteristics
Pineal	Near pituitary	?	Regulates early growth
Thymus (?)	Back of a breast-bone	?	Retards sexual development

Similar results have been observed wherever castration has occurred.

Glands and personality. It can readily be seen from the preceding paragraphs that much of what we are is controlled by the ductless gland system. We have seen how our skeletal growth may be influenced by the pituitary, how our mental as well as physical development is under the control of the thyroid. Our disposition is influenced by the adrenals. Much of our appearance and health depends on the proper behavior of these ductless glands. And we are only at the beginning of our knowledge. No wonder, then, that the glands have been nicknamed "glands of personality" and that a wealth of literature, not always reliable, has arisen to meet the demand of readers who want to know more about this fascinating subject.

Only a physician has the experience necessary in treating glandular cases. Drugs which guarantee to change your personality in a week or more usually are dangerous and should be avoided.

Summary

The ductless glands secrete hormones directly into the blood stream. Hormones usually stimulate activity in various organs away from the glands which secrete them.

The thyroid secretion appears to control the whole rate of body metabolism. When it becomes enlarged, goiter results. The parathyroid glands produce a hormone which controls calcium metabolism.

The pituitary gland secretes at least five hormones whose influence regulates various blood, muscle, and reproductive activities. The thymus gland, which disappears after childhood, probably prevents the development of sexual maturity.

The secretions of the adrenal glands appear to depend on certain emotional conditions, since they become more active at these times than when the body is unexcited.

The pineal gland is still not well understood but it seems to produce a hormone which regulates early growth. The secretions of the ovary and testes develop traits of femininity and masculinity.

It is quite true that the ductless gland system actually controls and greatly influences personality.

Using Your Knowledge

1. The blood is the common source from which ductless glands obtain their basic substances. Yet each produces a secretion different from that of each of the others. How can this variation in function be explained?

2. How does a knowledge of hormones explain "strength of desperation"? Bearded ladies? Giants? Dwarfs?

3. Dr. McCollum states that there are dangers involved in putting iodine into the drinking water of an entire community or in using iodized salt without the advice of a physician. State your agreement or disagreement with his conclusion.

4. If the endocrine glands may be said to influence normal development, how do you account for their co-ordinated action? What governs the ductless glands?

Expressing Your Knowledge

endocrine glands	prolactin	pancreas
hormone	pitressin	chalone
thyroid	thymus	diabetes
goiter	pituitary	acromegaly
myxedema	cortin	pineal
cretinism	adrenal	castration
thyroxine	adrenalin	secondary sex characteristic
parathyroid	insulin	somotropic hormone
parathormone	pitocin	ketogenic hormone

Applying Your Knowledge

1. Through your butcher procure several kinds of ductless glands of any animal available, and preserve them in alcohol or formaldehyde.

2. Prepare a report on goiter and cretinism in the United States.

3. If possible, visit an institution and see patients who are examples of excess or in-

sufficient ductless gland activity. Ask the doctor to tell you about them.

4. Report on the discovery of insulin, together with a brief biographical sketch of Dr. F. G. Banting.

5. Investigate the work of Dr. Oscar Riddle, of the Carnegie Institute at Cold Spring Harbor, Long Island, N. Y., in reversal of sex in pigeons. What has this work revealed about the glandular system?

Chapter 45

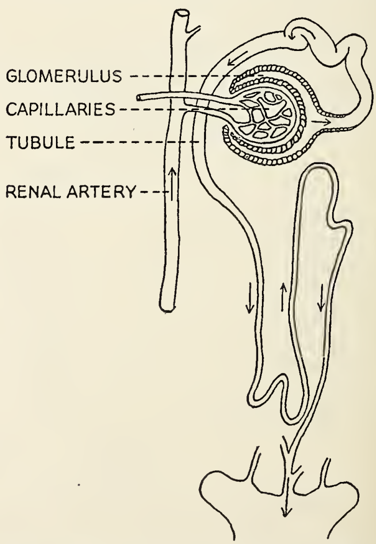
The Removal of Waste

You have learned that food is used in the body in two primary ways: in the making of protoplasm or assimilation, and in the production of energy or oxidation. All the activities of the body require energy, whether in the muscles, nerves, special sense organs, or glands. The release of energy in the body is produced by oxidation. You will recall that oxidation is a chemical process which produces heat and forms certain waste products which must be removed from the body. Chief among these substances are carbon dioxide, removed from the blood by the lungs; water, removed from the blood by the kidneys, skin, and lungs; urea, removed from the blood by the kidneys. Certain mineral substances are also excreted through the skin and kidneys.

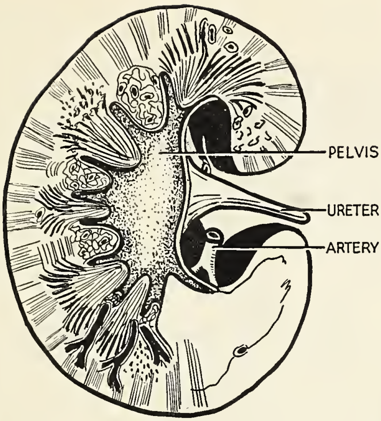
The kidneys. The *kidneys* are bean-shaped glands located near the spine at the " small of the back." They are about two by four inches in size, usually embedded in fat. Their internal structure is too complicated to describe here but is perfectly fitted for removing various wastes from the blood. Their blood supply is very large and they are thus the most important agents in removal of these wastes.

The ducts from the kidneys lead to the *bladder*, where the urine is stored until it is excreted from the body. The amount of urine is usually about three pounds per day and the nitrogenous wastes which it contains are of such character that, if incompletely removed, serious diseases are sure to result.

Exposure to cold, drinking large quantities of water, and excess of protein food all tend to increase the amount of urine.



Relationship Between the Blood Vessels and the Kidney



A SECTION OF THE KIDNEY

As some of the waste matters are not very soluble, it is a good thing to drink plenty of water to keep the kidneys well washed. As a rule we drink too little water rather than too much.

The lungs. The lungs are used as organs of excretion as well as for the supply of oxygen, their wastes being carbon dioxide mainly, together with considerable water and very little nitrogenous matter.

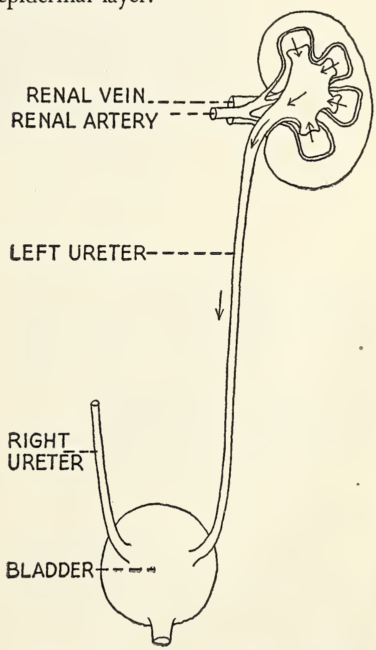
The liver and intestine. Both the liver and intestine are concerned with the removal of bile, a part of which is waste matter. The intestine also removes the unused food refuse. This, however, is not strictly excretion. This food refuse, if retained too long in the intestine, may cause trouble. Regular habits of bowel movement should be established.

The skin. The skin excretes considerable water and only one per cent of solid matter, mainly salts. The chief function of perspiration is to regulate the temperature of the body.

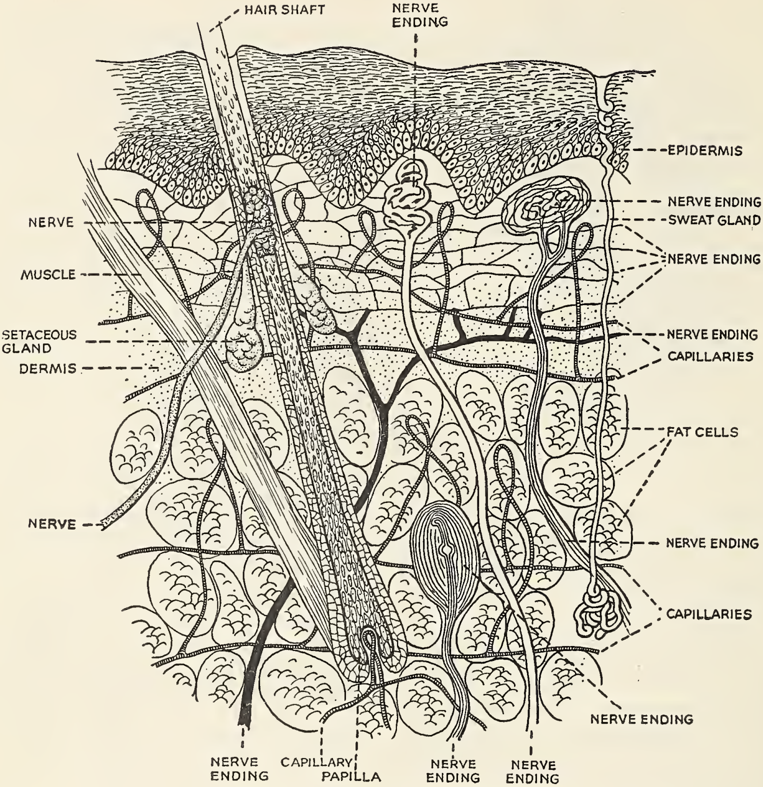
Although the skin is not primarily an organ of excretion, its structure and function may be discussed at this point. The human skin is a much thicker and more important organ than we usually suppose. If tanned it would make leather as thick as the cover of a football.

It consists of an outer portion (*epidermis* [*epi derm'miss*]) composed of many layers of cells. The outermost are dead, horny scales, the inner ones are more active and larger. The epidermis is mainly protective and the outer scales are constantly being rubbed off and replaced by new from beneath. Where subject to much friction or pressure the epidermis may grow to over a hundred cell layers in thickness, producing the familiar callouses on hands and feet.

Hair, nails, and color cells in man are developed from the epidermal layer. Scales, feathers, and claws found in other animals are modified forms of this same epidermal layer.



THE LEFT KIDNEY. A portion of the right ureter is also shown.



SECTION THROUGH HUMAN SKIN

Beneath the epidermis is a thicker layer (the *dermis*) consisting of tough, fibrous, connective tissue, richly supplied with blood and lymph vessels, nerves, sweat glands, and oil glands.

The functions of the skin. The functions of the skin include:

1. Protection from germ attack and mechanical injury.

2. Protection of inner tissues from drying. The skin, aided by oil glands, is nearly waterproof, neither absorbing nor letting out much moisture, except at the sweat pores.

3. Location of our nerves of touch.

4. Excretion of sweat as waste matter.

5. Excretion of sweat to regulate the temperature of the body.

This last statement needs explanation. Birds and mammals are the only animals whose temperature does not change with that of their surroundings. The rate of oxidation and hence the production of heat varies with that of the outside temperature. A heat-regulating device is therefore required.

To evaporate water requires heat; therefore if moisture is excreted on the surface of the skin, the body's heat is taken up in evaporating it and consequently the skin is cooled. The blood supply to the skin is great, the surface exposed for evaporation is also large, and so by the use of the body heat to vaporize (dry off) the perspiration, the blood, and hence the whole body, is cooled.

The greater our activity or the warmer the surrounding air, the larger is the amount of perspiration, and hence the greater cooling effect up to a certain point.

A complex system of nerve control governs the blood supply and gland activity of the skin, and mainly by its means our temperature is kept at 98.6° F. The great importance of this function of the skin is seen when we realize that a temperature of eight degrees either above or below the normal is usually fatal.

A comparison of plant and animal excretion. Since animals are immeasurably more active than plants, and since activity depends upon increased oxidation, this can only mean that the products of oxidation will be produced in much greater quantity in animals. This is so true that special organs like the kidneys, or similar organs in lower animals, are provided to remove dissolved salts and oxides of proteins from the blood in the form of urea. Urea, if retained in the body, would constitute a poison. Plants do not oxidize protein to any extent. Hence they do not require kidneys. Oxidation of carbohydrates goes on to a limited degree but not so fast as to tax the capacity of stomates and lenticels to carry off the carbon dioxide formed. In fact, while plants doubtless give off carbon dioxide at night, green plants unquestionably use up the excess carbon dioxide in the process of photosynthesis during the daytime.

Plants give off an immense amount of water in the form of vapor from the stomates and lenticels. Since this water passes off by evaporation, however, it cannot carry with it any salts or substances in solution, as occurs in animals in the excretion of sweat, water vapor in the breath, and urine. As a matter of fact, plants do not need to get rid of such dissolved substances because they can use them in making food nutrients.

Summary

Wastes are removed from the human body in various ways through the actions of the kidneys, the lungs, the liver, the large intestine, and the skin.

The kidneys remove various wastes from the blood. The lungs act in removing carbon dioxide, and the liver eliminates the unused matter in bile. The large intestine accumulates food refuse which is passed out through the bowels. The skin excretes large quantities of water together with a small amount of salts.

Plants and the lower animals have no excretory system as do the higher animals. Their waste products diffuse directly out through the cell walls.

Using Your Knowledge

1. If the liver could be removed without causing immediate death, how would that catastrophe affect the process of excretion of the body?

2. Why is a person who is very severely burned likely to suffer from kidney trouble?

3. We are urged to "drink plenty of water." Can you tell all the physiological advantages to be gained from such a habit?

4. Is the ignorant savage who has never seen a cake of soap less healthy on that account than the civilized man who takes a daily bath? Explain.

5. Most people like carbonated drinks, i.e., liquid charged with CO_2, as in soda water. Does it not seem contradictory to introduce CO_2 into the body by drinking it, when we have to breathe CO_2 *out* of the body because it is a waste?

Expressing Your Knowledge

kidney	urine	dermis
bladder	epidermis	perspiration

Applying Your Knowledge

1. Find out how much water the skin of an adult normally excretes during 24 hours.

2. After investigation, give scientific reasons for the selection of several soaps that are both pure and economical. Ask the chemistry teacher about this investigation.

3. Prepare a mounted collection of structures from different vertebrate animals illustrating modifications of epithelial tissue.

Chapter 46

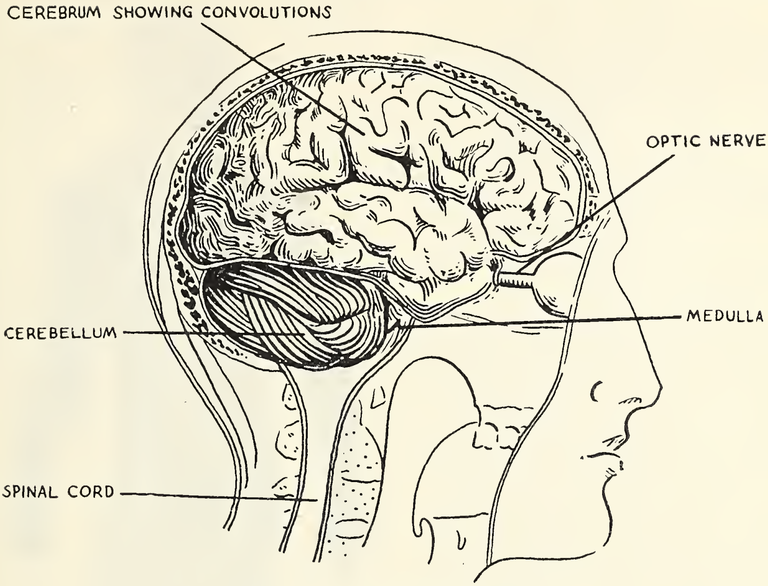
The Control of Body Activity

A castaway does not need a telephone; but communities do find a telephone valuable. Similarly, organisms of few cells do not have the problem of co-ordination because they do not have different systems and distant parts which must work together harmoniously. Higher animals, however, are a community of thousands, even millions, of cells. Health and continued life would be impossible without means of sending messages and receiving impressions.

This important function is performed by the nervous system. Just how, we do not know; but it has been proved experimentally that by means of the nervous system intricate bodily functions are regulated, sensations are registered through the sense organs, and physical reactions are produced in response to ideas.

The brain. The most important organ of the nervous system is the brain. It is the one organ which is capable of greater development in man than in any other animal. No amount of training will enable us to compete with fish, bird, or dog in speed, strength, locomotion, or keenness of sense. Practically every animal excels man in some way, and the one thing that makes man their superior is his greater intelligence or greater brain development.

The brain is sometimes called "the organ of the mind" but it does not secrete thought, as the liver secretes bile. It is the organ through which our mental, moral, and spiritual natures do their work, but the chemical changes of the brain, marvelous as they are, are not all there is to intellect or character. We must admit inadequacy of knowledge. The more highly the nervous system is developed and trained, the better we can cope with our surroundings. We have



STRUCTURE OF THE HUMAN BRAIN

only to consider the loss of hearing or sight to realize how much we depend on these senses for happiness, comfort, or even life itself. Despite this, we often devote more attention to other lines, in which we cannot hope for really useful success, and leave to very indifferent care the training of our one source of superiority.

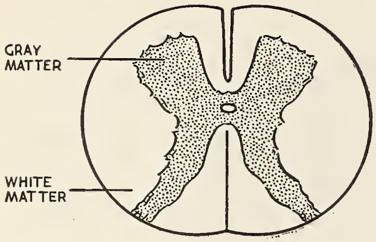
The structure of the brain. The brain consists of three general regions, the *cerebrum* [*sehr'ee broom*], the *cerebellum* [*sehr ee bell'um*], and the *medulla* [*med dull'ah*]. Connected with it are the spinal cord and nerves, which together with the brain compose the *central nervous system.*

The cerebrum. The cerebrum constitutes about nine-tenths of the brain; it occupies the upper part of the skull and is divided into halves called *hemispheres.* Its surface is deeply folded in irregular grooves (*convolutions*) and consists of *gray nerve cells.* Internally the bulk of its tissue is made up of *white nerve fibers.*

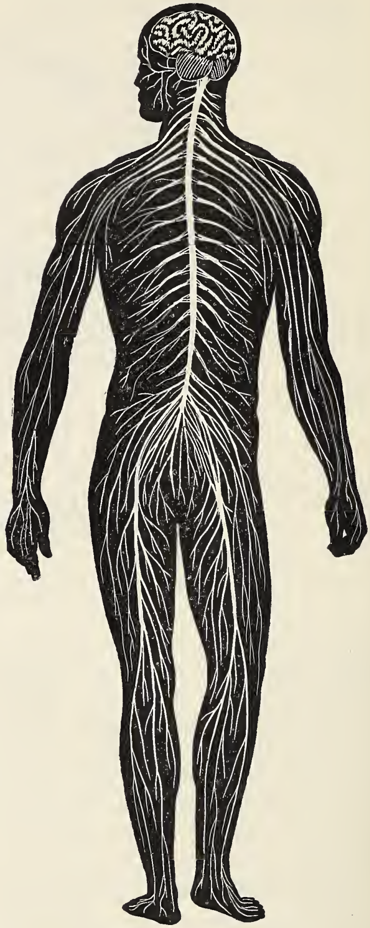
We know that the cerebrum is the most complicated organ in the world but we are far from a complete understanding of its structure, much less its mode of operation.

Experiment and disease have shown that the cerebrum is the center of intelligence, thought, memory, will, and the emotions. It is closely bound up with sensation, by which we perceive all that goes on about us, and in it arise the impulses which produce all our voluntary motions.

The cerebellum. The cerebellum is situated behind and below the cerebrum, is much smaller, is not divided, and has shallower and more regular convolutions. Its function is mainly to regulate and harmonize (co-ordinate) muscular action. When we run, skate,



Cross Section Through the Spinal Cord



General Arrangement of the Nervous System

walk, swim, or throw a ball, we use nearly all of the five hundred muscles of our body. Each muscle fiber is controlled by a nerve; each nerve impulse must reach its muscle at the proper instant. When we stop to analyze the simplest act and think how many muscles are made to work together in perfect harmony, we realize how important is this co-ordination of muscular action by the cerebellum. Without it, though the cerebrum might originate the impulse to do a certain act, no regulated useful motion could result.

The medulla. The *medulla* or *spinal bulb* is really an enlargement of the spinal cord but is within the skull and closely attached to the cerebellum. It is about the size of a walnut and is located at the extreme base of the brain.

The medulla is the center of control of respiration, circulation, secretion, movements of digestive organs and of swallowing, as well as other similar automatic and unconscious activities. Naturally, death follows injury to this vitally important part of the brain, though severe damage to the other parts may not be fatal.

The spinal cord. The spinal cord extends from the medulla through the protective bony arch of each vertebra, down almost the whole length of the spine, and from it branch the nerves that supply all parts of the body, except those which spring from the brain directly. The spinal cord is not merely a large nerve trunk, however, but is the center of many involuntary muscular actions (*reflex actions*) of the body and limbs. If we touch a hot stove, we do not have to *think* to remove our hand. Voluntary action would take too long and injury would result before the brain could have time to act, so most of such reflex actions are centered in the spinal cord and operate automatically, but not *unconsciously* as do the motions of the internal organs controlled by the medulla.

Thus the spinal cord has two functions:

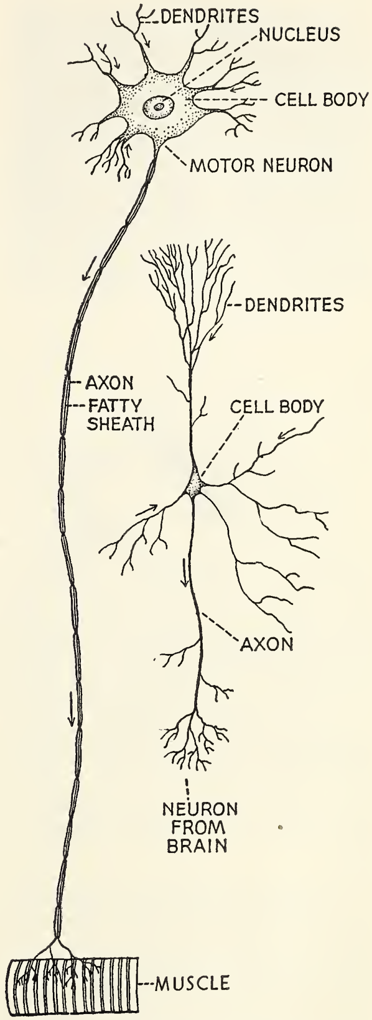
1. A connecting trunk between brain and other nerves
2. The center of reflex action.

The nerves. If all the other tissues of the body were dissolved, its outline would still be preserved by the network of nerves that would remain. Fibers made up of nerve cells reach every part of the body; brain, spinal cord, ganglia, and nerves are composed of these nerve cells.

Nerve cells are more complicated and in some cases larger than the other cells of the body. They are called *neurons* [*nu′rons*] and consist of a cell body from which extend projections called *processes.* There are usually several short branching processes, called *dendrites* [*den′drites*], and one long one called the *axon* [*ax′on*]. Some cells have two or more axons.

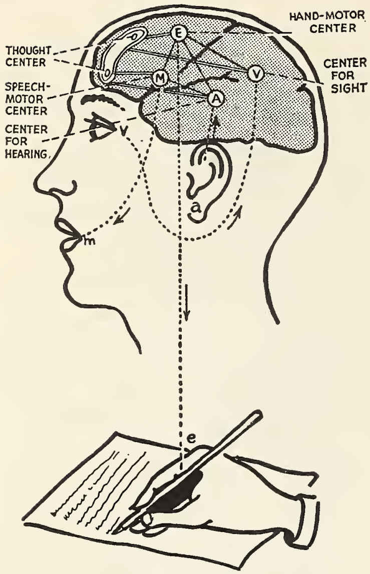
The cell bodies are located mainly in the gray matter of the brain, the inner portion of the spinal cord, and in various scattered masses, called *plexuses* [*plex′uss sez*]. The axons form the nerve fibers which largely compose the inside of the brain (white matter), the outside of the spinal cord, and the nerves themselves, which are bundles of axons enclosed in a sort of sheath.

The axons of one cell are in close contact with dendrites from other cells, and this seems to provide the means by which nerve impulses are transmitted from one cell to another. Axons may be long, some extending from the spinal cord out to the toes or fingers; others, connecting different parts of the brain or spinal cord, are very short. At their ends they usually divide into brushlike branches where they join a sense organ or muscle cell, or dendrites of other neurons.



Two Types of Nerve Cells. Left: motor neuron; right: neuron from the brain.

Sensory and motor neurons. Some neurons carry impulses inward from



RELATION OF VARIOUS BRAIN CENTERS

sense organs to the brain and are called *sensory* or *afferent* neurons. Others convey impulses to muscle or glands and are called *motor* or *efferent* neurons. In general, the sensory neurons are associated with what we call sensation and the motor neurons with secretion and muscular activity. There are also nerve cells which connect motor and sensory neurons.

If we see a pencil and pick it up the process is something like this. The light reflected from the pencil affects the nerve endings in certain cells of the eye. These convey the impulse along their axons to the sight center of the brain, situated at the rear, where dendrites pass it on to other cells and we then " see " the pencil.

Axons from these cells also communicate with motor neurons connected with the arm muscles, and we move these muscles by impulses sent along their axons to the muscle fibers. Nerve endings, instead of acting directly on muscles, appear to release charges of *acetylcholine* [*as set ill ko'leen*], which seems to be the immediate agent causing muscular activity. In 1936, a Nobel prize was divided between Sir Henry Dale of England and Professor Otto Loewi of Austria for their researches in this field.

The figure at the left shows several possible connections which might thus be made. Since every cell of the brain is in touch with almost every other, the number of possible connections is countless.

Nerve impulses are often compared to electrical currents, but it must be remembered that their nature is not understood. The nerve current is certainly much slower than electricity, being about 272 miles per hour whereas electricity travels at the rate of 186,000 miles *per second*. The comparison of the brain to a telephone " central " where incoming and outgoing connections are made, is a good one as far as it goes, but much happens in the brain besides mere cross connections.

Brain waves. In 1929, Hans Berger, a German neurologist, proved that living brains produce electrical impulses in rhythmic waves. By means of delicate vacuum tubes he amplified these impulses into sound waves. Recently, research workers in the Harvard Medical School discovered distinct brain-wave patterns in normal persons, differing according to the individual. Diseases like epilepsy produced a specialized type of pattern. This knowledge of brain waves may prove to be the most revolutionary approach to the study of interrelations of the body and the mind.

Reflex action. Picking up the pencil was an act controlled by the brain; we saw the pencil and decided to pick it up.

Such actions are called voluntary because regulated by the will. There is another important class of actions which is not directed by the brain but center in the spinal cord. They usually happen more quickly than voluntary actions, and are called *reflex actions.*

For example, if you touch a hot object, you pull your hand back instantly, without " thinking " about it at all. In fact, the motion preceded the feeling of the burn. The nerve route in this case was from the branches of a sensory cell in the finger to the spinal cord. There the axons of the sensory cell connected with dendrites of the motor cell, the impulse went out along the motor axon, and the muscles moved the finger out of danger.

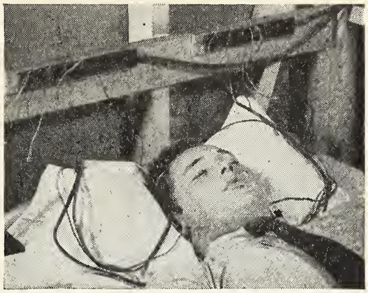
All this happened without waiting for brain action. After you jerked your hand away, other nerve cells in the cord communicated with the brain and you " felt " the hurt. By waiting for voluntary action, much damage would have been done.

Sneezing, coughing, winking, laughing when tickled, or jumping when surprised by sudden sights or sounds are all reflex actions. Most of them save the body from injury by getting a motor response more quickly than would come by voluntary action.

The sympathetic system. On each side of the spinal column but *inside* the body cavity are two rows of nerve ganglia which are connected with each other and with the brain and spinal cord.

From this double nerve chain extend branches to most of the internal organs and to other ganglia located in the chest and abdomen. The largest of these *sympathetic ganglia* is the *solar plexus,* located just below the diaphragm; another is near the heart, and a third is in the lower part of the abdomen.

The operation of the sympathetic system is not well understood, but it controls the secretion of glands, the regulation of blood supply in arteries, heart action, and other internal activities of which we are not conscious, but without which we could not live.



Ewing Galloway, N.Y.

APPARATUS FOR RECORDING BRAIN WAVES

The sympathetic system has nothing to do with " sympathy " in its usual sense, but is so named since it seems to keep the involuntary internal organs working in harmony, much as the cerebellum co-ordinates the action of the voluntary organs.

PROCESSES CENTERED IN THE NERVOUS SYSTEM

1. Reception of sense impressions by way of the sense organs and sensory neurons

2. Mental processes — thought, reason, memory, etc. — associated with brain activity

3. Voluntary actions originating in the cerebrum and co-ordinated by the cerebellum

4. Involuntary and unconscious actions of internal organs, controlled by medulla and sympathetic system

5. Involuntary but conscious actions (reflex) controlled by the spinal cord

6. Actions, at first voluntary but which have become reflex (automatic), like walking

Fatigue and rest. After running fast for half a mile, why do you have to stop? Because you are "tired." Perhaps by running more slowly you can keep it up for a mile. Still there comes a time when you are "tired out" and can go no farther.

Now assume that you stop for an hour, perhaps take a shower bath and brisk rubdown. You probably can again run the mile, almost as well as at first. Why? Because you are rested. You have had no food, no new source of energy, and yet you can do almost as much work as at first. What is the explanation?

Fatigue toxins. It seems probable that work produces actual poisonous substances in the tissues, which are called *fatigue toxins*. These affect the action of muscles, nerves, and glands. Oxidation and excretion remove them as fast as possible. If the rate of work produces fatigue toxins faster than they are removed, some remain in the system and produce fatigue.

If the rate of work is slower, oxidation and excretion come nearer to complete removal, and the fatigue point, where you are tired out, is postponed. That is one reason why you can run a slow mile more easily than a fast half.

During the period of rest, most of the fatigue toxins were removed, the tissues were "rested," and the body became able to work anew. This is the reason for recess periods and relief drills in schools and for "pause periods" which are being introduced among factory workers.

Fatigue toxins affect the secretions of glands and the action of the digestive organs; hence eating while tired often results in indigestion. The white corpuscles are also affected, and though their number is increased, a tired body is actually more liable to infection than one normally rested. Worry, anger, and fear seem to cause toxic effects similar to those of fatigue and should be avoided, both on their own account and because of the physical effects.

Sleep. In the end, a day's work produces an excess of fatigue poisons, and the body must have an extended opportunity of getting rid of them. This is provided by sleep. During sleep the body takes care of the accumulated wastes of the day and the working and growing cells have opportunity to repair loss and increase in number.

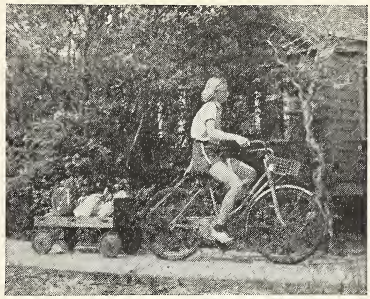
This means that sufficient sleep must be had or a condition of chronic fatigue will develop. Young people need more sleep than adults because growth, as well as repair, has to proceed. The amount of sleep required by adults varies widely, but eight hours is a fair average. Children should have more. The morning should find all fatigue toxins out of the system and the body fully refreshed and ready for another day with "yesterday's bills all paid."

Habit formation. To accomplish a given act or thought, the nerve impulse has to connect up various parts of the brain. At first this is done with difficulty as when we are learning to read, to ride a bicycle, or to play a piano. However, repeated voluntary acts soon make their proper nerve connections more easily, as if a path were being worn in the brain along which the impulses travel with greater and greater ease.

If we continue doing a certain act or thinking a certain way often enough, it becomes the easiest way to act or to think, and we say we have "acquired the habit." *Habit* comes from the Latin word *habeo,* meaning "to have" or "to hold." So instead of our "getting the habit," as we say, the habit has "got" us.

It a serious thing to think of, for our whole life is a complex mass of habits

— things which hold us—acts and thoughts that do themselves, and which we "just can't help." How careful we should be that those brain paths are the best arranged so that habits of thought shall be prompt and accurate. How watchful we should be to see that only good and helpful paths are followed, for, whether we wish it or not, the habit will get and hold us. It is only too true that "As a man thinketh . . . so is he."



Philip D. Gendreau, N.Y.

HABIT FORMATION. Bicycle riding is an acquired habit.

Habit selection. Not only are there habits of *doing* which must be acquired, but there are habits of *not doing* (inhibition) which are just as important. We can acquire habits of *doing* the right thing and also learn to *inhibit* wrong impulses. We may see an article which we want, but we must learn to refrain from stealing it. We may feel like making an angry reply but we can learn to restrain our temper. We can choose to form right habits of eating, exercise, posture, or speech and we can elect to refrain from habits that harm our physical bodies.

Habits of thinking precede habits of doing. Nine times twelve did not always make us think "108," but once the habit is formed it becomes easy and saves much time. Reasoning logically from cause to effect, using control experiments, excluding everything but facts — this is a kind of thinking that requires effort to make into a habit. Once formed, such a habit is a long step toward a trained mind and efficient intellect.

We can select and train our habits of *feeling* too. We may form the habit of being discouraged by difficulties, or they may only make us the more determined to succeed. We can let ourselves feel snobbish or superior to those less fortunate, or we can learn to form habits of charity and tolerance for our neighbors. Whether we will or not, we are forming today the habits that will "hold" us throughout life. We must constantly choose among them. We can cultivate useful habits of work and thus become efficient and successful. We can inhibit acts which harm others or ourselves. We can train our minds to be accurate and prompt servants, and we can regulate our feelings so as to have a happy and helpful life. *Or* we can do just the opposite.

The habits which we acquire become so fixed that they control our lives. The sum total of our habits is our *character*. Youth is the time of easiest habit formation. We should choose wisely and practice diligently to acquire only those habits which will help in building a strong character.

Summary

The brain of man is much larger in proportion to his size than that of any other animal. It is the most important organ of the nervous system. With it are connected the spinal cord and nerves. Together they constitute the central nervous system.

The brain is said to be "the organ of

the mind" because through it our mental, moral, and spiritual natures do their work.

The spinal cord acts as the connecting link between the brain and the nerves and is also the center of reflex action.

The nerve cells, called neurons, are complicated cells which reach every part of the body. Sensory nerves carry impulses from the sense organs to the brain. Motor neurons, on the other hand, carry impulses from the brain to the various muscles and glands.

The sympathetic nervous system comprises two rows of nerve ganglia located on each side of the spinal column and inside the body cavity. It controls the secretion of the glands, the regulation of the blood supply in the arteries, the action of the heart, and many other activities.

Man's mental ability, due to the presence of his highly specialized brain, brings great responsibility. He can bring about normal health through adequate exercise, proper rest, plenty of sleep, and the selection of good habits. On the other side, he can undermine his physical and mental prowess by all kinds of bad habits which will most certainly result in injuring both his body and his mind.

Animals, because of their less highly specialized brain, do not have this responsibility. They are not able to bring about good or bad health.

Using Your Knowledge

1. There is a popular idea that fish is excellent food for the brain. If this were true, would we not expect to find many of our great statesmen, financiers, and captains of industry coming from the ranks of those who live on fish, such as the inhabitants of coasts like Labrador, Greenland, etc.? Is this the case?

2. Can you better explain the nervous system and its functions by comparing it with a telephone system?

3. Are growth and repair in the body accomplished more when you are awake or when you are asleep? Explain. Are you taller when you go to bed or when you get up?

4. Can you explain what is happening in the nervous system when you faithfully practice your scales and musical exercises? Why is such practice invaluable for proficiency?

5. Is a burglar who steals money without getting caught successful? Is there any difference between being a successful burglar and a successful *man*?

6. Can you list ten important habits which if acquired will surely lead to success? What ten habits tend to lead to failure?

7. Think of someone whom you admire either in real life or in fiction. List in order of importance the qualities which you think have been outstanding in the personality of that individual.

8. Explain why it is more difficult for most adults to learn a language than for young people.

9. How can memory be trained?

Expressing Your Knowledge

medulla	nerve	solar plexus
cerebrum	neuron	sympathetic system
cerebellum	dendrite	fatigue toxin
central nervous system	axon	acetylcholine
convolutions	plexus	habit formation
spinal cord	sensory neuron	inhibition
reflex action	motor neuron	white nerve fibers

Applying Your Knowledge

1. Select a new habit that you want to acquire or an old habit that you want to break. By resolution, action, repetition with no exception, and attention, prove that you can be successful in reorganizing your life.

2. From your own observations, make a list of evidences of habits which you see in yourself or in others in matters of dress, posture, eating, walking, social relations, writing, voting, and speaking.

Chapter 47

The Sense Organs

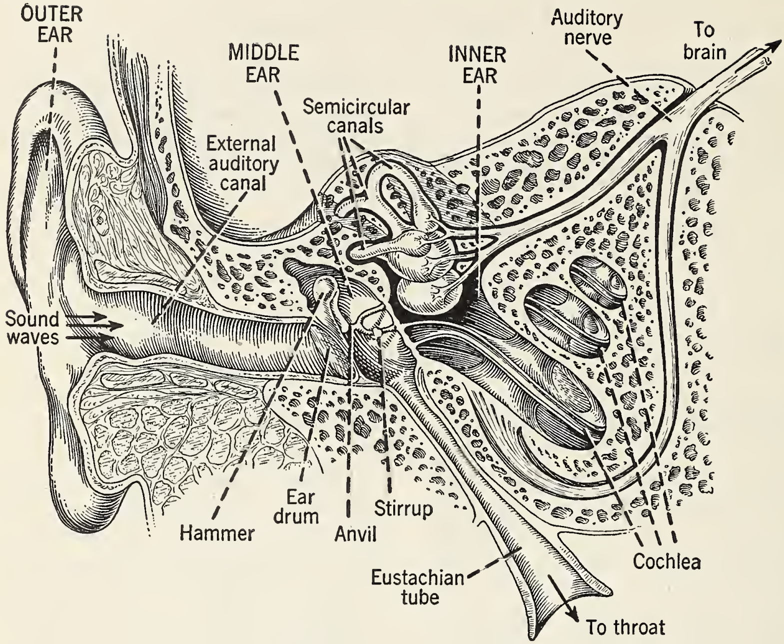
As you learned in the preceding chapter, one of the chief functions of the nervous system is that of control. Another function, even more complex in character, is that of sensation. Most animals have sense organs for seeing, hearing, smelling, tasting, and feeling. Certain animals have senses more acute than our own. In the higher animals, two of these sense organs, the eye and the ear, are marvels of intricate construction, made up of microscopic cells adapted in an amazing way for their peculiar functions. Yet, with all their wonderful structure, the sense organs would be useless without nerves. It is therefore fair to consider them in connection with the nervous system.

Irritability. All living things respond more or less to their environment. Plants react to light, moisture, contact, and gravitation, and thus have a very simple sort of response, usually called *irritability*. These responses enable plants to reach food and water supplies, to turn leaves toward light, to climb by means of tendrils, and to perform certain movements concerned in pollination and seed dispersal.

Touch. Even the simplest animals are affected by actual contact with surroundings. The *Amoeba* recoils from hard or hot particles, absorbs food when in contact with it, and thus may be said to exhibit a primitive sense of touch.

In higher forms, the whole body surface possesses this sense more or less. It is often especially developed in tentacles, hairs, or papillae. In man the sense of touch is common to all parts of the skin, especially the fingertips, forehead, and tongue. The skin possesses special nerve endings that receive temperature, pressure, and pain impressions. If we gently touch different places on the back of the hand with a pencil point, some spots will feel warm and others cold, due to the presence or absence of these nerve endings sensitive to temperature.

Taste. All animals seem to prefer some foods and reject others. We have to assume a sort of taste sense to account for this. To be tasted, a substance has to be in solution and in contact with certain organs near the mouth. The mouth parts, palpi, and tongue are the usual taste organs, and in man the different parts of the tongue are sensitive to dif-



Section Through the Ear

ferent tastes. The back part responds only to bitter, the tip to sweet, the sides to sour, and the whole surface to salty flavors. Most of what we attribute to taste is due to the sense of smell; if eyes and nose are closed one cannot distinguish between an apple, an onion, and a raw potato. Taste and associated smell enable animals to judge of foods, stimulate the flow of digestive fluids, and in aquatic forms may give information as to their location in the water.

Smell. Both touch and taste require the substance to be in actual contact if it is perceived. Smell reaches a little farther away and enables animals to detect substances in the form of vapor or dilute solution, even though at a distance.

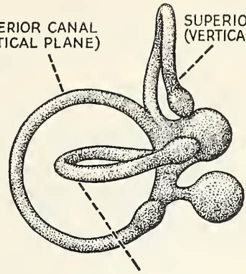
The organs of smell are sometimes hairs, often antennae, while vertebrates have some sort of " nose." These are usually near the food-getting organs, and in air breathers are associated with the inlet to the lungs. Primarily the sense of smell is used to judge of food and air supply but in many cases it is also useful in finding food, detecting enemies, and locating mates. It is little developed in aquatic animals but very keen in insects, Carnivora, and most Ungulates.

Hearing. Hearing puts us into touch with our surroundings through the medium of sound waves conveyed by air or water. This brings within range of our consciousness things at a much greater distance and is the chief avenue of communication among all higher animals, most of which possess some form of sound-producing organs.

The simplest ears in the lower animals consist of mere sacs lined with nerve endings. These may be balancing organs rather than true ears. In insects the sacs are covered with a tympanum or drum membrane, and possibly the antennae also are sensitive to sound vibrations. Ear organs may be located on legs, abdomen, antennae, or head.

The structure of the human ear. The vertebrate ear is a wonderful complicated organ. The external ear opens into an auditory canal embedded in the skull. This canal is closed at its inner end by the *tympanic* [*tim pan′ick*] *membrane* which separates it from the middle ear.

The middle ear connects with the throat by way of the *Eustachian* [*you stay′shun*] *tube,* which serves to equalize the air pressure on both sides of the drum and thus prevents breakage, while permitting free vibration. Across the middle ear extends a chain of tiny bones which connects the tympanic membrane with a somewhat similar membrane in the wall of the inner ear.

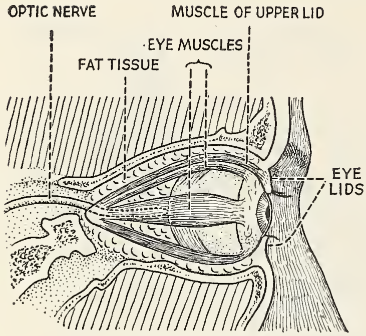


THE SEMICIRCULAR CANALS

The inner ear consists of two general parts. The *cochlea* [*coke′lee ah*] is a cavity in the skull shaped like a snail shell. It is filled with a liquid and lined with

COMPARISON OF SENSATIONS

Sense	Organs	Medium	Uses	Examples	Range
Touch	Surface Skin, hairs Tentacles Papillae	Contact with solids, liquids and gases	Recognition of food and surroundings	Most widely distributed Simplest	Actual contact
Taste	Palpi Mouth parts Tongue	Contact with substances in solution	To judge food and surroundings	Less general	Solution in contact
Smell	Antennae Hairs Nose	Vapor particles	To judge food and air, locate enemies and mates	Keen in the Carnivora, Ungulates, and insects	Semidistant contact
Hearing	Sac and nerve endings Ears, tympanum, antennae, hairs	Air waves	Communication Warning Implies sound-making organs	Sacs in polyp, worm, mollusk, and crustaceans Tympanum in insects and vertebrates	Distant Voice *vs.* speech
Sight	Pigment spots Retina, lens, nerves	Ether waves	Most valuable in all above uses	Compound and simple eyes	Vast distance



STRUCTURE OF THE EYE

a complicated set of nerve endings which receive the sound impressions. The *semicircular canals,* three in number, are little loop-shaped tubes each at right angles to the other, and have to do with maintaining the balance of the body.

How we hear. When a person speaks to us, he starts certain air waves which are gathered in by the external ear, and conveyed to the tympanum, which is thus made to vibrate. By means of the bones of the middle ear, this vibration is communicated to the fluid in the inner ear, and this in turn acts upon the nerve endings of the cochlea. This disturbance of the nerve endings is transmitted to the brain by way of the auditory nerves and we hear the sound of words.

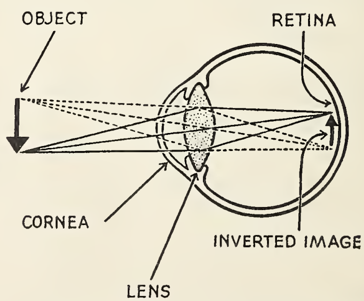
The human ear can distinguish vibrations varying from sixteen to forty thousand per second, but we have reason to believe that insects can hear sounds of higher pitch.

The care of the ears. Fortunately this delicate and important organ is deeply embedded in the skull where little harm can reach it, but care must be observed not to injure the tympanum by probing with hard implements, ear spoons, etc., when trying to clean the ear. In this connection it has been said that one ought never to explore his ears with anything sharper than his elbow.

Ear wax has a useful function in keeping out dirt and insects, and excess can be properly removed by ordinary washing. Foreign bodies should be washed out, never removed by " poking " with hairpins and other implements. Water which enters the ears in diving does no harm if it is shaken out afterwards.

Ear ache or a discharge from the ear may indicate a serious condition. Temporary deafness may be caused by inflammation of the Eustachian tubes as a result of a cold. Permanent deafness may be caused by a blow on the ear bursting the tympanum, or by disease of the middle or inner ear. These conditions should have immediate attention from a physician.

Sight. Plants and the simplest animals respond to light but can hardly be said to " see." The sensation of sight reaches us by means of waves in the ether. These light waves reach us from vast distances and at enormous speed and put us in touch with our surroundings to a wider extent than all the other senses combined. This fact, with its relation to our other activities, makes sight the most valued of all our senses. Yet there is



HOW WE SEE. Can you explain why the image is inverted on the retina?

hardly an organ that we abuse more than we do our eyes.

The simplest eyes are mere colored spots (starfish), with special nerves to absorb light and tell its direction. The highest animals have lenses developed to concentrate light upon these sensitive pigment spots, muscles to adjust both lens and eye, and various devices to protect the whole mechanism.

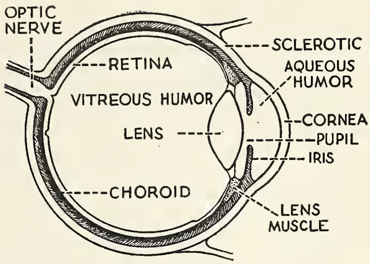
The structure of the human eye. The eye is almost spherical in shape, flattened a little from front to rear. The wall of the eyeball consists of three layers. The outer one is tough and white, called the *sclerotic* [*skle rot′tick*] coat, and shows in front as the " white of the eye." The anterior surface of the sclerotic bulges a little, and becomes transparent in the circular region called the *cornea* [*kor′ nee ah*].

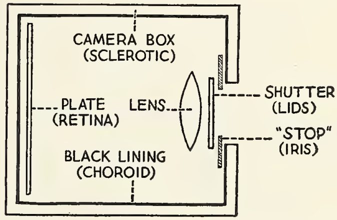
The second coat, called the *choroid* [*ko′roid*], is richly supplied with blood vessels and pigment (color) cells which prevent reflection of light inside the eyeball. This coat shows in front as the *iris* [*eye′ris*] or color of the eye. The iris is provided with muscles which regulate the size of the center opening, the *pupil*, according to the amount of light.

The inner layer is the most delicate and complicated part of the eye and is called the *retina* [*ret′in ah*]. It is really the expanded end of the optic nerve and connects directly with the brain. It also has a dark pigment and though only 1/80 of an inch in thickness, it consists of at least seven distinct layers of cells which help in receiving the impressions of light waves.

The lens of the eye is located just behind the iris and is joined to the choroid by delicate muscles which can change its thickness, to adjust its curvature for near or distant vision.

The space in front between the lens and cornea is filled with a watery fluid, and the ball of the eye is occupied by a jellylike, transparent substance which keeps the eye in shape.

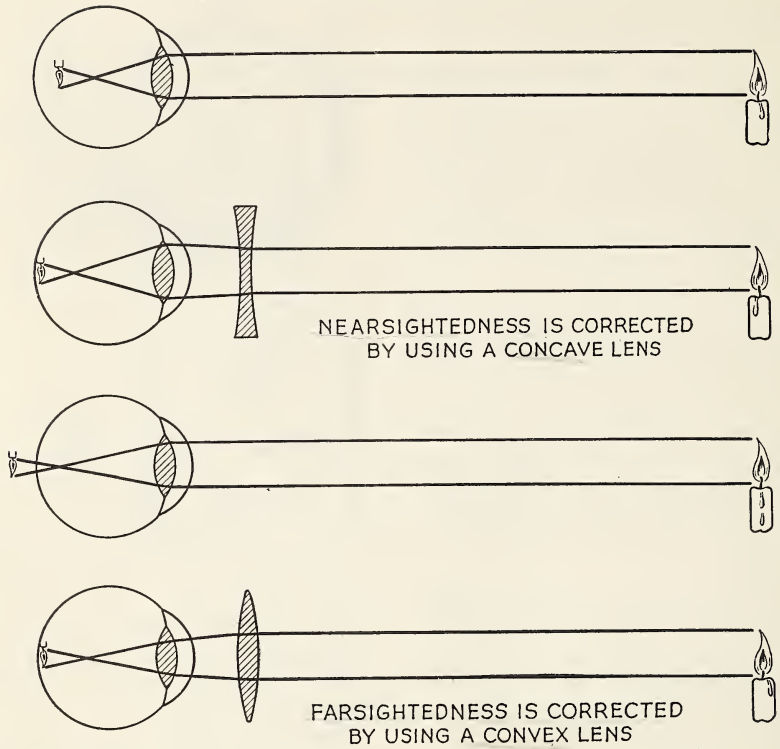




Comparison of the Eye and Camera. Explain how each functions.

How we see. Light waves from an object pass through the cornea to the lens which concentrates (focuses) them upon the retina as you would focus a picture on the film of your camera. The iris controls the amount of light entering the eye and the lens muscles change its shape so that the picture on the retina may be sharp and clear. The retina is affected by the light that falls upon it and the impression is carried to the brain by the optic nerve.

The protection of the eye. Obviously, the eye cannot be buried in the skull for protection, like the ear, but it is well guarded none the less. The bony socket, walled in by the forehead, nose, and cheeks, wards off any but direct blows. The pad of fat on which it rests saves it from jar or pressure. The eyebrows keep



DEFECTS OF THE EYE. Explain how nearsightedness and farsightedness may be corrected.

out perspiration and the lids and lashes protect from dust. Tear secretion constantly washes the front surface and a complicated set of reflex actions helps us to avoid most injuries to this important sense organ.

The living camera. The eye is often compared to a camera, and there are so many resemblances that the following table of comparisons may be helpful.

In making this comparison it must always be borne in mind that there are also fundamental differences. The eye is alive; the camera is not. The eye produces a sensation within the brain; the camera makes a picture. The eye focuses

Part of eye	Corresponding to	Part of camera
Ball	" "	Camera box
Lens	" "	Lens
Lids	" "	Shutter
Iris	" "	Stops or diaphragm
Pupil	" "	Lens opening
Lens muscles	" "	Focusing devices
Black pigment	" "	Black lining
Retina	" "	Plate or film

by changing the shape of the lens; the camera by changing the distance of the lens from the film.

The defects of the eye. The care of the eye is dealt with in the next chapter, but it is well to remember that seldom are eyes perfectly normal and frequent examination by a competent specialist is the only sure way of preserving their usefulness. Below are tabulated some of the common conditions and their causes, but only an expert can determine the exact kind of lens or method of treatment which will remedy the defect. An *optometrist* [*op tom'ah trist*] may be able to diagnose and remedy most eye troubles, but many people feel safer in consulting an *oculist* [*occ'you list*]. The optometrist, who is not a doctor of medicine, measures power of vision and prescribes lenses by mechanical means. The oculist is a medical doctor trained as an eye specialist.

Condition	Defect of eye	Remedy
Near sight	Eyeball too thick (from front to back) or lens too curved	Concave lens glasses
Far sight	Eyeball too thin (from front to back) or lens too flat	Convex lens glasses
Astigmatism	Irregularity in shape of lens, or cornea	Special cylinder lens glasses
Old age	Loss of lens adjustment resulting in far sight	Convex lens glasses

Summary

The quality of sensation includes the various sense organs which enable us to touch, to taste, to smell, to hear, and to see. These are all dependent on the nervous system.

The ear is a complex and very delicate organ. It consists of three parts, the external, the middle, and the inner ear. The external ear receives sound waves which are transmitted to the middle ear by the tympanic membrane. The bones in the middle ear then carry these vibrations to the fluid in the inner ear, which acts on the nerve endings there. These auditory nerves in the inner ear send the sounds to the brain and hearing results.

Equally delicate is the eye. In this organ light waves from an object pass through the cornea to the lens which focuses them on the retina. The iris controls the amount of light entering the eye and thus makes the image on the retina sharp and clear. The retina, which is really the expanded end of the optic nerve, connects directly with the brain, and the impression is conveyed there with the result that we see.

Both ears and eyes deserve the most thorough care, and regular visits to a doctor will do much to prevent any impairment of hearing or vision, and to correct any defect which may develop before injury occurs.

Using Your Knowledge

1. If you lost both the senses of smell and taste, do you think your selection of food would become more scientific? Explain. Do you think your health might be affected? Why?

2. Can you name all the different types of auditory organs found among animals?

3. Do you know how many vibrations per second middle A on the piano has? Would the same note on a violin have the

same number of vibrations? How could there be sounds that we could not hear?

4. What part of the brain functions as the co-ordinating center of vision?

5. Can you give clear explanations to show how glasses will correct (*a*) nearsightedness, (*b*) farsightedness?

6. Explain how animals like the cat can "see in the dark."

7. Which animals have the best vision? What makes this possible?

8. Name several animals which never make any sounds. What compensations enable them to live successfully?

Expressing Your Knowledge

irritability	cornea	pupil
cochlea	iris	optometrist
Eustachian tube	choroid	oculist
tympanic membrane	retina	concave lens
semicircular canal	optic nerve	convex lens
lens	sclerotic coat	astigmatism

Applying Your Knowledge

1. Report on "black light" or ultraviolet light. Also report on infrared light.

2. Get a butcher to save for you the eye of a cow, sheep, or calf. Very carefully dissect it to find all the parts.

3. With a watch held at various distances test yourself and the other members of your family to see whether hearing is normal in both ears.

4. Report on the use of hearing aids.

Chapter 48

Maintaining a Healthy Body

One of the chief reasons for the study of biology is to learn how properly to care for one's own body in order to maintain it in healthy condition. The science which deals with the care and health of the body is called *hygiene* [*high'jeen*]. Because it applies knowledge and information to practical uses, hygiene is frequently referred to as an *applied science*.

Superstition and individual beliefs often give rise to strange "rules of health." Here are some examples: "Night air is injurious." "Proteins and carbohydrates must not be eaten together." "Never drink water at meals." "The wearing of a flannel band will prevent colds, and a piece of salt pork worn around the throat will cure a sore throat." If you will use the general biological knowledge that you have in a common-sense application to living, you should be able to construct your own hygienic rules. This would be better than trying to memorize a set of directions for living without understanding the reasons for so doing.

Health is the normal condition of the body, and yet there are few who are never sick. Lack of health is due to some biologic mistake. While we can probably never avoid disease entirely, our study of biology ought to help us to escape those troubles whose causes we know. If we live as well as we know how, we will be stronger, healthier, and happier.

Hygiene of the muscles. Proper muscular exercise is being stressed by individuals and by nations, and it is well to understand some of the reasons.

1. Exercises strengthen the muscles used by increasing their size. This, though most often mentioned, is the least important result.

2. Exercise increases oxidation from three to ten times, thus liberating greater bodily energy.

3. Exercise withdraws the blood from the internal organs to the muscles and so relieves the tendency to over-supply and congestion; this is shown by the " health color " of the complexion due to the blood supply in the outer muscles; a very pale skin usually indicates poor health.

4. Only by proper exercise do the heart, arteries, lungs, and other internal organs maintain a normal tone.

5. Motion of the muscles is one of the chief causes of lymph flow, and we know that upon the lymph circulation depends the nutrition of the tissues.

No rules will be given as to special kinds of exercise, since different people need different kinds, just as we need different amounts of food.

Rules for Proper Exercise

1. Exercise should be vigorous, continuous, and kept up for a reasonable time. For example, a brisk walk is one of the best of exercises, while a short stroll or saunter does little good, though often mistaken for " excerise."

2. The body muscles should be used as well as arms and legs; walking, swimming, and throwing are good examples.

3. There should be full, deep breathing, preferably in the open air. Loose clothing and erect position are equally important.

4. The exercises should be varied and should occupy the mind as well as the body; movements, however excellent, lose much if they are not enjoyed. This is the objection to many " systems of exercise " which become distasteful because of mere physical routine. Physical culture by means of radio or phonograph instruction is becoming increasingly popular.

Exercise and rest. There should be a proper balance between rest and exercise, both in a physical and mental sense. Generally every muscle in the body should be exercised daily.

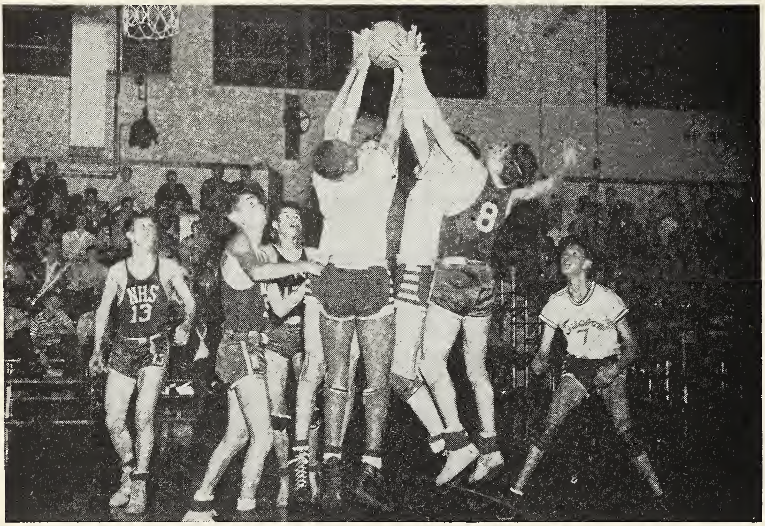
The most beneficial exercises are those which stimulate the action of the heart and lungs, such as rapid walking, running, hill climbing, and swimming.

The exercise of the abdominal muscles is most important in order to give tone to those muscles and thus aid the portal circulation and the passage of food products through the intestine. For the same reason, erect posture, not only in standing but in sitting, is important.

Exercise should always be limited by fatigue, which brings with it fatigue poisons. This is nature's signal.

One should learn to relax. This habit produces rest, even between exertions coming close together, and enables one to continue those exertions for a much longer time than otherwise. The habit of lying down when tired is a good one.

The same principles apply to mental rest. Avoid worry, anger, fear, excitement, hate, jealousy, grief, and all depressing or abnormal mental states. This is to be done not so much by repressing these feelings as by *dropping* or ignoring them — that is, by diverting and con-



ONE FORM OF EXERCISE. Basketball and other sports are beneficial because they stimulate the action of the heart and lungs, and give the body muscles the necessary exercise for proper functioning.

trolling the attention. The secret of mental hygiene lies in the direction of attention. One's mental attitude ought to be optimistic and serene, and this attitude should be striven for, not only in order to produce health, but as an end in itself, for which, in fact, even health is properly sought. In addition, the individual should, of course, avoid infection, poisons, and other dangers.

Occasional physical examination by a *competent* medical examiner is advisable. In case of illness, reliable treatment should be sought.

Finally, since proper air, water, and food depend on health legislation and administration, everyone, for the sake of others as well as for his own good, should take part in the movements to secure better public hygiene in city, state, and nation.

Posture. The human animal is not as yet completely adapted to his erect position. This makes especial care necessary in youth to achieve a healthful posture in walking, standing, and sitting.

One of the reasons for compulsory physical exercises in school is to correct errors of posture and to develop an erect carriage of the body and healthful functioning of all its organs.

Round shoulders and slouchy posture are due to careless or lazy habits of muscle control. So much work is done while seated and with the body leaning forward that it is easy to let the muscles relax, the shoulders sag, and the spinal column bend over in a way never intended by nature. This restricts lung action and displaces the other internal organs, resulting in impaired health as well as poor appearance.

The state of mind influences the posture more than we realize. If we allow ourselves to feel afraid, our cringing, fearful attitudes will reveal that fact. If

Ewing Galloway, N.Y.

Incorrect and Correct Posture. What is wrong with the posture of the girl on the left?

we think mean thoughts or are conscious of mean acts, we cannot so easily hold up our heads, look persons in the eye, and appear at our best.

In the same way posture affects our state of mind. Even if you are tired or discouraged, square your shoulders, pull in your chin, and you will feel better able to meet your difficulties. "Keep a stiff upper lip" and "Hold up your head" are not merely figures of speech but good hygienic advice.

Walking is a daily exercise in posture development, if we really have "learned to walk." With head and shoulders erect, though not stiff, and a free stride with feet carried straight ahead, walking becomes wonderful posture training. Yet, notice how few people walk really well or have the endurance to walk far.

Even mere standing is seldom correctly done. The trunk should be erect and the shoulders so held as to give the lungs room to expand. Heels should be close together, the back flat, and the abdomen drawn in. The ideal is not an exaggerated military bearing, but such a posture as will permit easy balance, free breathing, and good appearance. The obvious remedy is to *think good posture.* Then we shall sit back in the chair with shoulders up; and, when we lean forward, the trunk will move from the hips which is the way it should be.

Food. Masticate all food up to the point of involuntary swallowing, with the attention on the taste, not on the mastication. Food should simply be chewed and relished, with no thought of swallowing. There should be no more effort to prevent than to force swallowing. If you attend only to the agreeable task of extracting the flavors of your food, nature will take care of the swallowing, and this will become, like breathing, involuntary. The instinct by which most people eat is perverted through the "hurry habit" and the use of abnormal foods. Thorough mastication takes time, and therefore if the best results are to be secured one must not feel hurried at meals. Sip liquids, except water, and mix them with saliva as if they were solids.

The stopping point for eating should be at the *earliest* moment when one is really satisfied. Many overeat.

The frequency of meals and time to take them should be so adjusted that no meal is taken before the previous meal is well out of the way, in order that the stomach may have time to rest and prepare new juices. Normal appetite is a good guide in this respect. One's best sleep is on an empty stomach. Food puts one to sleep by diverting blood from the head, but may disturb sleep later. Water, however, or even fruit, may safely be taken before retiring.

An exclusive diet is usually unsafe. Even foods which are not ideally the best are probably needed when the appetite especially calls for them or when no better are available.

The amount of protein required is much less than ordinarily consumed. *To balance* our meals is of highest importance. If one could trust the appetite, it would be an almost infallible method for some people, but definite knowledge of foods will help all of us. The aim, however, should always be — and this cannot be repeated too often — to educate the appetite to the point of deciding all these questions automatically.

Be sure that the water you drink is free from dangerous germs and impurities. "Soft" water is better than "hard" water. Ice water should be avoided unless sipped and warmed in the mouth.

Drinking plenty of water, especially a glass half an hour before breakfast and on retiring, is an excellent plan for everyone.

Hygiene of digestion. For the general study of foods refer to Chapter 40. The following is a summary of facts explained there:

1. The amount and kind of food should be adjusted to the work of the body. Vitamins should be supplied.

2. The "balance" of the ration should be maintained.

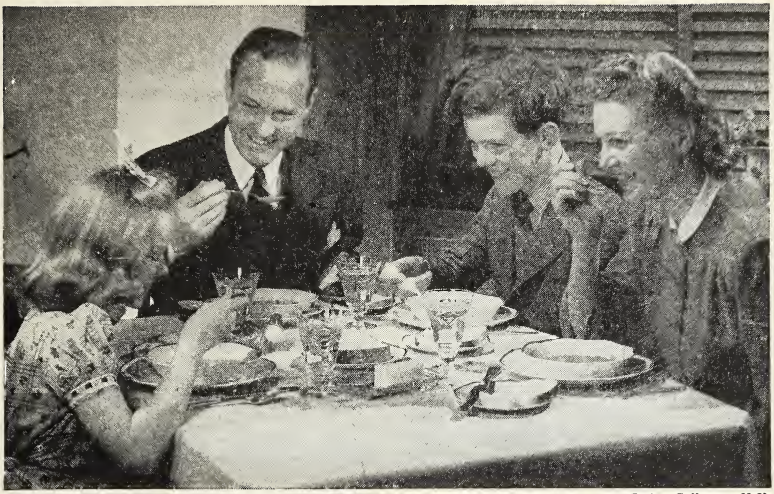
3. The food should be clean and properly prepared.

4. Usually the heartiest meal should come after the day's work and should be preceded by a brief rest. Only when the brain or muscles are not working can the digestive organs get a proper supply of blood.

5. Eating between meals is usually a bad practice, especially in the case of sweet foods, as it prevents proper desire for, and digestion of, the solid food which the body requires.

6. Water should be drunk in abundance (six to eight glasses per day), especially between meals, but not to wash down unchewed food nor to flood the stomach at mealtime.

7. It is unnecessary to dwell upon the importance of thorough chewing. The smaller the food particles, the greater the surface exposed for digestion and the less burden is put upon the stomach. The starch digestion in the mouth may not



Ewing Galloway, N.Y.

A FAMILY DINNER. The meal is eaten slowly; the family is relaxed and enjoying good conversation. There is no feeling of hurry or of tension.

be very extensive, but thorough mastication prevents overeating and too rapid eating, both of which produce more indigestion than all other causes put together. " Leave the table hungry " is a good rule for most people.

8. Ignore certain popular beliefs, such as not eating protein and carborydrates together.

9. Exercise, study, worry, or any severe physical or mental activity at or near mealtimes interferes with digestion.

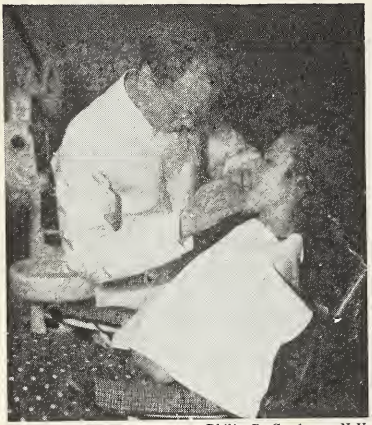
10. Regular attention must be given to the removal of waste from the intestine, as many illnesses can be traced to lack of care in this regard.

Hygiene of the teeth. Conditions in the mouth are ideal for the growth of bacteria which cause decay. Warmth and moisture are sure to be present, and unless great care is observed, particles of food will remain for the bacteria to feed upon. If dental floss is passed between the teeth and the odor then noted there will be no doubt that decay has been taking place. The total area of possible tooth infection is equal to that of two standard Petri dishes (over twelve square inches).

The decay of food between the teeth destroys the protective enamel and the dentine then goes rapidly. The immediate results are bad breath, pain, and loss of teeth. Fully as serious are the secondary consequences of poor chewing: indigestion, pus diseases from infected gums, rheumatism, and nervous disorders. Tonsils, throat, ears, and even the lungs and heart may be infected from the teeth.

Proper care is therefore necessary if the teeth are to be preserved and the food to be well chewed. This means frequent, thorough brushings, and a visit to the dentist at least twice a year, whether you " need " it or not.

Hygiene of respiration. We have learned the use which the body makes of oxygen in releasing the energy in our foods and keeping us alive and active.



Philip D. Gendreau, N.Y.

At the Dentist's. This patient has her teeth checked regularly by her dentist twice a year.

Naturally, proper breathing is required if this process is to go on in a healthful way. We should breathe through the nose and also breathe deeply.

Few of us know how to breathe, even though we use the expression "natural as breathing." Correct breathing means using more lung tissue, getting more oxygen, and developing the diaphragm and rib muscles properly. We cannot use *all* our lung capacity at once, but should use all we can. We train the other muscles for less important uses; why not train our breathing muscles for the race of life? Erect position and comfortable clothing aid proper breathing.

Diseased tonsils and adenoids should be examined by a competent physician, to see if they should be removed.

Air and ventilation. Stay out of doors as much as possible.

When indoors, have the air as fresh as possible (*a*) by airing the room before occupancy; (*b*) by having it continuously ventilated while occupied.

Not only purity but coolness, dryness, and motion of the air, if not extreme, are advantageous. Air in heated houses in winter is usually too dry, and may be moistened with advantage.

Clothing should be sufficient to keep one warm. The minimum that will secure this result is the best. The more porous your clothes, the more the skin is educated to perform its functions with increasingly less need for protection. Take an air bath as often and as long as possible.

Fresh air is not necessarily cold air as some people seem to think, though in sleeping rooms the temperature should be lower than in living quarters. Extreme cold is not an advantage, even in sleeping rooms, except in cases of tuberculosis, and many people subject themselves to dangerous exposure in this way. Air should be pure, cool, and abundant, but there is no virtue in extreme coldness.

Dust removal. Dust carries bacteria, hence air should be as free from it as

Monkmeyer Press Photo Service

Skiing. Fresh air is necessary even in winter, and the clothing worn should be sufficient to keep you warm.

possible. This means replacing the broom and feather duster by the vacuum cleaner and oiled dust cloth. Rugs and hardwood floors should take the place of the permanent carpet. Smooth walls, simple furniture, and few hangings offer less opportunity for the accumulation of dust. Sprinkling, oiling, and flushing the streets are sanitary methods of dealing with outdoor dust.

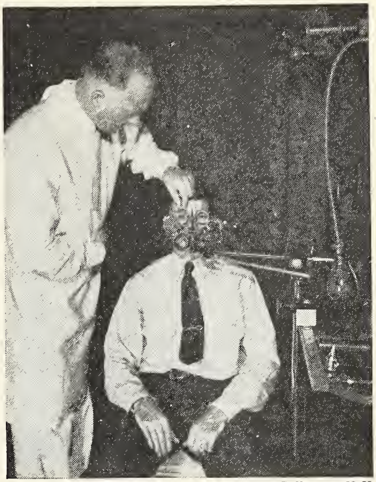
Hygiene of the eyes. The human eye is such a delicate and necessary structure that its care should be emphasized, but just because it is so complicated, no rules can be made which will properly safeguard it. The one safe procedure is to have the eyes examined from time to time by a competent expert, even if no defect appears to be developing.

Reading in poor light, or at evening when light is gradually failing, is a common error. Almost as bad is the use of too bright light directly facing the eyes, or reflected from too shiny paper. Long continued use of the eyes on very fine print or sewing causes severe strain.

Actual defects in structure or, more often, overuse under poor conditions, produce eyestrain, and from this result headache, sleeplessness, and nervous troubles of serious nature, in addition to the damage to the eye itself. Common sense in their use, immediate rest when any feeling of fatigue is caused, and prompt advice from an expert are the only rules for the care of our eyes.

Hygiene of bathing. Bathing is primarily to remove dirt. Dirt is objectionable for two reasons: it is offensive to refined people and it often carries germs.

Washing to " keep the pores open " is not a true reason, because the skin excretes but little waste, and the pores open automatically, even in the dirtiest skin, when perspiration is required for heat regulation.



Ewing Galloway, N.Y.

Eye Examination. This airlines pilot is having his eyes checked by the oculist to be sure that his vision is perfect.

There is a strong argument for a daily cold bath, because it gives the skin practice in adjusting itself to sudden changes of temperature similar to those it encounters in everyday exposure. The cold shower or sponge bath, if followed by brisk rubbing, causes the skin arteries to contract and then expand again, as evidenced by the glow of the skin.

This is precisely what the body should do when exposed to sudden chill of any sort; and, if trained by frequent cold bathing, the arteries should be ready to regulate the blood supply, and no cold or congestion should result.

Neither bathing nor swimming should be done within at least an hour after mealtime, as the blood is needed to absorb the food and should not be diverted to the skin. The bath should not be so cold nor the swim so long-continued as to cause a permanent chill or prevent the warm reaction when the body is rubbed dry.

X RAY OF FEET. A: position of bones in an unshod foot; B: position of bones in a well-fitted shoe; C: cramped bones in a tight shoe.

The cold bath is primarily a means of prevention of colds and all that they lead to; if indulged in, it should be taken in the morning, immediately upon rising. The warm bath is a means of cleansing the skin and is valuable in cases of fatigue and needed relaxation. A very hot bath should be taken only on a physician's orders.

Hygiene of the feet. With the possible exception of the eye, no human organ has been more abused than the foot. We crowd our feet into airtight leather boxes, bend the toes together, lift the heel high off the ground and then wonder why we suffer from corns, bunions, and fallen arches. Proper shoes should have the inner edge nearly straight, heel low and broad, toe with room enough to allow the toes to separate and "wriggle." The uppers should be flexible, as porous as possible, and not too tightly laced. The arch of a normal bare foot should not touch the floor on the inner edge. The shoe should be so shaped as to support this upward curve, but the shank of the shoe should be flexible. The selection of shoes should be guided by the expert advice of a doctor or trained fitter and not be governed by the vagaries of style or the demands of fashion. Feet were made to walk on, not to look at. In walking, the feet should be carried forward with the toes straight ahead. "Toeing out" is as abnormal as "toeing in" but it is so common that often it is unnoticed.

Flat feet and fallen arches are frequently caused by improper shoes or by wearing shoes badly "run over." This condition is often painful, sometimes leads to other disorders, and may interfere seriously with standing or walking.

An exercise suggested for one type of fallen arch consists in standing "toed in" and rising on the toes several times every day. This will strengthen one of the foot arches. Standing on the outer edge of the foot and curling the toes back toward the heel is another helpful exercise. Walking with feet parallel and toes straight ahead is the correct way to walk and tends to prevent flat feet.

It is important to wash the feet and to change the stockings daily, as poisonous matter is constantly excreted through the skin of the feet.

Treatment of foot disorders is not a simple matter, and an expert should be consulted whenever necessary.

Hygiene of the nerves. Man has reached the stage where mental activity takes the place of physical exertion, and there is constant danger of one-sided development.

Mental fatigue is just as real as muscular fatigue. The brain should not be forced to work when it is already tired or when the energy of the body has been used in hard physical labor.

Mental hygiene is just as important as physical hygiene. A well-trained brain, developed by proper exercise, is vastly more valuable than powerful muscles and needs even greater care in its development. True education means just this training and developing of the brain, rather than merely storing the mind with absorbed information. Accumulation of facts is important, but it is not to be compared with the development of the brain that comes as a result of observing, thinking, and reasoning.

Sleep is the period of rest from nerve activity, relaxation of muscles, repair of waste, and growth of new tissue. It is thought to be a temporary loss of consciousness which comes about due to a lessening of the nerve impulses. No real theory to explain it satisfactorily has been given. But it is known that any emotional disturbance in the nervous system, or any abnormal excitement, will prevent sleep for a while.

Because children, by their intense activity, are growing as well as using tissue, they need more sleep than do adults. While seven to eight hours' sleep will do for most grownups, children need from nine to ten hours.

Summary

Good health is the normal condition of the body, and lack of it is due to some biological mistake. In order to keep the body in this natural state of good health, attention must be paid to keeping the various organs and systems of the body in the best possible health.

Proper muscular exercise, balanced with adequate rest, is very important. Good posture in walking, standing, and sitting is also necessary as a means of keeping the various organs functioning in the most healthful way.

To maintain a good digestive system, food should be well chewed, eaten slowly, and carefully selected so as to keep a balance between the proteins, fats, and carbohydrates. A short rest period following meals is desirable. Regular attention must be given to the removal of waste from the intestine.

Fresh air is essential to good health. As much time as possible should be spent out of doors, and when indoors, the air should be kept pure, cool, abundant.

Proper care of the teeth, eyes, and feet also leads to good health. Mental fatigue is dangerous, and the brain should not be forced to work when it is tired. Sleep is essential to all healthy bodies, because during sleep the body relaxes the muscles and nerves, and builds new tissues.

Using Your Knowledge

1. Can you explain why greater benefits accrue if exercise is enjoyable?

2. What are the benefits and what are the dangers of relaxation?

3. Can you name all the ways in which preventive oral hygiene pays health dividends?

4. Which method do you think gives more hygienic and healthful results during fluctuating temperatures of cold weather: the practice of wearing heavy flannels or underclothing, or the practice of putting extra clothing on the outside when necessary?

5. Can you explain why feather dusters are still used in some institutions?

6. Which method do you think is preferable for thorough ventilation? Give arguments.

Expressing Your Knowledge

sanitation	optimistic	" milk " teeth
applied science	educated	bunion
masticate	shank	arch
hygiene	last	corns
relaxation	posture	congestion
eyestrain	flat feet	ventilation
adenoid	dust	diet
infected	tonsil	exercise

Applying Your Knowledge

1. Make a report on the " Munson " last, which was used as the basic model for the shoes manufactured for the U. S. Army.

2. Do some investigating and find out some " makes " of shoes that have: (*a*) a flexible shank, (*b*) the inner edge nearly straight, (*c*) a fairly low heel.

3. Inquire of your local dealer and ask him to give you all the facts pertaining to air conditioning.

Chapter 49

Alcohol and Narcotics

For thousands of years, for one reason or another, some members of the human race have indulged in habits not necessary to life. These habits include the use of tobacco, alcoholic beverages, and drugs. Rarely, in all probability, do individuals determine to form habits of this kind. Repetition, even without voluntary thinking, makes it easier to continue, and before the person is aware of it the habit has been formed.

It is unfortunate that the physiological and mental effects of the use of alcohol and tobacco are often spoken of together, as if they had much in common. Young people, seeing adults little harmed by the use of tobacco, assume that alcohol is no worse, and they may thus begin a ruinous career of drinking. They may also conclude that tobacco is harmless for themselves, although all the data which we have shows that nicotine and other derivatives produce dangerous results if used by growing boys and girls.

Tobacco. Tobacco contains a harmful alkaloid, *nicotine* [*nick'ko teen*], and also when burned produces a small amount of carbon monoxide, a poisonous gas. In addition, if the smoke is " inhaled," a substance called *acrolein* [*ack ro'lee in*], together with the smoke particles, tends to irritate throat and lungs. The lungs also have a larger area than the mouth for absorption of nicotine and carbon monoxide.

Tobacco is narcotic in effect. *Narcotics* are substances which deaden nerve action and tend to decrease bodily efficiency and hinder growth. The physical effects, while not to be compared with the possible ravages of alcohol, are nevertheless important and should be noted.

Effect on endurance. Any narcotic interferes with nerve control, especially of heart and lungs. That this is the case with tobacco has been abundantly proved. For this reason, no trainer permits smoking by members of his team, knowing well that endurance and "wind" cannot be developed when tobacco is used. If the use of tobacco could be of any assistance in helping athletes to be successful it would certainly be prescribed. Statistics from six leading colleges show that of those who "made the team" approximately two-thirds were nonsmokers.

Effect on co-ordination. A rifle coach, connected for twenty years with two of the New York City high schools presents an interesting report. Competition was keen for places on the first team which was a consistent winner and had carried off two championships of the United States. Opportunities were afforded to note the lack of nerve control in boys who "tried" tobacco. Such boys were invariably more erratic and usually "blew up" in a tight match. A notable example one year was the captain, who nearly lost his place on the team before even the coach knew that smoking was causing his low scores.

Effect on growth. In some cases, the use of tobacco seriously affects digestive processes and in its early use the stomach usually revolts at its presence. The effect of excessive smoking may even extend to the vital activities of protoplasm and actually "stunt the growth" of various organs. This is possible where it is used by young people.

Effect on mental development. Many investigations at different schools and colleges have thoroughly proved that the use of tobacco impairs scholarship. Dr. G. L. Meylan, formerly physical director at Columbia University, concludes:

1. Smokers averaged eight months behind nonsmokers in their advancement.
2. Scholarship standing of smokers was distinctly lower.
3. Use of tobacco by students is closely associated with lack of ambition, application, and scholarship.

Antioch College has issued a special report showing a definite relationship between smoking and poor scholarship.

Another investigation shows that:

1. Smokers average lower in grades.
2. Smokers graduate older.
3. Smokers grow more slowly in height and weight.
4. Ninety-five per cent of honor pupils are nonsmokers.

Boys certainly will note many successful men, perhaps their own fathers, who do not seem to be harmed by smoking and, forgetting the difference in ages, will draw wrong conclusions. Tobacco might do less harm if it were more harmful, so that its effects could be more easily traced.

Tea and coffee. To a degree much less than tobacco, these beverages contain harmful *alkaloids.* Alkaloids are substances usually produced in plants, which are capable of poisonous effects on animal tissues. As with tobacco, their use is not wise for the young. With adults, moderate indulgence may do no harm or may even be beneficial, though this is a matter which every person must decide for himself.

Neither has much food value and both tend to become habits. On the other hand they sometimes seem to soothe the nerves (which ought not to need soothing), or to permit one to continue work when tired — a rather doubtful benefit. The tannin of weak tea is less harmful than the caffeine found in coffee.

Cocoa and chocolate. These contain fewer alkaloids and a great deal of fat, hence are real foods. More people should learn to prepare them properly and then tea and coffee would be less used, with benefit to all concerned.

There is a growing tendency to drink beverages advertised as "pick ups" for tired nerves. It seems unnecessary to say that no beverage containing caffeine or similar stimulants, alcohol, opium, morphine, chloral, cocaine, or any of their derivatives, or medicines containing any of the foregoing, especially "painkillers," should *ever* be used except by advice of a reputable physician. The danger of forming a "drug habit" in this way has led to strict laws, which we should all help to enforce. This danger is very real.

The uses and effects of alcohol. In ancient times, alcohol had only one use: as an ingredient in beverages. Today, alcohol is an indispensable chemical substance which is used as a solvent, a preservative, and a raw material in a growing number of industries. These are matters that concern the manufacturing chemist, while biology has to do only with its effects when used as a beverage by man.

Because alcohol is a stimulant, the consumption of alcoholic liquors is a biological problem involving critical evaluation of its physiological and social effects. Many opinions and conclusions regarding alcohol and its effects on the body have been voiced by doctors, chemists, biologists, and the general public. It is only during recent years that sound experimental evidence has been available to evaluate scientifically the vast amount of literature on the subject. Many of the experiments, statements, and conclusions in this chapter are based on the exhaustive investigations of Dr. Abraham Raskin, on "The Effects of Alcohol" (1941).

Alcoholic beverages. The common alcoholic beverages are:

Beer (3–8% alcohol), made from fermented barley

Wine (15–20% alcohol), made from fermented grapes or other fruits

Gin (22–48% alcohol), distilled from fermented grain and malt

Rum (40–50% alcohol), distilled from fermented molasses

Whisky (40–54% alcohol), distilled from fermented grains

Brandy (50–54% alcohol), distilled from wine

Liqueurs (50–60% alcohol), alcoholic spirits, flavored

In addition to the more commonly known alcoholic drinks, different countries produce their own kinds, usually from native fruits and foods. For instance, in Mexico the juice of a cactus is fermented to make *pulque* and then distilled to make *mescal.* In Russia, *vodka* is the national drink. Throughout the world, wine is probably more widely used than any other alcoholic beverage. Both primitive and modern methods can produce liquors with a high concentration of alcohol.

Can alcohol be regarded as a food?

1. Alcohol, like carbohydrate foods, can be oxidized in the body, one gram furnishing 7 Calories; but it cannot, like protein, furnish building material for tissue making or repair. To a limited degree, alcohol can take the place of fat, carbohydrates, and proteins which might otherwise be oxidized. Starling states that in moderate doses, 98 per cent of the alcohol consumed is oxidized and the remaining 2 per cent is excreted in the breath and in the urine. The amount of alcohol in the blood corresponds to the amount consumed.

2. Alcohol can be absorbed directly from the stomach and is rapidly distributed throughout the entire body.

3. Alcohol increases the flow of saliva. In amounts less than 10 per cent of the stomach contents, alcohol increases the flow but decreases the quality of gastric juice.

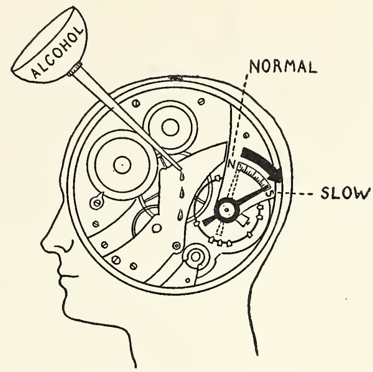
4. Alcohol in concentrations above 19 per cent has a bad effect on stomach digestion.

Alcohol can release energy in the body and to that extent might be called food. However, it is not a safe food, because it is exceedingly expensive compared with true foods, and dangerous in its possible results on the body.

How does alcohol work as a body fuel? Experimental evidence seems to indicate that moderate amounts of alcohol do not appreciably lower the ability to perform unskilled work. Alcohol must not be considered as a true stimulant for continuous work, because it is too quickly oxidized and because it tends to affect adversely the nervous system and mind.

In work requiring skilled acts (coordination), the adverse effects of even small or moderate amounts of alcohol have been clearly demonstrated. H. M. Vernon found that 30 centimeters of alcohol diluted to 150 c.c. and taken with food had little effect on typewriting speed, but increased the errors by 67 per cent. Without food, the same dose increased the typewriting time 5.6 seconds *and the mistakes by 105 per cent.*

Alcohol and the circulation. Alcohol causes a temporary enlargement of the blood vessels near the surface of the body. Thus a larger amount of blood than usual rushes to the skin from the internal organs and the individual feels warm and flushed, or "stimulated."



Alcohol and Mental Activities. The continued use of alcohol definitely slows down mental activities.

Because of this result, alcohol may be of assistance in emergencies. On the other hand, the use of alcohol during a period of exposure to cold might easily lull the individual into a dangerous state of belief that he is warm and safe, while actually he may even be in danger of freezing to death.

Alcohol, in small or moderate quantities, does not particularly affect the heartbeat or the blood pressure. Nor does moderate drinking seem to affect the red and white blood corpuscles, though large quantities of alcohol adversely affect the activities of the white blood cells.

It should be noted, first, that the relaxation of the blood vessels is due not to any true stimulation but rather to a *deadening* of the nerve controls, proving that alcohol is a narcotic; and second, that, although the skin feels warm owing to the excess blood, it is actually losing heat, because so much blood is brought to the surface.

Alcohol and respiration. According to the best authorities, moderate amounts of alcohol do not affect the respiratory system. However, most investigators believe that excessive indulgence in alcohol has a decidedly bad effect in lowering the body resistance to pneumonia. Dr. Osler once said that drunkards have a very slim chance of recovering when attacked by pneumonia. Other authorities confirm the experimental evidence that previous alcoholic excess increases the possiblity of death in cases of pneumonia.

Alcohol and the nervous system. As has been shown, alcohol's principal line of attack is by way of the nervous system, and it is here that its effects are most serious. In the development of the nervous system, the centers of control form in this order:

1. Heart and circulation control
2. Respiration
3. Large muscles
4. Speech and other senses
5. Moral and intellectual control

The peculiar harm of the narcotic action of alcohol is that it impairs these nerve centers in reverse order. The higher emotions, moral sense, modesty, judgment, and self-control are first attacked, and from this effect arises the record of alcohol as a cause of immorality and crime. With the body control but little impaired and able to carry out the impulses of a disordered mind, a man will commit crimes or perform other acts which he never would have considered doing if his self-control had not been affected by liquor. As intake increases, the speech and sight centers are attacked, and thick speech and double vision result. The large muscles are affected causing a staggering gait and uncertain movements. Finally, the breathing is interfered with, the heart action may be partially or wholly paralyzed, and the condition of "dead drunkenness" or even death may follow.

If the order of its effects were reversed, alcohol would not be so dangerous, because the body would then be unable to carry out the demands of the deranged brain. Unfortunately this is not the case; and herein lies one of alcohol's greatest biological dangers. All authorities agree that alcohol is an enemy of the higher mental processes such as perception, comparison, reasoning, and judgment formation. Statistics show that the memory is definitely impaired by chronic drinking.

Alcohol and disease. Not only does alcohol have the specific effects already mentioned, but it injures the general health in two other ways: (1) it is a direct cause of certain diseases; and (2) it lowers bodily resistance to nearly all diseases.

Some examples of the first case are as follows:

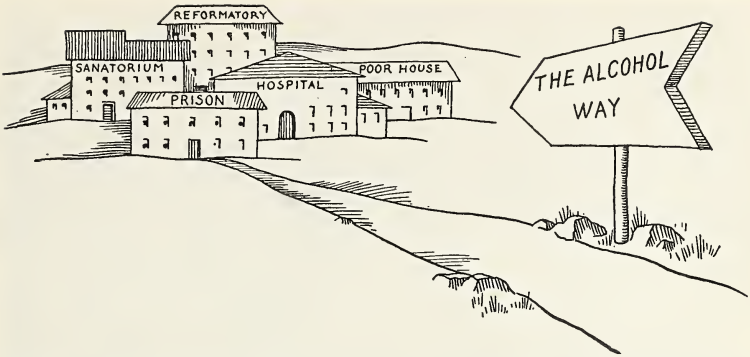
1. Indulgence in alcohol may reduce the intake of foods containing vitamins. The lack of vitamin B, for example, results in a disease called *polyneuritis*.

2. Inflammation of the liver, "hobnailed liver," and fatty liver are directly caused by alcoholic indulgence.

3. Cirrhosis of the liver frequently follows these other liver derangements.

4. Alcohol in amounts exceeding 10 per cent interferes with digestion and in excessive amounts tends to cause gastritis.

Far more important, however, is the effect of alcoholic over-indulgence in lowering the resistance of the body to bacterial invasion, and in creating abnormal internal conditions which are likely to make the course of certain diseases more serious, though they were not directly caused by the use of liquor. Experimental evidence shows that small amounts of alcohol, however, seem to have little or no harmful effect on the efficiency of the body defenses against infection.



Alcohol and Crime. The alcohol way is too frequently a one-way road ending in disaster.

Alcohol and mental disorders. There is no doubt but that chronic alcoholism can produce what are called alcohol psychoses, which frequently develop into cases of depression, irritability, hallucinations of sight and hearing, a serious mental condition called *delirium tremens,* or even alcoholic paranoia.

Such mental disorders may bring the victims into insane asylums. The Massachusetts Commission of Mental Hygiene reported that in 1928 more than one quarter of the male first-admissions to state institutions on regular court commitment were recorded as intemperate users of alcohol. Of 522 persons, 40 per cent had definite alcoholic psychoses. It is only fair to note, however, that such statistics do not of themselves prove alcohol to be the only cause. Such persons may be so weak-willed that they drifted into the alcoholic habit.

Alcohol and crime. Since alcohol inhibits mental control, it is obvious that under the influence of liquor a person is quite likely to commit acts which he would not countenance if sober. J. Koren studied the records of 13,402 convicts in 12 states. His conclusion was that alcohol was an important factor in at least 50 per cent of these cases, and the sole cause of the crime in 16.8 per cent of the cases. During a two-year period in New York City, over 40 per cent of the persons who were fatally shot or stabbed died while intoxicated.

Athletes and alcohol. Competition in school athletics is very keen. Those who make the team are required to follow definite training rules covering sleep, diet, and special activities, with a particular ban on alcohol and tobacco.

These rules are not designed to make the athlete subordinate to the whims of a coach; they are the result of long years of experience on the part of trainers and coaches who are hoping that their teams will be successful in competition. If alcohol were a help toward athletic victory, we may be sure that its use would be insisted upon by trainers and coaches. Its prohibition during the training season, therefore, is a matter of the greatest importance to every thinking person.

Amos Alonzo Stagg several years ago said, " After forty-seven years of coaching football, I can say without hesitation that a football player, as well as any boy or girl, would be a fool to drink alcoholic liquor. Why put poison into your system? Give your body a fair break. Don't play with dynamite.

Ewing Galloway, N.Y.

BETWEEN HALVES AT A FOOTBALL GAME. There is an absolute ban on drinking among athletes.

"I honestly believe that the main reason why at seventy-five years of age I am able to coach football and to play tennis and run half a mile when I choose is that I have not impaired my bodily mechanism by drinking alcoholic beverages."

The effects produced by alcohol vary in individuals. It is very important to remember that in the case of poisonous drugs, such as *strychnine,* small prescribed amounts may benefit the nervous system for a time, although larger amounts would be fatal. Similarly, small amounts of alcohol do not produce the same results as do larger amounts.

Again, some individuals are much more sensitive to the effects of alcohol than are others. A person who is a heavy drinker may be able to drink abnormal amounts of alcoholic beverages with only an apparently mild reaction. The Medical Research Council states that some men can drink the equivalent of a quart of whisky without immediate harm; but such an amount of alcohol might kill a person not accustomed to drinking. The factors of age, weight, occupation, and even climate affect the expected results of alcoholic consumption. Some persons come to have such a craving for alcohol that it becomes an overpowering habit to which business, friends, home, and self are sacrificed. Foods, especially fats and oils, taken with alcohol reduce its effects to a marked degree.

Life-insurance companies and alcohol. Life-insurance companies ask applicants for life insurance about their use of alcohol and drugs. Of course, there seems to be little opportunity to check the accuracy of the answers. And it is quite possible that a person who is a total abstainer when taking out insurance may later in life become to some extent a user of alcohol — or a drinker may become an abstainer. However, even if we admit the unscientific nature of some of this testimony, there is still remarkable agreement among life-insurance companies as to the effect of alcohol in low-

Philip D. Gendreau, N.Y.

ALCOHOL AND DRIVING. If you drive, do not drink.

ering normal longevity. Exhaustive experiments confirm their findings: non-abstainers have a higher mortality rate than do abstainers, and heavy drinkers of alcohol have a *much higher rate of mortality* than do abstainers.

Alcohol and driving. Many persons who drive a car think that "a drink or two" could not possibly affect their driving. In fact, such a person after drinking usually is pervaded with a feeling of well-being and self-satisfaction which persuades him that he is even more skillful than usual. Yet motor-vehicle officials throughout the country are blaming upon alcohol more and more of the staggering total of persons killed and injured in automobile accidents annually. Early in 1938, reports from different states showed that automobile accidents directly traceable to drinking were constantly increasing in practically every part of the country; the average increase was 45 per cent.

Important experiments have recently been carried on by Dr. Heise and Dr. Halporn in Pennsylvania to test thoroughly, under actual road conditions, the relation of drinking to driving a car. Motorists who had been given measured amounts of alcohol but who were not drunk (all but one passed the standard police sobriety tests) were found to make all sorts of accidental errors. Not only did most of these drivers have a slower braking-reaction time, but they were also inaccurate in performance. Yet every one of these drivers thought that he was doing well. The fundamental trouble, graphically proved by psychological tests, was found to be the *impairment of judgment after only a few drinks.* The plain fact gained from these objective experiments is that even one or two drinks impair co-ordination of eyes, arms, legs, and brain.

Commissioner Goodwin of the Massachusetts Department of Motor Vehicles says to *moderate* users of alcohol: "For at least four hours after a dose of alcohol formerly considered 'permissible,' you, as a motor-vehicle operator, may well be considered a menace to society."

W. R. Miles reminds us that "the death toll from automobiles is approaching 100 per day with 2,500 more injured per day. Kirby and Rosenau attribute from 7 to 10 per cent of fatal highway accidents directly to the use of alcohol, while competent traffic officials state that one third of these accidents are indirectly caused by alcoholic indulgence by the driver.

Miles says that the effects of alcohol upon a driver of a car are:

1. A poorer grade of attention to external signals and environment
2. Slower responses of eyes, hands, and feet
3. Less dependable, more variable muscular responses
4. Increased self-assurance which prompts the assumption of right-of-way and the willingness to take a chance

Alcohol as a medicine. Most doctors agree that alcohol should seldom be credited with any medicinal value. The American Medical Association in June 1917 adopted the following resolution:

"Whereas, we believe that the use of alcohol as a beverage is detrimental to human economy; and

"Whereas, its use in therapeutics, as a tonic, as a stimulant, or as a food, has no scientific basis; therefore be it

"Resolved, that the American Medical Association opposes the use of alcohol as a beverage; and be it further

"Resolved, that the use of alcohol as a therapeutic agent be discouraged."

Wood alcohol. Although called *alcohol,* this substance is entirely different from grain alcohol which is found in beverages. It is even more dangerous, being a violent poison, especially harmful to the eyes and often producing incurable blindness. Unscrupulous dealers sometimes mix wood alcohol with grain alcohol in beverages and thus make them doubly dangerous. Wood alcohol is used for fuel and as a cleanser and should be handled carefully. It should not be rubbed on the skin and even the fumes are harmful to the eyes. It is also called *methanol* and has other trade names. Look at your labels and be careful.

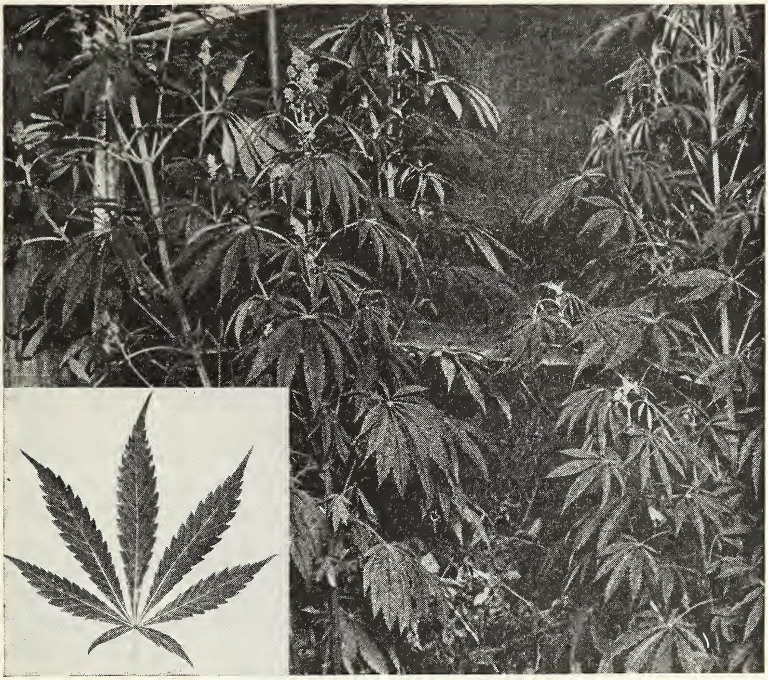
The effect of narcotics on cell life. Alcohol is used as a killing and preserving agent for plant and animal specimens. Its action upon such organisms is readily studied.

Prepare two slides with active Paramecia or other Protozoa on each. Place them under separate microscopes. To one add a drop of 3 per cent alcohol. Watch both for the behavior of the Protozoa.

On the slide to which alcohol was added, the motion of the Paramecia will be speeded up for a few minutes, as compared with those on the other slide. However, the stimulation soon ceases and within ten minutes the animals are usually dead. Those on the check slide remain alive and active.

A tobacco solution can be made by blowing smoke through a little water, until it is colored light brown. If this solution is used on a Paramecium slide, in place of the alcohol, the Protozoa will gradually cease to move and eventually die.

Narcotics taken into the body probably never reach the tissues in sufficient concentration to kill the cells. Nevertheless, the protoplasm, especially the synapses of the nervous system, can be injured; and this is particularly true in younger persons.



MARIJUANA. This weed is common and looks harmless. But the extract obtained from it is deadly.

Other narcotic drugs. *Opium* is prepared from the juice of the white poppy. From it are derived *morphine* [*more' feen*], *codeine* [*ko'deen*], and *heroin* [*hair'o in*], all of which are extremely dangerous narcotic drugs, even more injurious to their victims than alcohol. The habit is often formed by using these drugs or their compounds to relieve pain, sometimes by the advice of a physician. Like alcohol, their use creates a terrible craving for more and the grip of the habit is much harder to break. The results are also more serious. The victim suffers both physical and moral breakdown. Sleeplessness, difficult breathing, irregular heart action, and acute suffering, especially in absence of the drug, are accompanied by both mental and moral derangements which make the user entirely irresponsible for his actions.

Cocaine is another narcotic which is made from the leaves of the South American coca plant (not connected with the table beverage cocoa). It deadens sensibility to pain and is used in medicine and surgery. Its use is often continued or begun because of its soothing effects, but the habit once formed is as difficult to break as the use of opium, and the results are similar. The victim suffers loss of physical and moral control, often resorting to crime to obtain more of the deadly narcotic. The sale of both these substances is limited to the medical profession, and their use should be limited to imperative medical needs.

Recently it has become generally known that a weed called *marijuana* [*marry wa'na*], possessing strange narcotic powers, is being cultivated, frequently among other weeds growing in vacant lots or gardens. Its strength is so great that it is usually diluted with tobacco before being smoked. The government, early recognizing its menace, has made the possession of it in any form unlawful. Assist in wiping it out in your community.

Summary

Tobacco contains the harmful alkaloid nicotine. When tobacco is smoked not only is the nicotine absorbed by the lungs, but also a small quantity of the poisonous gas carbon monoxide, as well as an irritating substance called acrolein. Tobacco is narcotic in its effects, and tends to deaden nerve action and to decrease body efficiency and hinder growth.

Tea, coffee, cocoa, and chocolate also contain various alkaloids, but the latter two are rich in fats and may be classed as food substances.

Alcohol is a stimulant, and its use as a beverage is a biological problem which requires critical evaluation of its physiological and social effects. Since its chief detrimental reactions are on the nervous system, these are extremely serious. It also injures general health by lowering the resistance of the body to nearly all diseases.

Neither tobacco nor alcohol can be of any possible benefit to those partaking of them, and because the harm they do is great they should be avoided, along with other narcotics and stimulants. All are habit forming, and dangerous to good health and to a strong body.

Using Your Knowledge

1. If all statistics seem to prove that tobacco is harmful to adolescents, why do so many young people smoke?

2. What poisonous effects are produced in the body by nicotine, carbon monoxide, and acrolein?

3. What does it mean to say that " endurance and wind " cannot be developed when tobacco is used?

4. Are you familiar with conclusions based on investigations other than those in the text covering the effects of tobacco?

5. Can you name any persons known to have been affected by excessive use of tobacco? (A president of the United States should be included.)

6. What taxes did the American people pay on tobacco last year?

7. Can you explain why explorers in arctic or antarctic regions consider it dangerous to use alcohol?

8. Why do railroad companies insist upon abstinence on the part of their engineers?

9. Can you find any statistics to show the relationship between alcohol and crime? Between drugs and crime?

10. Is intoxication considered a legal excuse in the case of an automobile accident? Explain.

Expressing Your Knowledge

stimulant	ethyl alcohol	fatty liver
therapeutic	mescal	polyneuritis
codeine	co-ordination	nicotine
heroin	reaction time	acrolein

carbon monoxide	caffeine	marijuana
narcotic	tannin	concentration
induced	stringent	cirrhosis
ingredient	wood alcohol	visual impression
absolute alcohol	grain alcohol	alcohol psychoses
gastritis	morphine	opium
tolerance	cocaine	chloral

Applying Your Knowledge

1. Investigate and report accurate figures showing the amount of money spent by people in this country for tobacco in various forms.

2. Soak a cigarette until the water is colored. Put a small goldfish in a beaker of water, into which a spoonful of the " cigarette water " has been placed. Note the reactions of the fish.

3. Examine a life-insurance policy (one of your family will doubtless lend you a policy) and copy the questions relating to the use of alcohol. Do you know why the insurance companies make such inquiries?

4. Find out from the police department in your city or village what the relationship in your community is between the use of alcohol and crime, poverty, unemployment, and divorce.

5. Ascertain from a few typical companies what their attitude is toward the use of alcohol by their employees. Find out also if there has been any distinct change of attitude in recent years.

6. Write to the Motor Vehicle Bureau of your state requesting information as to laws and penalties for driving an automobile after drinking alcoholic liquor.

Increasing Your Knowledge of This Unit

Berman, Louis. *The Glands Regulating Personality.* 2nd Edition Revised. The Macmillan Co., New York. 1928

Best, C. H. and Taylor, N. B. The *Human Body and Its Functions.* Henry Holt and Co., New York. 1932

Bogert, L. J. *Dietetics Simplified.* The Macmillan Co., New York. 1937

Carlson, Anton J. and Johnson, Victor. *The Machinery of the Body.* The University of Chicago Press, Chicago. 1937

Cassils, Peter. *The Amazing Story of Your Wonderful Human Body.* The World Publishing Co., Cleveland. 1945

Chandler, Asa C. *The Eater's Digest.* Farrar and Rinehart, Inc., New York. 1937

Clemenson, Jessie Williams and La Porte, William Ralph. *Your Health.* Harcourt, Brace and Co., New York. 1942

Clendening, Logan. *The Human Body.* Revised Edition. Alfred A. Knopf, New York. 1937

Davis, Adelle. *Vitality Through Planned Nutrition.* The Macmillan Co., New York. 1942

Dorsey, George A. *Why We Behave Like Human Beings.* Harper and Brothers, New York. 1925

Emerson, Haven, editor. *Alcohol and Man.* The Macmillan Co., New York. 1932

Fulop-Miller, Rene. *Triumph Over Pain.* The Bobbs-Merrill Co., Indianapolis. 1938

Furnas, Clifford Cook and Furnas, S. M. V. *Man, Bread and Destiny; The Story of Man and His Food.* Garden City Publishing Co., Garden City, New York. 1942

Haggard, W. Howard and Jellinek, Elvin M. *Alcohol Explored.* Doubleday Doran and Co., New York. 1942

Jackson, Josephine A. *Outwitting Our Nerves.* 2nd Revision. Garden City Publishing Co., Garden City, New York. 1944

Kimber, Diana Clifford, Gray, Carolyn E. and Stackpole, Caroline E. *Textbook of Anatomy and Physiology.* 11th Edition. The Macmillan Co., New York. 1942

Kohn, Louis Winfield. *Your Digestive System.* The Blackiston Co., Philadelphia. 1944

Montague, Joseph F. *Nervous Stomach Trouble.* Blue Ribbon Books, Garden City, New York. 1945

Pattee, Alida F. and Munsell, Hazel E. *Vitamins for Everyone.* G. P. Putnam's Sons, New York. 1942

Phillips, Mary Catherine. *Skin Deep; The Truth About Beauty Aids — Safe and Harmful.* Vanguard Press, New York. 1934

Pomeranz, Herman. *Your Respiratory System.* The Blackiston Co., Philadelphia. 1944

Schlink, F. L. *Eat, Drink and Be Wary.* Covici Friede, New York. 1935

Schwartz, Louis H. *Your Eyes Have Told Me.* E. P. Dutton and Co., New York. 1945

Sherman, H. C. *Chemistry of Food and Nutrition.* The Macmillan Co., New York. 1937

Taylor, Clara M. *Food Values in Shares and Weights.* The Macmillan Co., New York. 1942

Tokay, Elbert. *Fundamentals of Physiology.* Garden City Publishing Co., Garden City, New York. 1944

Woodhouse, Charles G. *Dental Careers.* Funk and Wagnalls Co., New York. 1939

Ewing Galloway, N.Y.

Unit 9

Biology and the Problems of Disease

AMONG the many phases of the study of life included in biology, none is more important to everyone than the study of disease. Happiness and prosperous living are closely allied to the health of the individual, his community, and his nation.

The problems of disease have attracted the attention of many of the greatest biologists. As the association of supernatural forces and practices of superstition with disease were gradually discarded, man emerged from the plagues of the Middle Ages with an organized field of medicine. A relatively small number of scientists dared to challenge the unscientific practices of their day in the presentation of better methods of dealing with the disease problem to a world extremely antagonistic to change. These men laid the cornerstones for the modern hospitals, clinics, and research foundations which are now serving humanity.

Chapter 50

The Conquest of Disease

There is no more dramatic chapter in the development of biology than the story of the conquest of disease. It reads like a detective story, in which evidence was gathered over a period of years through the tireless efforts of many great biologists, whose accomplishments made them immortal among scientists and humanitarians.

We, who enjoy comparative safety from many dread diseases which stalked the civilized world a few decades ago, owe a debt of gratitude to the heroes in the conquest of disease. The names Jenner, Pasteur, Koch, Lister, von Behring, and others are significant in the field of medicine. Their contributions are a part of every hospital, clinic, and doctor's office today.

It is fitting, therefore, that our study of disease, especially of infectious disease, include a brief review of the contributions of these great scientists. Their discoveries form a chain of evidence which gradually unmasked the most notorious of all killers — microorganisms or microbes.

We shall begin our story of the conquest of disease with the Middle Ages. At that time, infectious disease was rampant. Great plagues were sweeping through civilization like black clouds, engulfing entire cities, striking people down by thousands, and leaving the more fortunate terror stricken. Man, by this time, had progressed beyond the age of witch doctors and medicine men, but the basis of medical practice, while different, was really not far removed from the foolish notions of primitive man. Superstition and magic still influenced many doctors, and the more "progressive" performed ridiculous practices based upon little more than notions about disease. Let us visit a doctor's office in the early eighteenth century, before the first great contributor to modern medicine had arrived upon the scene to influence medical practice.

A patient, stricken with infectious disease, is taken to the doctor's office for diagnosis and treatment. His body is weak from infection and flush with fever. The doctor examines the patient briefly and explains that his condition is due to bad blood or "humor," and that he can recover only if the "bad humor" is withdrawn from his body. Accordingly, a barber is summoned and the "blood letting" treatment is begun. The barber opens a vein in the patient's arm, which has been placed over a basin to catch the flowing blood. Blood spirals down the arm in wide, red streams — a living duplicate of the striped pole which stands before the barber's shop as a symbol of his trade. The "letting" process continues for some time, the amount of blood withdrawn depending upon the seriousness of the disease, and this patient is very ill. Finally, the patient is sent home to fight his own battle, his chances of recovery much reduced due to his loss of blood and probability of infection from the wound inflicted in his arm by the barber "sur-

Ewing Galloway, N.Y.

BLOODLETTING IN ARABIA. Arabian surgeons operate on their patients for every manner of ill in the open market place. This eighteenth century practice is still used today in some parts of the world.

geon." Had the patient been taken to another doctor, leeches might have been applied to his body to remove blood in a somewhat slower manner.

Somewhat later, when the infectious nature of disease was beginning to be recognized, doctors believed that dirt and filth were poisons which caused disease. It was during this period that malaria received its name, for malaria means, literally, bad air. It was thought that air coming from the marshes was poisonous, especially at night. Accordingly, people were cautioned about leaving their homes, especially when the wind was blowing from the marshes. The fact that certain individuals became infected with disease while others, who had been with them, were spared was explained by the *disposition theory* of disease. According to this theory, certain individuals had a "disposition" for a disease, while those who did not take it did not possess the "disposition." Other theories were based upon "seeds of disease" and "seeds of vermin" which were thought to be living poisons, capable of producing infection.

Edward Jenner — country doctor. Such was the state of affairs in England during the latter part of the eighteenth century. Smallpox was sweeping the land in epidemics which spared few. Rare, indeed, were faces which did not bear ugly pock marks as grim reminders of the dreadful disease. During epidemics, victims of the disease were cruelly isolated and confined in pest houses to die. Efforts were made to control the disease by inoculations made from pus taken from pustules on the bodies of sufferers having mild cases. This method of control was based upon the fact that those who had the disease

Ewing Galloway, N.Y.

AN EARLY VACCINATION

and were fortunate enough to recover were not subject to further attacks. Thus, people would risk their lives in deliberately contracting the disease through inoculation in the hope that they would recover from a mild case and be spared the more virulent forms which occurred in epidemics.

On May 14, 1796 Dr. Edward Jenner performed an experiment that has made this day famous in medical history. He had observed that dairy maids were frequently infected with a disease of cattle called *cowpox* or *vaccinia*. The infection produced running sores or pustules on the hands of the dairy maids where they had contacted infected areas of the cow. The pustules resembled those of smallpox. It was noted, also, that dairy maids were seldom afflicted with smallpox during epidemics. Putting two and two together, in a true scientific manner, Dr. Jenner conceived the idea of transferring material from a cowpox pustule to a healthy person with the hope that immunity to smallpox would result. On this important day, he transferred some material from a cowpox pustule on the hand of a dairy maid to the arm of an eight-year-old boy named James Phipps. The process was called vaccination because the serum contained infectious material of the disease vaccinia. The vaccination produced a sore which later formed a scab and healed entirely. The real test came somewhat later when the boy was deliberately inoculated with smallpox to test the effectiveness of vaccination. To the extreme joy of Dr. Jenner and all others concerned, the boy did not contract the disease. James Phipps was immune to smallpox although he had never had the disease!

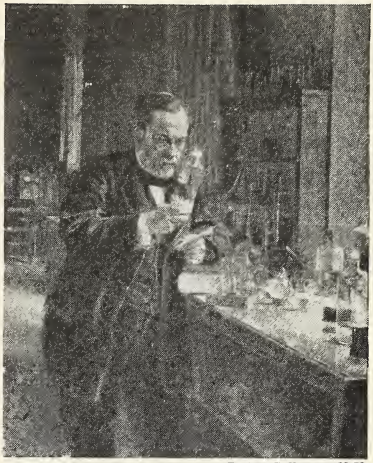
Dr. Jenner immediately set out on a campaign to vaccinate all people against smallpox. But to his amazement and utter disappointment, he found many of the populace bitterly opposed to his discovery. Posters were hung along the streets, depicting children with heads and hoofs of cattle — the result of vaccination with a disease of cattle. Anti-vaccination groups were formed both in England and America. Laymen, especially, opposed Dr. Jenner and threw all possible obstacles into his path. Eventually, however, the populace began to realize the significance of the discovery and vaccination became a successful practice in England and other countries.

Today, vaccination against smallpox is almost universal in the civilized world. The result has been that few people ever see a case of smallpox except when members of a community become lax in administering vaccinations.

Louis Pasteur, the father of bacteriology. Edward Jenner died in 1823. A year before his death, a second great figure in the conquest of disease was born in Dole, France. At fifteen, Louis Pasteur, a young country boy, traveled to Paris by stagecoach to begin his study of chemistry. He was forced to leave Paris because of homesickness, but returned four years later to begin his brilliant work in the field of chemistry.

Pasteur became interested in fermentation and its causes. One day he examined several drops of sour milk under a microscope and was amazed to find numerous rod-shaped bodies in the milk. They seemed to be alive! Accordingly, he transferred some of them to a sugar solution and found that they soured the solution by forming lactic acid just as they had done in milk. He reasoned, and correctly, that the microorganisms caused the fermentation and disproved the theory that fermentation and decay produced living things by spontaneous generation. The many advocates of this theory had held that nonliving matter could change to living matter, as maggots appear in meat during spoilage. Pasteur concluded, further, that these tiny organisms got into the milk from the air, and that the air probably contained many more types of microorganisms. As a result of his contentions, he was scoffed at and ridiculed by the "learned" men of his day. Even after experiments were conducted to show that sterile, sealed liquids did not ferment, and that fermentation could be stopped by boiling, he still could not convince the stubborn believers in spontaneous generation that microorganisms caused fermentation in wine, milk, and other liquids.

Pasteur, in no way discouraged, turned his attention from wine and milk to diseases of animals. He reasoned that if microorganisms could change sugar to acid and cause liquids to ferment, they might also cause reactions in the body of an animal which would result in disease. He went to southern France,



Ewing Galloway, N.Y.

Louis Pasteur in His Laboratory

where a disease called *pébrine* was destroying the silkworms and threatening the entire silk industry. After more than five years of tireless effort, he discovered that microorganisms were carried from one generation of silkworms to another within the eggs. By destroying all diseased individuals and hatching silkworms only from healthy females, the disease was controlled and the silk industry saved.

During May and June of 1881, he conducted another experiment with animal disease which proved to be of tremendous importance to the advance of medicine. A disease called *anthrax* was passing through farm animals, especially sheep, in epidemic form. Pasteur believed that he could immunize animals against anthrax. No one else believed he could, so he was challenged to conduct an experiment for all to observe, and he readily accepted the challenge.

Fifty animals, mostly sheep, were divided into two experimental lots. Pasteur gave each sheep in one lot five drops of liquid containing germs of anthrax which had been weakened. Twelve days later, the same twenty-five sheep were given stronger injections. After fourteen more days, all of the animals, both inoculated and uninoculated, were given fatal doses of anthrax. Two days later, the group assembled to laugh at Pasteur. Imagine their amazement when they arrived to find all of Pasteur's inoculated sheep healthy and vigorous and all of the uninoculated sheep dead or dying of anthrax! The evidence was at hand. Now his wisdom could not be doubted.

Pasteur's greatest contribution to mankind. During the latter years of his life, Pasteur turned his genius toward experimentation with one of the most horrible of all human diseases, rabies or *hydrophobia*. This disease was prevalent in his time and was transmitted to humans through the bite of a mad dog or wolf. There was no cure and it was nearly always fatal. While experimenting with dogs in his laboratory, Pasteur found that the brain and spinal cord of infected animals contained material with which he could readily inoculate healthy animals with the disease. He found no microorganisms when he examined brain and spinal cord tissue with his microscope, as we can well understand today, for rabies is caused by a virus, quite invisible even under the modern microscope. Pasteur had pieces of infected spinal cords of various ages on hand for his investigations. He chanced to discover one day that the material lost its potency with age, and that after fourteen days, it was so weakened that it failed to produce rabies in a healthy animal. To Pasteur's brilliant mind, this was a significant discovery. He began a series of injections, beginning with fourteen-day-old material and gradually increased the strength of each injection until he had administered virus from a dog which had died the day the last injection was made. The dog which had received the series was not affected by even the most potent injection.

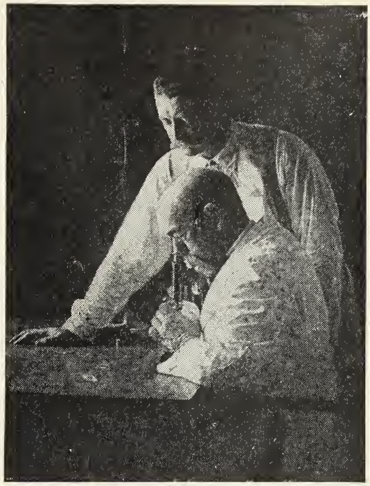
During his experimental work with dogs, a nine-year-old Alsatian boy was brought to the laboratory, horribly bitten by a mad dog and doomed to die. Pasteur was prevailed upon to administer the treatments on the boy which had worked successfully with dogs regardless of the outcome. Somewhat uneasily, Pasteur administered fourteen-day-old virus. This was followed by thirteen-day, twelve-day, and so on, until the last injection was full strength. Joseph Meister lived through the treatment and was given immunity before the deadly virus from the original bite developed in his body. News of this triumph spread rapidly. There was the usual opposition to the idea of a chemist practicing medicine, but Pasteur's success was too significant to be stifled long. Some time later, a group of Russians who had been bitten by a mad wolf were brought to Pasteur for similar treatment. Their cases were of longer standing than was Joseph Meister's, and some of them died before treatment could be completed. Most, however, were saved by the Pasteur injections.

Robert Koch, the father of bacteriological technique. We have discussed the work of two great scientists, one an Englishman, the other a Frenchman. We now turn to Robert Koch, a native of Germany. He was born in the Harz mountains in Germany, the son of a poor miner, and one of thirteen children. By some means or other, Koch was able to attend the University of Göttingen, where he graduated at the age of nineteen.

His first outstanding contribution to

medicine was in the study of *anthrax,* the disease with which Pasteur had worked earlier. In examining the blood of animals dead from the disease, he found abundant rod-shaped organisms. He could not afford cattle for his experiments, so he confined his work to mice. He found that he could kill a healthy mouse by injecting infected blood into a cut near the base of the tail. He found, also, that the organisms multiplied rapidly during the course of the disease, the small number he used in inoculation spreading through the blood of the mouse. Koch was not satisfied until he had actually observed this multiplication. Accordingly, he obtained a drop of sterile fluid from the eye of a freshly killed ox and placed into the drop a small portion of the spleen of a mouse, containing anthrax germs. He patiently watched through his microscope until the germs spread entirely through the drop. He transferred germs from one drop to another and succeeded in growing them in the complete absence of any mouse spleen or blood. His next step was to try inoculating healthy mice with his laboratory-grown organisms to see if they would produce the disease. The mice died soon after inoculation and microscopic examination of the blood disclosed the same abundant rod-shaped organisms.

Koch, in his work with anthrax, had established a pattern for scientific investigation which remains today as a guide to follow. His brilliant procedure is summarized in four steps called the *Koch postulates.* In studying these postulates, you will find that they follow exactly his procedure used in experimenting with the germs of anthrax and mice in his laboratory.



Monkmeyer Press Photo Service

ROBERT KOCH IN HIS LABORATORY

1. Isolate the organism probably causing the disease. (Koch found anthrax organisms in the blood stream of infected animals.)

2. Grow the organisms in laboratory cultures. (Koch used sterile fluid from the eye of an ox.)

3. Inoculate a healthy animal with the cultured organisms. (Koch inoculated a mouse with the eye fluid containing germs.)

4. Examine the diseased animal and recover the organisms which produced the disease. (Koch found that the organisms he inoculated into the mouse had multiplied enormously in the blood stream.)

Koch's discovery of tuberculosis organisms. Following his work with anthrax, Koch began his work on tuberculosis. He discovered the causative organism in the lungs of victims of the disease. In 1882, he announced that tuberculosis was caused by a tiny rod-shaped organism. His announcement was based upon long hours of research, during which he inoculated experimental animals with the disease by using pieces of infected lung tissue. He experienced difficulty in growing tuberculosis organisms in his laboratory, for they failed to grow on the numerous kinds of media he had perfected. Finally, he produced a successful medium by adding blood serum to agar. Thus, he was not only the first person to see the tuberculosis organism, but the first to grow it under laboratory conditions.

Koch thought that he had discovered a cure for tuberculosis in a substance called *tuberculin* which he filtered from his cultures of tuberculosis organisms. It was found later that tuberculin could not be used to cure tuberculosis, but its discovery was none the less important, for this substance is widely used even today in the diagnosis of the disease, as you will find in a later chapter.

Lister and antiseptic surgery. While Koch was performing his brilliant work in Germany, a famous English surgeon, Sir Joseph Lister, was making outstanding contributions in the field of surgery. Prior to Lister's work, wound infection was extremely common in surgical patients. In fact, many more patients died from infection than from the effects of the actual surgery. Within a few days after an operation, pus formed in the wound, often causing death. Surgeons found that when the pus contained red streaks (indicating streptococcic infection) the patient nearly always died. When the pus was yellowish in color (indicating staphylococcic infection) the chances for recovery were better. Hence, the doctor was pleased to see the latter type of pus in the wound and called it " laudable pus." But pus, whether laudable or otherwise, did not please Lister, who regarded it as avoidable infection. He hated the wooden operating tables, and the bloodstained coats worn by the surgeons to indicate their practice.

Lister studied carefully the work of Pasteur and particularly his references to air-borne organisms. He applied this knowledge to his surgery. Splints and bandages were soaked in carbolic acid, instruments were sterilized, and those present in the operating room were required to wash thoroughly. He even devised a carbolic acid spray which produced a fine mist over the area of the operation. The results revolutionized surgical practice the world over. Boric acid came into prominence as an antiseptic, to be followed by others. As professor of surgery at the University of Glasgow, Lister taught his doctrine of antiseptic surgery to scores of young surgeons who were to carry on his notable contribution to the advance of surgery.

Von Behring and his discovery of toxins and antitoxins. Our story of the conquest of disease now shifts back to Germany, to the laboratory of Emil von Behring. Von Behring's work followed closely the work of two other famous scientists, Roux and Yersin, in a field quite different from any we have discussed. Von Behring concentrated his efforts on *diphtheria*, one of the chief killers of the time, especially among children. Roux and Yersin had demonstrated that diphtheria germs, when grown on media, produced a powerful toxin or poison. It was concluded that this toxin, when present in the blood of a victim of the disease, caused damaging effects upon the system. Von Behring grew diphtheria organisms on laboratory media, filtered off the toxins, and injected them into guinea pigs. The result was a well-defined case of diphtheria without any organisms. In the course of his experience, he found that his animals could be used only once, for they developed an immunity to the disease. Von Behring then removed blood from animals which had recovered, separated the corpuscles, and injected the liquid or serum portion into animals which had not been subjected to the disease. He found that immunity could be transferred from one animal to another by means of a substance present in the blood which he called an *antitoxin*. With this discovery, he decided to prepare an immune serum, containing antitoxin, for use in protecting babies from diphtheria. He inoculated sheep with diphtheria toxins and waited until they had produced antitoxins in their blood. He then removed a portion of the blood and separated out the serum containing antitoxin. After considerable experimenting with guinea pigs, it was first used in the Children's Hospital in Berlin with success.

It was found, however, that the immunity did not last. Apparently, the sheep antitoxins were slowly destroyed in the human blood stream. If children could be induced to form their own antitoxins immunity would be more permanent. To give diphtheria toxin would constitute giving the disease. Accordingly, experiments with a mixture of toxin and antitoxin, called *toxin-antitoxin*, were tried and with success. The toxin stimulated the blood to produce antitoxins and the antitoxin destroyed the harmful effects of the toxin. Von Behring did not quite attain this success, for his work was interrupted by the first World War. Dr. William H. Park of the New York City Laboratories brought the work to a successful climax.

In your study of disease, you will refer again to the contributions of these and many other outstanding men of medicine. Jenner, Pasteur, Koch, Lister, and von Behring are included in this chapter not only because they are among the most famous, but also because each one contributed greatly to the development of a field of medicine. Through their efforts as pioneers in their fields, scores of others have been given examples to follow. The dreams of these immortal scientists are now a reality in this, the golden age of medicine.

Summary

Jenner's discovery of vaccination against smallpox was especially significant, not only because it brought a means of controlling one of the worst epidemic diseases of mankind, but also because it marked the beginning of a great era of scientific advance in the conquest of disease. Pasteur is called the father of bacteriology because he first recognized bacteria as causative agents of fermentation and disease. He opened the way for all future investigation of germ diseases. His discovery of a treatment for rabies, still in use and named the Pasteur treatment in his honor, is one of the most notable scientific achievements of all time.

Koch is called the father of bacteriological technique because of the brilliant procedure he developed in studying unknown diseases. His procedure, used in the study of anthrax and later applied to the study of tuberculosis, has been summarized in four steps or postulates which remain as a pattern for the investigation of disease. Koch is also famous for his investigations in the field of laboratory culture of bacteria and the discovery of many types of culture media.

Lister's great contribution was in the field of surgery. He first used antiseptic methods in his operating room with the result that infections were greatly reduced and mortality among surgical patients lowered accordingly. Von Behring worked in more advanced phases of bacteriology and medicine since he had the knowledge of Pasteur, Koch, and others to build upon. His greatest contribution was the discovery of diphtheria antitoxin. The first World War interrupted his work with diphtheria toxin-antitoxin to be used in immunizing children against diphtheria.

Using Your Knowledge

1. Upon what theory was bloodletting practiced early in the eighteenth century?

2. Explain the theory of " disposition for disease."

3. Why was the fact that Edward Jenner was a country doctor very important in the discovery of vaccination against smallpox?

4. Discuss the reaction of the townspeople to Jenner's practice of smallpox vaccination.

5. What is vaccinia, and why is it important in the control of smallpox?

6. Describe the first vaccination.

7. What kind of bacteria did Pasteur first observe in his laboratory?

8. Explain how the uninoculated group of sheep served as a control in Pasteur's famous experiment with anthrax immunity.

9. What specific regions of an animal's body did Pasteur find to be the seat of rabies infection?

10. Enumerate some of the methods Lister used to combat infection in his surgery.

11. Explain how von Behring discovered diphtheria antitoxin in working with the deadly toxins.

Expressing Your Knowledge

plague	vaccinia	pébrine
epidemic	seeds of disease	anthrax
smallpox	inoculation	serum
bloodletting	pustule	rabies
humor	immunize	injection
disposition theory	bacteriology	Koch postulates
infectious	fermentation	tuberculosis
vaccination	sterile	tuberculin
Jenner	antiseptic	diphtheria
Pasteur	infection	toxin
Koch	laudable pus	antitoxin
Lister	carbolic acid	toxin-antitoxin

Applying Your Knowledge

1. Prepare a report on the practice of medicine during the eighteenth century.

2. Obtain figures from your Board of Health on the prevalence of smallpox today.

3. Ask your doctor what precautions are taken in modern surgery to prevent infection. Make a list of the procedures and report them to the class.

4. Prepare a report on the Pasteur treatment for rabies.

5. Assume that you are investigating a disease. Outline the steps you would follow in conducting your research according to the Koch postulates.

6. Obtain as much information as you can find on the conquest of tuberculosis. Do not include treatment for the disease, but limit your report solely to the history of tuberculosis and to the men who helped conquer it.

Chapter 51

The Nature of Disease

With the discoveries of Pasteur and Koch, bacteriology began to develop rapidly as a science. Since 1895, progress in this important field has been almost phenomenal. It seems incredible that nearly all of our present advanced knowledge of the treatment of infectious disease could have been acquired in slightly more than fifty years. The conquest of disease continues in hospitals, clinics, and research laboratories all over the world. We have gone far, but we have far to go. This generation will probably succeed in controlling many diseases which, at present, have not been conquered.

You will learn, in this chapter, what disease is, how it is produced, and how the body reacts against it. You may need to review some of the things you learned about bacteria and other microorganisms in earlier chapters. In the study of disease, you will have an opportunity to apply the knowledge you gained in the preceding unit in the study of the biology of the human body.

Forms of disease. *Disease* may be defined as any condition which actively impairs the health or interferes with the normal functioning of the body of an organism. It may be due to various causes which can be classified into distinct groups. These groups include:

1. Diseases caused by microorganisms (infectious)
2. Organic diseases, due to abnormalities in body organs, abnormal growths, etc. (non-infectious)
3. Functional diseases, due to abnormalities in the functioning of body organs (non-infectious)
4. Diet deficiency diseases, due to a lack of proper diet, especially of vitamins (non-infectious)

We shall consider first the infectious diseases, since they constitute the greatest threat to man because of their contagious nature.

Causative agents of disease. The term *pathogenic* is applied to microorganisms capable of causing disease. These pathogenic organisms, often called *microbes*, include various kinds of plants as well as certain minute forms of animal life. Pathogenic organisms include the following types:

1. Bacteria
2. Viruses
3. Molds and mold-like fungi
4. Yeasts
5. Protozoans and protozoan-like organisms

Diseases caused by yeasts, molds and mold-like fungi, and protozoans and protozoan-like organisms are much less common than diseases caused by bacteria and viruses. Our discussion of microorganisms and their relation to disease will, therefore, be limited to the bacteria and viruses and, especially, to bacteria.

The viruses are the smallest form of living matter. Their exact nature is not clearly understood, for they are too small to be seen with the highest power of the microscope. Actually, they may not be living organisms at all but, rather, protein molecules which assume the properties of living organisms when they contact living protoplasm. They cannot be cultured outside of the organisms which they attack in the manner in which bacteria may be cultured on laboratory media. Virus diseases are especially difficult to study for that reason. Among the famous virus diseases are rabies, mumps, smallpox, chickenpox, measles, German measles, infantile paralysis, and yellow fever. Many viruses are especially dangerous because they attack the nervous system.

A group of organisms which seem to be midway between the viruses and bacteria are the *Rickettsiae* [*Rick ett'see eye*]. They are like viruses in that they cannot live outside of a host organism, but resemble bacteria in form, although they are smaller than bacteria. Rickettsiae seem to be associated with biting insects and are the cause of typhus and Rocky Mountain spotted fever.

Bacteria constitute the largest group of pathogenic microorganisms. They may be *coccus, bacillus,* or *spirillum* forms. Pathogenic bacteria do not differ in form from many of the harmless and beneficial types you studied in Chapter 23. They cause harm in that they invade the human body rather than other organic hosts with damaging effects. Among the bacterial diseases are diphtheria, scarlet fever, tetanus, typhoid, tuberculosis, meningitis, and various types of pneumonia.

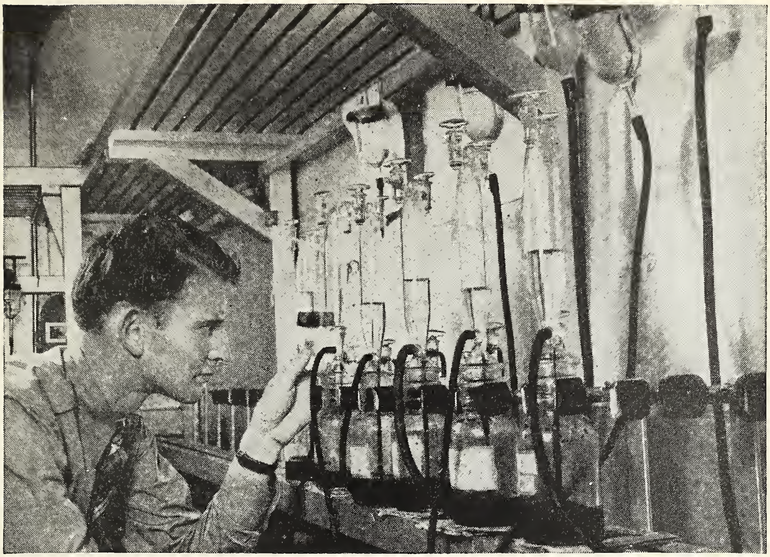
Spirochetes [*spir'oh keets*] resemble both bacteria and protozoans and seem to be forms of life midway between the two. They are long, spiral forms resembling corkscrews. The syphilis organism is the best known of the spirochetes.

The spread of infectious organisms. Bacteria and other pathogenic organisms are able to exist in dormant form for considerable periods of time. In this manner, infectious diseases may be transmitted from person to person by means of numerous agents or carriers.

Filth-borne diseases are frequently carried through contaminated water and food. Typhoid, cholera, dysentery, and food poisoning organisms live in the intestinal tract of man and are present in sewage where the diseases occur.

Eating utensils and dishes in public places, unless thoroughly sterilized, are common sources of infection. Frequent outbreaks of intestinal infection, especially during the summer months, can often be traced to this source. Certain individuals may be immune to these intestinal infections and yet serve as dangerous carriers. Among the most famous typhoid carriers was "Typhoid Mary," who was responsible for more than one serious outbreak of typhoid fever. "Typhoid Mary" had a peculiar immunity to typhoid and showed no signs of illness, though she harbored living cultures of the deadly organisms in her intestinal tract. Through lack of cleanliness, she frequently carried the organisms on her hands and, in several instances, transmitted them to food she was preparing in a restaurant. After several outbreaks of typhoid among different people, the health authorities finally traced her as a carrier and placed her under careful supervision to prevent further outbreaks.

Water is another common medium for the spread of filth and sewage-borne organisms. Many streams and lakes are contaminated with typhoid and other intestinal parasites because of the presence of untreated sewage in the water. Shallow, open dug wells are especially dangerous because they are usually located in low areas and are open to surface drainage which may contain polluted water. One should be extremely



Ewing Galloway, N.Y.

SEWAGE DISPOSAL LABORATORY. The amount of pure oxygen utilized by bacteria feeding on sewage is being determined here.

careful to drink water only from deep, driven wells or from supplies of city, treated water. If dug wells are used, samples of the water should be sent periodically to the Board of Health for examination. If you must drink from a doubtful water supply, it is a simple matter to boil it for at least ten minutes before using.

The role of the housefly in spreading disease has already been discussed. These filthy creatures are most likely to spread intestinal diseases because they frequent sewage when possible to lay their eggs. Modern sewers and methods of sewage disposal have eliminated much of this danger, but this is no indication that we can afford to let up in our campaign against flies.

Droplet infection. Respiratory infections, especially, are spread through discharges from the nose and throat. Sneezing and coughing result in the discharge of a fine mist of droplets into the air. These droplets contain numerous bacteria and viruses which may be pathogenic. Among the diseases which are frequently transmitted through droplets of saliva and mucus are: diphtheria, scarlet fever, tuberculosis, pneumonia, measles, mumps, whooping cough, colds, and influenza.

Diseases spread through droplet infection are usually prevalent through the winter months when people are confined indoors. The air in streetcars and busses and in public gathering places becomes heavily laden with droplets of water which may contain cold viruses and other pathogenic respiratory organisms. Even more dangerous than inhaling infected droplets from the air is contact with articles contaminated by droplets. Public drinking cups have been

PHOTOGRAPH OF A SNEEZE. The tiny droplets, though invisible to the eye, contain quantities of bacteria. Why should you use your handkerchief whenever you cough or sneeze?

largely replaced by sanitary, disposable cups as a health measure. However, public drinking fountains remain as a health hazard if the water is low and one must place his mouth against the spout to obtain water. Spitting in public is an unpardonable practice, but constitutes a common source of infection. Even pocket handkerchiefs are extremely unsanitary when one is suffering from a cold or other respiratory infection and should be discarded in favor of paper tissue which can be burned after use.

Diseases spread through contact. Many diseases are spread by direct contact with an infected person or with an object which the person has handled recently. Numerous skin diseases such as ringworm and barber's itch or impetigo are extremely contagious upon contact. Smallpox may, likewise, be spread through contact with the virus present in pustules on the surface of the body. Even unbroken skin does not prevent entrance of the virus of this disease. Pinkeye is extremely contagious and may be contracted even by using an infected towel. Diseases spread by contact include, also, syphilis, gonorrhea, and other venereal diseases.

Wound infections. Wounds serve as a portal of entry for several kinds of organisms which produce extremely dangerous infections. Tetanus organisms thrive in deep puncture wounds which heal at the surface and form an airtight cavity. The deadly virus of rabies enters the blood stream through wounds resulting from the bite of rabid animals, especially dogs. Gangrene and other wound infections which commonly result in blood poisoning likewise enter the body through wounds. It is imperative that all minor wounds be cleansed thoroughly and treated with antiseptic, and that all major wounds and deep puncture wounds receive immediate attention of a doctor.

Diseases spread through insect bites. These diseases were discussed earlier in connection with specific insect carriers. They need only be mentioned again in connection with the transmission of disease. Malaria and yellow fever are transmitted only by specific mosquitoes. The malaria and yellow fever organisms must pass through certain stages of their life history within the body of certain mosquitoes and cannot be transmitted in any other way. Typhus is associated with the human body louse, bubonic plague with the rat flea, and African sleeping sickness with the tsetse fly. All of these carriers of disease are biting insects and introduce the disease organisms into the blood stream by breaking the skin.

The production of infection. Fortunately, all of the disease germs we contact do not produce infection or our lives would be very short, indeed. The surface of the body and the mouth and nasal passages contact numerous dangerous organisms which have not gained entrance. If everyone could see cultures of bacteria grown from the hands or sputum from the mouth, fingernail biting and kissing would be far less prevalent.

To produce an infection germs must gain entry into the body, they must be able to multiply, and must be capable of causing harm to the body. Growth of bacteria on culture media in the laboratory does not constitute an infection because there is no reaction on the part of the medium. Infection involves both the activity of harmful bacteria and the reaction of the body to these bacteria.

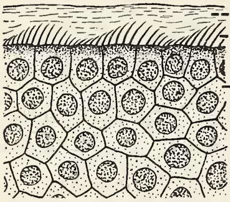
How bacteria cause disease. The mere presence of bacteria within the body does not constitute disease. The intestinal tract, for example, normally harbors great numbers of parasitic bacteria which do no harm and, in fact, are essential to proper digestive activity. Many forms, however, carry on activities which are harmful to the body and, thus, are classified as pathogenic. These organisms cause harm in several ways which include:

1. Tissue destruction
2. Production of toxins
3. Production of ptomaines and other food poisons

Certain bacteria invade the body and cause destruction of the body tissues. For example, tuberculosis organisms destroy lung tissue, causing lesions which permit blood to enter the air cells and passages, and result in hemorrhages. Typhoid organisms produce lesions in the walls of the intestines, resulting in seepage of the intestinal content into the body cavity. This may infect the peritoneum (lining of the abdominal cavity) and cause *peritonitis.* Streptococci may invade the blood stream and destroy corpuscles at a rapid rate, causing a condition referred to as *blood poisoning.*

In addition to the physical damage of tissue destruction, large numbers of bacteria produce poisons or *toxins* which also destroy the body tissues. These toxins may be produced by living bacteria and may penetrate the tissues at the seat of the infection to be carried by the blood throughout the body. Since these toxins are formed by living cells and are excreted through their walls into the tissues of the host, they are called *exotoxins* or true toxins. In the case of many *exotoxin diseases,* damage is done by the toxins rather than by the bacteria themselves. Such diseases include diphtheria, scarlet fever, tetanus, and streptococcic infections.

Ptomaines and other food poisons, likewise, are dangerous toxic substances which are formed especially in protein



STRUCTURE OF MUCOUS MEMBRANE

foods. In this case, the damage is done externally by various organisms of decay and the poisons are taken in with the food. Ptomaines usually cause a body reaction within one-half hour to two hours from the time they are consumed. Their effects are noted as soon as they have entered the blood stream by absorption from the digestive organs. One of the most dangerous of food poisons is called botulism. The botulism germ grows in sealed cans of food and forms a powerful toxin similar to tetanus toxin. Symptoms usually appear within a few hours after the toxin is consumed. It affects the nervous system, somewhat in the manner of tetanus, causing extreme weakness, dilation of the pupils, difficulty in swallowing, and frequently mental disorder. Mortality is very high, averaging from sixty to ninety per cent.

Food poisoning is often confused with food infection, though the symptoms are quite different. In the case of food poisoning, the toxins are already formed, and the onset of disease is usually sudden and soon after eating. In the case of food infections, however, the disease germs are eaten with food and set up an infection in the digestive organs. Symptoms usually do not occur for several days, after an incubation period in the digestive system.

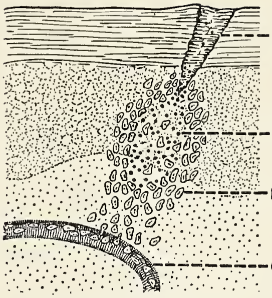
Defenses of the body against disease. Perhaps you wonder how, with tissue-destroying bacteria, toxins, ptomaines, and other deadly bacterial products lurking within and without our bodies, anyone escapes these evils to live to a ripe, old age. True, many succumb to infectious disease, but the human body is so marvelous in its construction that it can fight off numerous attacks of deadly microbes. When invaded by infectious organisms, it immediately sets up a counterattack and usually wins — for it can only lose once! The defenses of the body are set up along three lines. They are referred to as the first, second, and third lines. These lines of defense should be familiar to everyone, for conscious effort and co-operation on the part of the victim of an attack aids the body greatly in its defense.

The first line of defense. The most effective way of avoiding an infection is to prevent the organisms from entering the body. This is the function of the first line of defense. Skin covers all of the external parts of the body and, if unbroken, is bacteria proof. Unfortunately, it is not virus proof, hence we have little protection against the entry of this group of pathogenic organisms. The openings of the body are lined with mucous membranes which serve as a protective lining. Mucous membranes are much thinner than skin, usually consisting of a single layer of cells. Frequently these membranes are provided with cilia which remove foreign objects from the sticky surface of the membrane by fanning back and forth. Those membranes which line the trachea are covered with cilia which sweep foreign particles, including bacteria, upward toward the throat. When the foreign particles irritate the membranes a cough results and the particles are blown out into the air. Irritation of the membranes of the nasal passages results in sneezing.

Other first line defenses include the acid of the stomach which destroys large numbers of bacteria taken in with food. The eyes are protected by tears, which are slightly antiseptic and cleanse the eyeballs continually, washing foreign matter through the tear ducts into the nasal passages.

Normally, these first line defenses prevent bacteria from gaining entrance into the body. However, skin may be broken or mucous membranes may become irritated, thus allowing the organisms to enter the body. An unknown factor called *general resistance* seems to play an important part in maintaining the defenses against disease. It concerns not only the first line, but the other lines as well. Resistance seems to be a general condition of the body. We know that exposure to cold air or wet weather may cause irritation of the mucous membranes and permit cold germs, pneumonia organisms, or even tuberculosis organisms to gain entrance and start an infection. General resistance seems to affect this first line defense too, because lack of sleep and a general run-down condition makes the entrance of disease germs much easier.

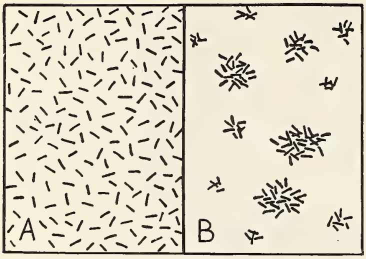
The second line of defense. Once the bacteria have passed the first line of defense, they are confronted with a second line which operates within the body. This line is defended by wandering cells from the blood stream called *white corpuscles* or *phagocytes* [*fag'oh sites*]. They originate in the lymph glands and normally are present in the blood in an approximate proportion of one to one thousand red corpuscles. When bacteria pass the first line of defense as, for example, through a break in the skin, these wandering cells leave the blood vessels and migrate through the tissue fluids to the seat of infection. They make a wall around the invading germs and begin to engulf them much in the man-



The Second Line of Defense

ner of the *Amoeba*. It then becomes a race between the multiplication of bacteria and their destruction by the white corpuscles. During the infection, which is still local, the tissues involved often swell and become inflamed. Redness often results from the rush of blood to the area to promote healing. This struggle with the second line of defense may also cause a rise in the body temperature known as *fever*. It is as though the body were using every known method of making conditions unfavorable for the growth of bacteria. Fever is a body reaction against infection and is beneficial unless it becomes too high for too long a period. The remains of the struggle, in the form of dead bacteria and white corpuscles, collect at the seat of infection as pus which is later discharged externally or carried to the organs of excretion for elimination.

The third line defenses. If the bacteria overcome the army of white corpuscles, a " break through " occurs and the organisms enter the blood stream. The infection then becomes general and the patient begins a fight for his life. The battle now occurs in the blood itself. Bacteria or their poisons are carried by the blood throughout the body with damaging effects. The fever usually rises sharply and the patient be-



AGGLUTINATION. A: Bacteria before an agglutinin has been added. B: The addition of an agglutinin causes the bacteria to gather in small clumps.

comes increasingly weak. The infection now becomes a battle between bacteria and their products and various substances which are produced by the blood to destroy the bacteria or neutralize the effect of their poisons. These blood substances are, generally, called *antibodies*. These antibodies are extremely complex and are not entirely understood. They seem to be *specific* — that is, a single kind of antibody is effective against a specific kind of organism or its products. While antibodies are very numerous, the principal types include:

1. antitoxins
2. agglutinins [*ag glute'tin ins*]
3. bacteriolysins [*back ter ee oh lye' sins*]
4. precipitins [*pre sip'pit tins*]
5. opsonins [*op'so nins*]

Antitoxins serve to neutralize toxins. In the case of diphtheria, for example, the organisms in the throat pour toxins into the blood stream which cause most of the symptoms of diphtheria. The blood is stimulated by the infection to produce diphtheria antitoxin which neutralizes the effect of the toxins. If the blood produces antitoxin more rapidly than toxins are formed by the germs, the patient recovers. *Antivenins* [*anti ven' nins*] are similar to antitoxins, except that the source of the toxin or poison which they neutralize enters the system through the bites of poisonous snakes.

Agglutinins are substances formed in the blood which cause bacteria to gather in clumps. When they are congregated, white corpuscles may surround them and devour them. *Bacteriolysins* are strange chemical substances formed in the blood which cause bacteria to dissolve. *Precipitins* are little understood, but seem to cause bacteria to settle out of the blood, thus making it easier for the blood stream to filter them out in lymph glands and various organs and for the white corpuscles to destroy them. *Opsonins* are peculiar substances which prepare bacteria for ingestion by white corpuscles. The word opsonin comes from the Greek word *opsonion* which means "sauce" or "seasoning." Perhaps these strange antibodies make bacteria more palatable!

These antibodies, like antitoxins, are specific.

Immunity to disease. To say that one is immune to disease is to say that he will not contract it. The definition is simple, but the explanation of the phenomenon is much more difficult. The study of immunity has become so advanced in recent years that it constitutes a specialized field of bacteriology and medicine called *immunology*.

The discovery of the basis for immunity is usually credited to two famous scientists. Eli Metchnikoff, a Russian naturalist, discovered white corpuscles while experimenting with starfish in Sicily. He found these curious roving cells wandering about through their bodies. He watched them engulf particles in the manner of the *Amoeba* and conducted experiments to prove that they would also ingest foreign matter inserted artificially. He found them, likewise, in the blood stream of other animals and concluded that they destroyed bacteria. Upon this conception, he based his theory of immunity.

Von Behring, in his work with diphtheria, discovered that animals which were given the disease afterward developed an immunity against its deadly toxins. He concluded that chemical substances produced in the blood accounted for immunity. Actually, both Metchnikoff and von Behring were right, for immunity is accomplished by both white corpuscles and chemical antibodies.

Immunity may be of several types. It may be *natural* or *acquired* within the lifetime of the organism. Acquired immunity, in turn, may be more or less permanent (active) or only temporary (passive).

Natural immunity. Man is not subject to most animal diseases, due, probably to differences in structure. The human body offers a somewhat different type of environment than that afforded by other kinds of animals. Consequently, we are not plagued by the diseases of horses, cattle, swine, and other animals. This type of immunity is termed *species immunity* since it includes all members of a species. Notable exceptions to species immunity are tuberculosis, which may be transmitted from cattle to man through milk, anthrax, which may cause lesions on the human body in addition to infecting animals, and tularemia, which may be carried from rabbits to man.

Certain races of people seem to carry *racial immunity* to certain diseases, though this fact is difficult to prove. For example, native Indians are immune to yellow fever, while white persons in the same area are very susceptible to the disease. It may be, however, that the Indians have experienced the disease early in life and that the immune adults are merely those who were fortunate enough to recover. Similarly, the North American Indian seems to carry immunity for scarlet fever and the Negro, to some extent, to diphtheria. On the other hand, the colored race seems to be more susceptible to venereal diseases and to tuberculosis than his white neighbor. If racial immunities actually exist, there has never been adequate explanation to account for them.

Acquired immunity. *Acquired immunity,* as the name implies, is established during the lifetime of the individual. It may be *active* or *passive,* depending upon the manner in which it is acquired.

Active immunity results from having a disease. The infection stimulates the body to form its own specific antibodies against the germs or their products, depending upon the disease. For example, a person who has diphtheria produces diphtheria antitoxins, while one who has typhoid forms typhoid agglutinins. Active immunity may be acquired artificially, however, by using biological preparations consisting of weakened or dead bacteria or products removed from living cultures. In this way, the body is stimulated to form its own antibodies without actually experiencing the disease. Vaccines, toxoids, and other products used to produce artificial active immunity will be discussed in more detail in the next chapter.

Passive immunity is acquired artificially by the injection of antibodies from the blood of other individuals or from animals. For example, tetanus antitoxin is obtained from the blood of the horse and may be injected into the blood of man to give immediate immunity in the case of deep wounds. The horse antibodies remain only temporarily and, when destroyed, no longer render the individual immune. In the same manner, human blood serum containing antibodies for scarlet fever may be used to give immediate, but only temporary or passive immunity.

Summary

Diseases caused by microorganisms are classed as infectious because they are usually transmitted from person to person. While bacteria are the causative organisms of the majority of infectious diseases, viruses, molds and mold-like fungi, yeasts, protozoans and protozoan-like organisms are the cause of many diseases.

Infectious organisms may be spread through water and food contaminated with filth and sewage, by droplet infection, through contact, wounds, and the bites of insects. Pathogenic organisms, after gaining entrance into the body may produce disease by destroying tissue, producing toxins, and by forming poisonous substances called ptomaines in food.

The defenses of the body include three lines. The first line includes the skin and mucous membranes, the second line, the white corpuscles, and the third line, specific antibodies. Immunity may be natural or acquired. Acquired immunity, in turn, may be active or passive.

Using Your Knowledge

1. In what respect are infectious diseases different from other diseases?
2. Name five classes of organisms which may cause infectious disease.
3. Give a specific illustration of the spread of a filth or sewage-borne disease.
4. What kinds of diseases are usually spread by droplet infection?
5. Give three examples of diseases spread through direct contact.
6. From your previous knowledge of bacteria, explain why tetanus organisms develop in deep wounds.
7. Why do you not consider the growth of bacteria in food and other substances an infection?
8. Explain how bacteria cause disease by tissue destruction and give an example.
9. Classify the types of immunity.

Expressing Your Knowledge

pathogenic	droplet infection	agglutinin
virus	active	bacteriolysin
microbe	passive	precipitin
ptomaine	specific	opsonin
phagocyte	fever	natural
carrier	antibody	acquired

Applying Your Knowledge

1. Make a list of common practices in your school which may spread disease through droplet infection or contact with contaminated articles.
2. Make a diagram showing three lines of defense against disease and include as forts in each line the proper agents of defense.
3. Prepare a list of the diseases to which you are immune either by having the disease or by vaccination or " shots." Ask your doctor if the shots are always effective.

Chapter 52

The Treatment of Disease

You are probably familiar with the famous painting, "The Doctor," in which a small boy is lying critically ill on a bed, the doctor sitting quietly at his side. In the background, the father is standing tensely; the mother is sitting close by, her head bowed in grief. The atmosphere is one of sadness and anxiety as the little boy hovers between life and death in his struggle against disease.

This scene was very common a generation ago when a disease progressed beyond the control of the medicine of that day and the illness became a struggle between deadly activities of bacteria and the ability of the body to produce neutralizing antibodies. Some diseases cannot be effectively controlled even today, but medical advances have gone far in the conquest of many diseases which took a large toll of life a short time ago.

The modern doctor has been provided with numerous biological preparations to aid his patients in their fight against disease. He no longer must wait for the patient to produce natural antibodies, for they may be injected directly into the blood stream in the form of various serums. He likewise has powerful chemical germ killers at his disposal in the form of sulfa drugs, penicillin, and streptomycin. The doctor and the staff behind the doctor, working in hospitals and laboratories over the nation, have gone far in the conquest of disease.

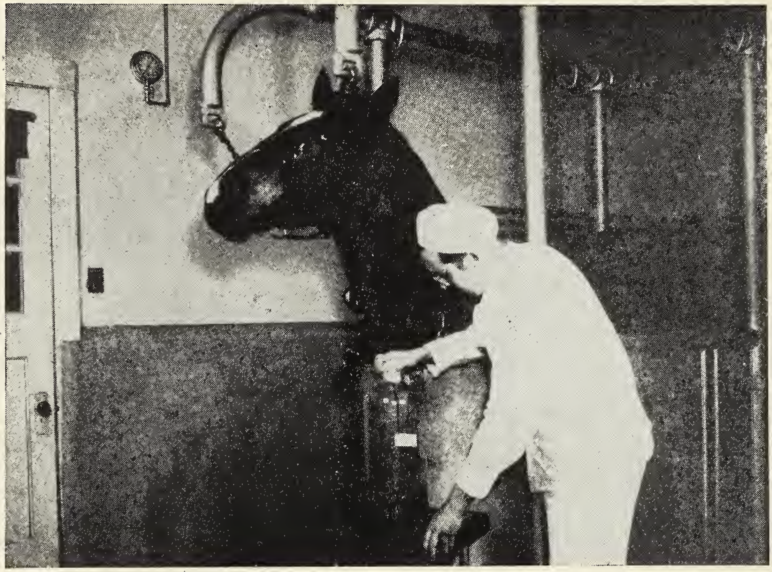
You will learn, in this chapter, about numerous biological and chemical preparations used in the treatment of disease. The next time you see vaccines, serums, and other products arrayed in your doctor's office or in the drugstore you should have a much better conception of what they are and how they are used.

Specific products used in the control of disease. Specific biological products are widely used in medicine to accomplish two general purposes. One type is used to produce immunity, while the other is used in the treatment of disease. Active immunity results from the formation of antibodies in the blood against the organisms or products of a specific disease. The actual experiencing of a disease is a rather costly method of obtaining immunity. But if germs or their products are injected into the blood in controlled amounts and conditions, an immunity may be produced without the persons actually having the disease. This is the principle of the biological preparations called *vaccines*.

Vaccines are products of the laboratory, prepared under carefully controlled conditions. In general, they contain weakened organisms or their products. The nature of the vaccine depends upon the disease involved. It may contain:

1. Weakened virus
2. Germs killed by heat or chemicals
3. Living germs but in small numbers
4. Germs mixed with antibodies to hold them in check
5. Bacterial products which have been treated to reduce their potency, as in the case of toxin-antitoxins and toxoids

Serums are used in the treatment of disease to neutralize the effects of bac-



Preparation of Diphtheria Antitoxin. Blood is withdrawn from carotid artery in the neck of the horse and placed in sterile containers. It is then processed to remove the antitoxins from the rest of the blood substances.

teria and their products. Serums contain antibodies for specific diseases which have been produced in the blood stream of other individuals. Certain types of serums are called *immune serums* or *convalescent serums.* In some cases they are obtained from the blood of persons who have recovered from a certain disease. The majority of serums, however, are obtained from animals which have been inoculated with disease and have produced antibodies in the course of their recovery. Horses, cattle, sheep, goats, and rabbits are frequently used for this purpose.

Since vaccines and serums are specific, and are prepared differently for each disease, they may best be discussed in connection with certain diseases.

Diphtheria, a typical toxin disease. The conquest of *diphtheria,* involving the brilliant work of von Behring and other scientists which was discussed in Chapter 50, is an excellent example of the successful use of antitoxin. Before the introduction of antitoxin treatment, half of those who caught diphtheria died of this terrible disease. Most of the victims were children. Death could be caused either by strangulation from the membranous colonies of bacteria which line the throat or from the effects of the deadly toxins produced by the germs and carried throughout the body.

With the use of antitoxin, however, nine out of ten children recover, and if the disease is found within the first few days, there is seldom any fatality. The antitoxin has the effect of immediately neutralizing the toxins. It is valuable not only in actual treatment of a case of diphtheria but in the prevention of the disease as well. For example, if there are several children in a family and one becomes ill with diphtheria, all of the children receive antitoxin as a precautionary measure. The foreign antibodies contained in the antitoxin serum remain only temporarily, however, resulting in a passive immunity to the disease.

Antitoxin serum is prepared by injecting quantities of diphtheria toxin into the blood of a horse. This animal has a powerful resistance to the disease and soon recovers from the effects of the toxin with the production of antitoxins. Blood is then drawn from the carotid artery in the neck into sterile containers. It is then processed to remove the antitoxins from the rest of the blood substances. This method of producing antitoxin serum is in no sense cruel. "Diphtheria horses" probably lead much more comfortable lives than others of their kind.

Immunization against diphtheria. The original method of producing active immunity against diphtheria was the administration of toxin-antitoxin injections. The vaccine was prepared by mixing antitoxin with toxins obtained from cultures of the germs. The toxins stimulated the body to produce its own antitoxins, while the horse antitoxins included in the preparation prevented damaging effects from the toxin.

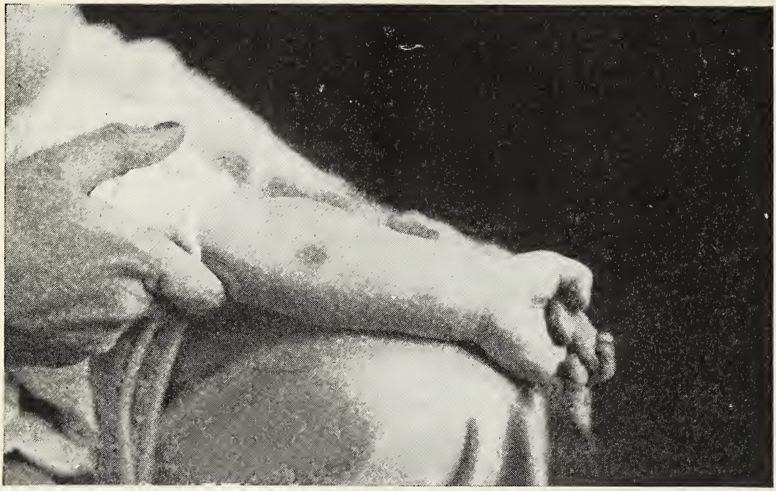
A more recent method is known as *toxoid immunization.* Toxin is weakened chemically in the preparation of toxoid, but is not changed enough to reduce the production of antitoxin when it is injected into the blood. Toxoid is more effective than toxin-antitoxin and does not cause the serious reaction which sometimes accompanies use of the latter. It is usually administered in three injections given two or three weeks apart. Immunity resulting from toxoid injections lasts for several years and, frequently, for life. If every child between six months and ten years of age could have this treatment, childhood would be saved from one of its worst illnesses and diphtheria would be a thing of the past. Since diphtheria is peculiarly a disease of young children, the treatment should be administered long before school age if complete protection is to be achieved. In very young children there is usually little if any reaction; in an older child there may be results severe enough to keep him out of school for possibly a day or two.

The Schick test. Some persons are naturally immune to diphtheria. That is, they already have the antitoxin in their blood and do not need immunizing treatment. A method, known as the *Schick test,* has been devised to test for immunity to the disease. A small quantity of toxin is placed beneath the skin on the arm of the person to be tested. If the person is not immune to diphtheria, a red spot will appear in two or three days; if he is immune, no spot appears. The Schick test usually follows toxoid treatments to test their effectiveness.

Scarlet fever and tetanus. These diseases are similar to diphtheria in that they are caused by powerful toxins produced from living organisms. This is, however, the only real similarity, for the organisms and symptoms of the diseases are quite different.

Scarlet fever is caused by a streptococcus organism which lives in the throat and pours powerful toxins into the body. The name, scarlet fever, comes from the red rash which appears as a characteristic symptom of the disease.

Treatment for scarlet fever consists of the administration of serum containing antitoxin. Scarlet fever antitoxin is not as efficient as diphtheria antitoxin and must be administered with much greater



A Positive Schick Test. The red spot appearing on the arm of this child shows that he is not immune to diphtheria.

care. Immunizing toxin is used to stimulate the body to form antitoxins. Toxoids are being perfected and will probably replace immunizing toxins in establishing immunity.

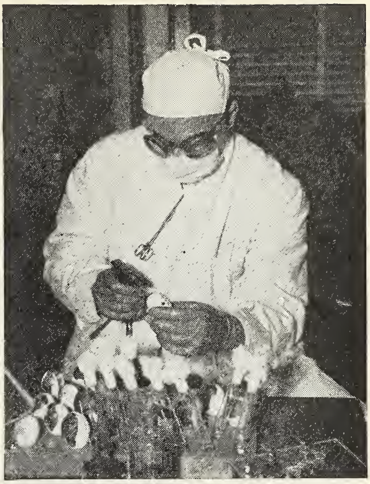
Tetanus, though rarer than scarlet fever and diphtheria, is even more dangerous when it occurs. In the case of deep wounds which may result in tetanus infection, antitoxin should be administered by a physician immediately. Tetanus antitoxin, obtained from the horse, will give immediate though only temporary immunity. However, it will last during the danger of infection from the wound.

Tetanus toxoids have recently been perfected and have been added to the list of immunizing " shots " given to children. This treatment results in an active, permanent immunity to the disease.

Smallpox. This dread disease was discussed in Chapter 50 as an example of an epidemic disease of early times. It is especially interesting, also, because it is the first disease against which vaccination was used. You will recall the work of Dr. Jenner in using virus from cowpox pustules in vaccinating against *smallpox*.

Today, *vaccination* is defined as the inoculation of a person with cowpox vaccine so as to build up an active resistance against smallpox. The vaccine virus is prepared by inoculating calves. The abdomen is shaved off and cleansed thoroughly, after which it is scratched in numerous places. The virus is then rubbed in and, after six days, produces numerous sores or pustules in the areas where the inoculations were made. The calf is then bled to death under an anesthetic and the material from the pustules is scraped from the abdomen into sterile containers. The virus is mixed with water and glycerin and stored in a refrigerator for several weeks. During storage, the virus loses its strength. It is then tested to make sure that it has lost its potency and is put into capillary tubes to be marketed.

A more recent method of growing the virus is in sterile eggs. The egg is inoculated with the virus before development has started. After inoculation through the shell, the eggs are incubated for a few days. The infection appears as a white spot on the egg membrane. The virus is then removed and is treated as virus from calves. Egg-grown virus has a distinct advantage over calf-grown in that it may be prepared under absolutely sterile conditions. This eliminates the possibility of other infections from vaccination.



Preparing Vaccine. This bacteriologist is preparing to inoculate eggs. First he drills two small holes in the shell, then punctures the inner membrane and injects the virus into the embryo.

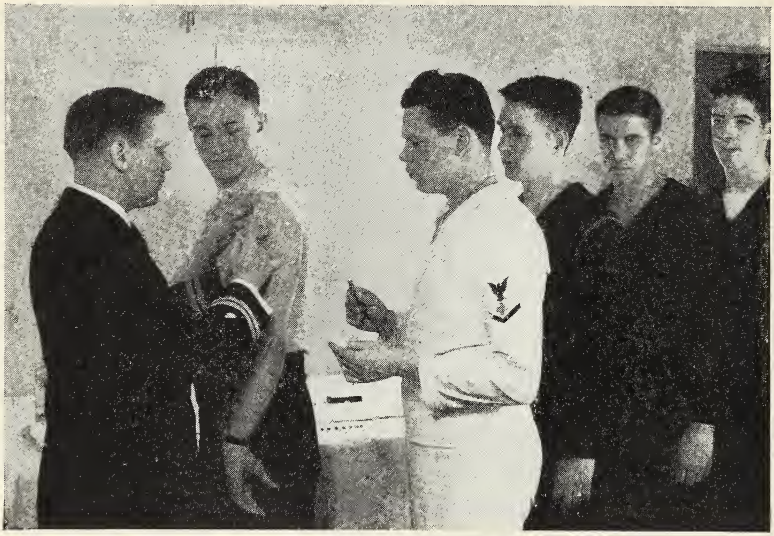
Typhoid fever. Another disease which has been checked tremendously by the development of a vaccine is *typhoid fever*. As recently as 1934 there were 22,133 cases in the United States with a mortality of 4,131. In 1938 there were only 14,397 cases. The death rate is now only about 2 in 100,000 cases. Sanitation, vaccination, and education are checking and controlling the disease.

Typhoid fever can easily be prevented by vaccination. The vaccine is made from dead typhoid germs and is injected under the skin of the arm. A slight redness soon appears and remains for a few days, accompanied in some cases by a mild headache. After this simple treatment one is immune to typhoid for several years. Frequently, paratyphoid organisms, the cause of food infections, are mixed with typhoid germs in the vaccine. This mixed vaccine results in immunity to food infections in addition to typhoid and is very valuable for one who is visiting an area where food infection is likely to occur.

In our Civil War, typhoid was one of the worst diseases; in the Spanish-American War, nearly 5,000 soldiers died of typhoid while only 300 were killed in action. In World War I and World War II, on the other hand, all of the armed forces were given typhoid vaccine injections with the result that typhoid was practically unknown.

In addition to vaccination, proper care of those who are sick, disinfection of all wastes from typhoid patients, and suppression of flies which may carry germs will prevent its spread from those already ill. Exposure to the disease may be avoided by use of pure water, pasteurized milk, and clean foods, and by proper disposal of sewage. Infection can be prevented, even if one is exposed, by the administration of antityphoid vaccination.

The *Widal test* is widely used in diagnosing typhoid and in locating typhoid carriers. A typhoid patient or carrier has typhoid agglutinins, the principal defense against the disease, present in the blood serum. This agglutinin causes



Administering Typhoid Shots

typhoid germs to clump together. If living typhoid germs are clumped or agglutinated on a microscope slide when the patient's blood serum is added, the reaction is termed positive and indicates that typhoid is present or that the patient is an immune carrier.

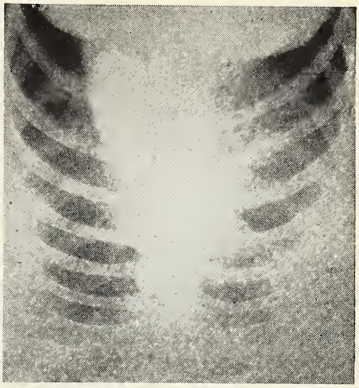
Colds and cold shots. In recent years numerous investigations have been made in an effort to find a vaccine which will immunize against the *common cold.* The results have been favorable in some cases, but totally unsatisfactory in others. One of the troubles seems to be in definitely classifying the cold organisms. Colds are not caused by any one organism. In fact, both bacteria and viruses may cause the infection. Colds taken at different seasons may be due to entirely different organisms and several kinds of organisms may be involved in the same cold. The problem, then, is to prepare a specific vaccine containing the proper organisms. Probably the most effective vaccine is *autogenous vaccine* prepared for specific individuals. This vaccine is made from the nasal discharge at the time of a cold. The bacteria and viruses present in the discharge are weakened or killed in preparing the vaccine and are then injected into the blood stream at regular intervals. By using autogenous vaccines one is certain to get the organisms to which he happens to be susceptible. In some cases an immunity to colds results, while in others, the injections seem to be of little value.

Tuberculosis. Until recently, *tuberculosis* has been the most mortal of diseases, causing one seventh of all deaths. It is often called the " white plague " and is a serious problem in all civilized countries. The disease affects the lungs chiefly, but is not uncommon in bones, glands, and other organs. It has a close relationship to economic conditions, since crowding, malnutrition, lack of fresh air, and other poor living conditions are important factors in its development.

Koch was eager to develop a preventive treatment for tuberculosis, similar to Jenner's smallpox vaccine or Pasteur's rabies treatment. He prepared a vaccine consisting of products of tubercular germs which he called *tuberculin* with the idea of using it to produce immunity. As was mentioned in a previous chapter, his efforts failed in that respect, but the product, tuberculin, has been extremely valuable in the diagnosis of tuberculosis.

When a small quantity of tuberculin is injected under the skin, a red area develops at the point of injection if the patient has or ever has had a tubercular infection. The tuberculin test is valuable for testing children and for testing animals, especially cattle. It is not satisfactory for human adults, however, because the average adult has, at some time in his life, experienced a tubercular infection. A positive reaction even among young people of high school age does not necessarily indicate an active infection. Sputum examination and X ray are necessary to confirm an active case of tuberculosis.

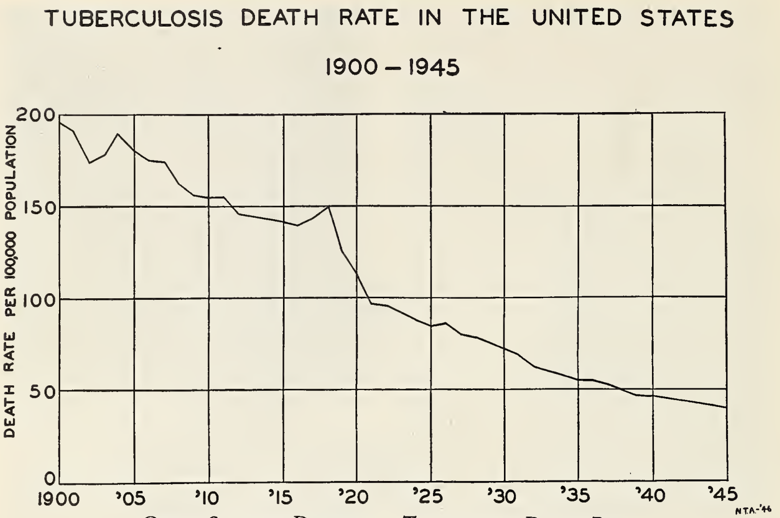
Treatment for tuberculosis is effective if the disease is discovered before it has progressed too far. It cannot be cured as rapidly as many other diseases due to a lack of specific biological products effective against the organisms. Scientists are still looking for a safe tuberculosis vaccine which can be used to produce immunity to the disease. Living vaccines are too dangerous to try, and dead organisms are so poisonous that they produce abscesses when injected into the skin. The only source of immunity seems to be a long exposure during the normal course of life. Dr. Calmette of France has produced a tuberculosis vaccine called B.G.G. which has had some success, especially with children. With this one exception, however, there is no injection which can be used to combat the disease.



X-RAY PHOTOGRAPH OF THE LUNGS. This patient shows moderately advanced tuberculosis (on the right side of the picture).

But even without the aid of specific biological products, the war against tuberculosis is being won. Since 1900, the death rate from tuberculosis has been lowered from 200 deaths to less than 50 per 100,000 population. There are over 600 sanitariums in this country alone where open-air cures are effected. Tuberculosis associations spread valuable information to the population and offer assistance to the afflicted. The war against tuberculosis is a campaign of prevention in preference to cure. Some of the preventive measures will be discussed in the next chapter.

Other diseases. The diseases which have been included in the discussion are but a few of the more common illustrations of the effectiveness of vaccines for immunization and serums used in combating disease. Vaccines and serums have been prepared for many other diseases and the list is constantly growing. *Whooping cough,* a serious disease in infants, is now effectively controlled by



Graph Showing Decline in Tuberculosis Death Rate

a vaccine which is given in three injections one week apart. Scientists are experimenting with a vaccine against the *influenza virus* by growing the organism in eggs. Control of this deadly organism which opens a path for numerous secondary invaders would be a great step in the conquest of disease. In laboratories and research foundations over the country, scientists are experimenting with the virus of *infantile paralysis*. In these recent experiments, the organisms are grown in the Rhesus monkey. Everyone hopes that within a short time this dangerous disease may be controlled by means of effective vaccines and serums.

Chemotherapy. The conquest of disease is not a war of biology alone, for chemistry plays a very significant part. Chemotherapy is a rather recent field in which specific chemicals are used to destroy germs. Rather by accident, quinine was found to be a specific cure for *malaria*. This was probably the first of a long line of drugs which can be used against organisms in the body without destruction of the body tissues.

The development of chemotherapy is associated with the work of a brilliant German chemist, Paul Ehrlich, in connection with his long search for a cure for *syphilis*. Ehrlich spent many years attempting to discover a drug which would kill the organisms in the blood stream without damaging the blood or other parts of the body. After 605 unsuccessful attempts, he finally succeeded. His 606th drug was an arsenic compound called *salvarsan*. It is widely used today in the treatment of venereal disease under the name, "Compound 606."

Ehrlich opened a new field in his discovery of "Compound 606." Other scientists began experimenting with chemicals in the treatment of disease. Dr. Gerhard Domagk [*Doh mag'*], another German scientist, discovered, in 1932, that a red dye called *prontosil* had remarkable germ-killing powers. Soon after his discovery of prontosil he was required to try it on his own daughter who was dying with a *streptococcic* infection which had progressed beyond medical control. It proved to be very effective in halting the infection with the result that the child's life was saved.

Further investigations of prontosil proved that only a part of the drug had germ-killing powers. This part was isolated and called *sulfanilamide*. It was the first of a very important family which now includes *sulfathiazole, sulfapyridine, sulfadiazine,* and others. The sulfa drugs are widely used in the treatment of certain infectious diseases. They have been extremely effective in the treatment of *scarlet fever,* a form of streptococcus. In fact, the sulfas have succeeded in making this disease a rather mild infection if treated in time. *Pneumonia,* likewise, can be controlled effectively by sulfa drugs, together with serums. The *sulfonamide* drugs are also effective against *streptococcic wound infections, tonsillitis,* and other types of infections. They should not, however, be taken like aspirins or other mild sedatives. Many persons began taking them regularly as " cure-alls " with damaging effects. Sulfa drugs should never be used except on recommendation and under the direction of a physician.

Penicillin. Penicillin was discussed in Chapter 22 as a product of the mold, *Penicillium notatum,* along with the methods used in growing the mold in laboratory cultures. The drug, penicillin, is said to begin where the sulfas cease in effectiveness.

In 1929 a London bacteriologist, Dr. Alexander Fleming, found that some of his cultures were contaminated by a fungus, *Penicillium notatum,* which retarded or stopped entirely the growth of bacteria on the medium. He set aside his regular experiments and concentrated on it. He established the fact that the fungus was active against certain kinds of bacteria, including many deadly forms. His work was published but was not further developed for several years.

With the opening of World War II, however, Dr. Fleming's work was reviewed as to the possibility of producing a new and badly needed drug to control wound infections and other diseases which the armed forces would be required to face. British scientists succeeded in isolating the active bacteria-destroying agent, penicillin, produced by the mold. The next step was to determine if it could be used to control disease. By 1941 this had been established and extensive clinical investigations were under way both in Great Britain and in the United States. Startling results were obtained, but until 1946 the use of the drug was greatly limited by scarcity and widespread demand particularly for use in the armed services. The sulfa drugs can be synthesized. Until 1946 science had to depend on the fungus itself for the commercial production of penicillin. During the autumn of that year several of the penicillins were produced synthetically, and the supply has now been increased sufficiently to make the penicillins standard products in the treatment of certain diseases.

The penicillins are especially effective in the treatment of *staphylococcic infections* including *carbuncles* and *boils, meningitis,* and *osteomyelitis*. They are used, together with sulfa drugs, in the treatment of *pneumonia*. They have also been found effective against *gangrene, streptococcus,* and other wound and blood infections. Experiments are now under way to discover their effectiveness against *syphilis*.

The penicillins have many advantages over sulfa drugs. They do not harm the body and do not seem to be critical in respect to dosage. Furthermore, bacteria do not appear to develop tolerance against penicillins as they do to sulfa drugs. While penicillins are limited in their scope, they are very effective against certain kinds of bacteria. They are available in many forms including solutions for hypodermic injection, ointments for external use, and powder for spraying wounds, or the throat.

Streptomycin. *Streptomycin* is an active agent against bacteria and, like the penicillins, is selective in the group of organisms it affects. The great value of streptomycin is the fact that it is effective against a group of organisms which are untouched by the penicillins. Thus, it is a valuable " teammate " for them.

Streptomycin is a product of a filamentous mold (fungus) which scientists class as an actinomycete and have named *Streptomyces griseus.* It was discovered by Dr. Selman A. Waksman at the New Jersey Agricultural Experiment Station of Rutgers University in 1944. Biological companies are in the process of establishing extensive plants for its large-scale production.

Streptomycin has been found effective against infections of the urinary tract which are not affected by penicillin. One of its most significant uses has been against *influenzal meningitis.* Streptomycin has been used with success, likewise, in the treatment of certain types of wound infections and infections of the blood stream. The dosage and use of streptomycin must be determined carefully by the physician.

Grisein is another new drug discovered in 1947 by Dr. Waksman in his search for " bigger and better streptomycins." It is closely related to streptomycin, and comes from a similar organism. He hopes that by combining it with streptomycin, those diseases which are not now effectively treated with streptomycin alone, will yield to these sister drugs.

Antiseptics. An effective check to the growth of bacteria is the use of *disinfectants* and *antiseptics,* which are chemical substances that destroy or hinder the development of germs.

Disinfectants, in general, are stronger than antiseptics and should not be used on the body. To be effective, a good antiseptic should destroy germs yet not injure human tissues. Johns Hopkins Hospital and the University of Pennsylvania, among others, have been prominent in research on antiseptics. Yet, the perfect antiseptic has still to be compounded, in spite of strenuous advertising statements by certain commercial companies. Iodine is the most reliable for ordinary wounds and minor cuts. Tests by Dr. Salle of the University of California placed iodine first among antiseptics in germ-killing ability and in freedom from injury to healthy tissue. Even a 1% solution of iodine is effective, but a 3½% solution (one-half the strength of the alcoholic solution usually sold as " tincture of iodine ") is better. Hydrogen peroxide, if fresh, hexylresorcinol, potassium permanganate, camphor, thymol, and even common salt and soap, are of definite antiseptic value in certain cases. A saturated solution of boric acid is a mild antiseptic eyewash, and 1% nitrate of silver is used in the eyes of newborn babies to prevent *ophthalmia.*

Among the newest disinfectants are the various kinds of electric lamps which when placed in air ducts completely kill germs by ultraviolet rays. These lamps are now used successfully in operating rooms of hospitals and have been proved to be an effective adjunct to the methods of sterilizing air.

MODERN STERILAMP. This lamp sterilizes the air in the nursery of this modern hospital.

The following chemicals are used to kill germs outside the body, as in the case of clothing, utensils, bedding, and rooms that have been occupied by persons ill with infectious diseases. *Bichloride of mercury* is a dangerous poison, but it is valuable for disinfecting the hands or washing woodwork. Dilute *carbolic acid* may be used for the hands, clothing, or bedding. *Formaldehyde solution* may be similarly used, though it is sometimes injurious to the skin. Several coal-tar products, such as *cresol, lysol,* and *creolin,* are said to be as efficient as carbolic acid, and less dangerous. Fumigation of rooms is no longer a common practice.

Bacteriophage. Scientists believe that there is a form of minute virus, called a *bacteriophage,* which enters the cells of bacteria and destroys their contents. When solutions of bacteriophage are added to cultures of bacteria, the colonies dissolve and disappear. It is possible, therefore, that bacteriophage might be used against infectious diseases. To some extent, this has been done by applications of the bacteriophage to external infections. However, this very advanced phase of the treatment of disease is still in the experimental stages and may be included in important future announcements of germ killers.

Summary

Vaccines and serums are the most important biological products used in the treatment of disease. Vaccines contain dead or weakened organisms or their products and are used to produce immunity to disease. Serums contain antibodies against specific diseases which, while they do not result in active immunity, are extremely valuable in the treatment of disease.

Chemotherapy is the treatment of disease by means of chemicals or drugs.

MODERN TUBERCULOSIS SANITARIUM. The Herman Biggs Memorial Hospital at Ithaca, N. Y.

Quinine and salvarsan, the latter discovered by Ehrlich, are older drugs. Recent additions include the sulfonamides, penicillin, and streptomycin.

Antiseptics are weak germ killers which do not destroy human tissues. Germicides, on the other hand, are powerful germ killers and cannot be applied to living tissue. Bacteriophage is a name applied to a type of minute virus which attacks bacterial cells. It is still only a prophecy of what may come in the future.

Using Your Knowledge

1. Why are vaccines and serums termed biological products?

2. Name three different ways in which a vaccine may be prepared.

3. What is the principle in the use of vaccines?

4. Explain the use of serums. Why don't serums give active immunity?

5. Explain the theory of autogenous cold vaccines.

6. Explain how typhoid agglutinins are used in the Widal test.

7. What is the important use of tuberculin? Why is it used only in the case of infants or small children?

8. For what medical achievement is Paul Ehrlich famous?

9. Discuss the discovery of sulfanilamide and the family of drugs called the sulfas or sulfonamides.

10. Discuss the source and uses of the new drugs penicillins, streptomycin, and grisein.

Expressing Your Knowledge.

vaccine
Schick test
Widal test
chemotherapy
salvarsan
prontosil
sulfanilamide
sulfathiazole
sulfadiazine
penicillin
streptomycin
grisein
bacteriophage
antiseptic
disinfectant

Applying Your Knowledge

1. Prepare a report on the production of diphtheria antitoxin in the blood stream of the horse.

2. Prepare a biographical report on Paul Ehrlich and his work on a cure for venereal disease which resulted in the discovery of "Compound 606."

3. Prepare a list of common household antiseptics and a list of germicides. In a separate column, list the correct use of each.

Chapter 53

The Prevention of Disease

It is very consoling to know that if we become ill, we have the benefit of the knowledge and the products of a very advanced medical age to aid us in recovery. *Curative medicine* has attained a very high level of efficiency with the products of many years of research at its disposal in the form of powerful drugs and biological preparations. But the cure of disease is only half of the battle. The other half concerns the prevention of disease.

We may well be proud of the number of cases of tuberculosis, typhoid, and other infectious diseases medical science is now able to cure. But how many of these cases could have been prevented? How much inconvenience, lost time, and medical expense could have been spared these individuals if they had not contracted disease in the first place?

In recent years especially, much of the energy of the medical profession has been turned toward *preventive medicine*. We have created a new front in the war against disease from which we strike the enemy before it has organized an attack. National, state, local, and private agencies are working in close harmony to safeguard the health of the nation. The things you eat, the water you drink, the products you buy — these and many other events in daily life are closely guarded for your protection by public health agencies. Preventive medicine is, to a great extent, a program of health education. It requires the full coöperation of everyone. This chapter will acquaint you with numerous activities of preventive medicine in the war against disease.

Curative and preventive medicine. The functioning of *curative* and *preventive medicine* is ideally illustrated in the fight against tuberculosis in America. During the time that Koch was investigating the cause of tuberculosis, a young American, Edward Livingston Trudeau, was caring for his brother, a victim of the dread disease. During his period of close association with his brother, Trudeau contracted the disease, though he was unaware of his condition for some time. After the death of his brother, Trudeau studied medicine and became a doctor. Early in his practice, however, he discovered that he, too, had tuberculosis and, abandoning his practice, went to the Adirondack Mountains in upper New York to spend his remaining years. To his great surprise, his condition improved. Other doctors, learning of Trudeau's experience, sent other patients to him and a small colony was established. Trudeau began extensive study of the effects of fresh air and healthful surroundings upon tuberculosis. When it was clearly demonstrated that these conditions aided immeasurably in effecting a cure for the disease, the first Cottage Plan Sanitarium for the treatment of tuberculosis was established at Saranac Lake.

With Trudeau's accidental discovery of the rest cure for tuberculosis, sanitariums were established all over the nation. Some were established by the states, other by counties, and still others by private organizations. Tubercular patients flocked to these hospitals with the hope of effective cures. Large numbers did recover, and the death rate from tuberculosis declined sharply. Thus, special tuberculosis hospitals were instituted as curative measures in the war against the disease. But, fortunately, the battle did not end there. Through the combined efforts of the National Tuberculosis Association, state associations, and numerous county associations, extensive campaigns of prevention were instituted.

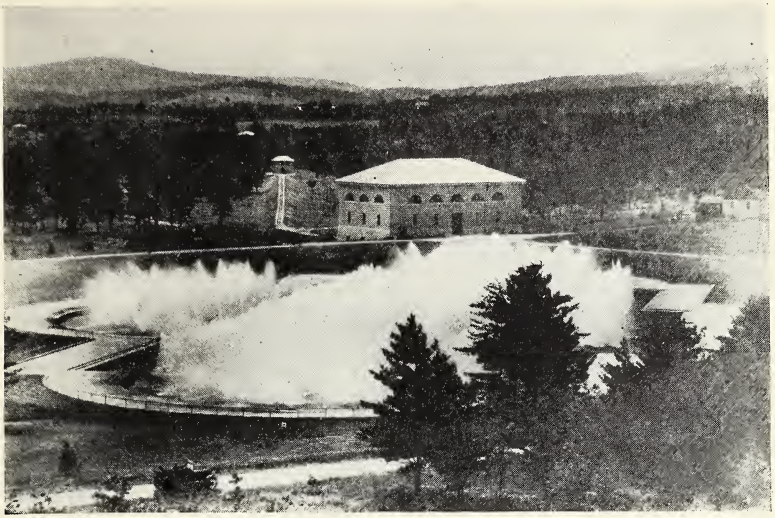
The splendid work of these organizations, supported by the public in the sale of Christmas seals, stands as an example to be followed in the prevention of other diseases. Through their efforts, school children are checked periodically for the presence of the disease in its early stages. In some cases, tuberculin tests are administered, followed by X rays of the chests of those with positive tuberculin tests. With improvement in X-ray machines, many areas now give X rays to all children. Similar tests are conducted in numerous industrial organizations, department stores, and other public places. Many states require that all those who prepare or serve food in public places be examined for tuberculosis. For children from homes in which tuberculosis is prevalent, and for those who are otherwise threatened with the disease, many Tuberculosis Associations maintain Nutrition Camps. Here, measures are taken to guard against an almost certain occurrence of the disease in the careful regulation of rest habits, diet, etc. In this way, many children are spared what would have been almost certain infection.

Other tuberculosis preventive measures include inspection of public places to guard against unhealthy conditions, provision of healthful working conditions in industry, testing of all cattle from which milk is sold to the public, and an extensive program of health education maintained by the Tuberculosis Associations and other organizations.

State and local Boards of Health. These organizations render an extremely valuable service in the prevention of disease. One important service is the quarantine of cases of disease. When a case of infectious disease is discovered by a doctor, he notifies the local Board of Health, which places the patient and, if necessary, the family of the patient, under quarantine during the period of contagion. We are all familiar with the signs or cards tacked on the front of such a house to warn the public of the presence of an infectious disease.

The Board of Health gathers valuable statistics on the diseases of a community which are extremely valuable to the doctors. This organization serves further in the tracing of epidemics and in removing the cause, where possible. The local food supply, water supply, public restaurants, and other public places are under the Board's continual scrutiny.

Safeguarding our water supply. Water supply is one of the most critical factors, especially in large cities where great



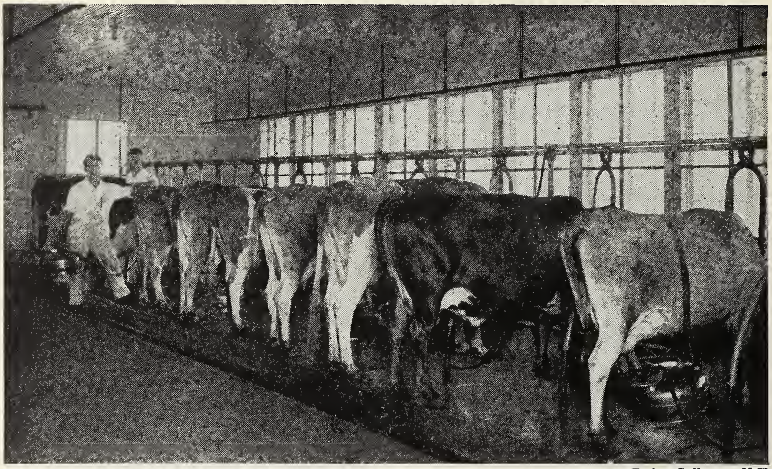
AERATING PLANT AT CROTON, N. Y. Aerating water by spraying it into the air and sunshine helps in killing disease germs, and at the same time gives the water a better taste.

numbers of people use a common source. Under such circumstances, infected water could cause an epidemic almost overnight. The water supply for a large city represents an enormous investment for establishment and operation. The watershed, or original source of the water supply, the streams or lakes from which the water is obtained, and the wells driven deep into the ground must be checked continually. When water is obtained from lakes or rivers, the water must be filtered to remove mud and other sediments, treated to remove objectionable flavors and odors, and thoroughly purified with chemicals to destroy bacteria and other forms of life. Chemical and bacteriological tests are run almost constantly. Thus, one living in a large city may be sure that his water supply is safe and healthful.

In smaller communities and individual farms, wells usually serve as the water supply. Water from these sources should be checked regularly by the Board of Health to guard against infection. The water supply should, at all times, be protected from pollution.

Control of the food supply. Almost every town and city has regulations in regard to food inspection. The stores, bakeries, slaughterhouses, and milk stations are under supervision of official inspectors. Foods must be protected from flies, bread must be wrapped, and food animals examined for their health.

Milk has always been a prolific source of disease among young children and every means is now taken to secure its purity and freshness. The farmer must have healthy cows and healthy men to care for them and, in addition, must have clean milk sheds and sterilized cans and utensils. As mentioned before, all animals of the dairy herd must be inspected for tuberculosis. The state and city inspectors enforce a list of rules covering in some cases over sixty items that tend toward supplying clean milk to the dealer in the city.



Ewing Galloway, N.Y.

A MODERN DAIRY. Mechanical milkers are more sanitary and efficient than hand milking.

The dealer is also subject to equally careful control. He must not let milk get warmer than fifty degrees, he must provide clean cans and handling conditions, he must sell in sealed and labeled bottles, and his milk must be subject at any time to examination for bacteria. If any of these conditions are not complied with and if the milk is found to be dangerous to health, it is destroyed. Most large dairies maintain their own laboratories to check the milk regularly for bacterial content and general quality and are the first to recommend destruction of any doubtful product.

Milk normally contains bacteria, mostly harmless and some useful, but the total must not exceed 100,000 organisms per cubic centimeter. This is not a high bacterial count, though well-handled milk should be far below this limit. Milk must have at least 3.25 per cent butter fat and must not contain any preservatives, such as borax, soda, or formaldehyde. Milk is graded as to bacterial content and general quality and must be sold according to the proper grade.

Regulation of the food supply extends to all commodities. The Federal Pure Food and Drug Law of 1906 and the Federal Food, Drug, and Cosmetic Act of 1938 provide for:

1. Inspection of all food animals
2. Standards of purity for food products
3. Freedom from adulteration
4. Prevention of harmful preservatives
5. Proper labeling of drugs and medicines
6. Proper labeling of package goods.

Federal Food and Drug Inspectors, assisted by inspectors of the local Boards of Health, maintain a constant vigil in warehouses, freight terminals, and other places where food and drug products are handled to see that regulations are observed.

Sewage and garbage disposal. Disposal of waste products, especially of sewage and garbage, is an important

A Modern Garbage Disposal Truck

problem in most cities. The original custom was to dump the garbage in special areas outside of the city and to carry the sewage through sewers to the rivers and streams. Both measures created serious health hazards which agencies of preventive medicine could not tolerate. Garbage dumps created breeding places for flies and general offensive conditions. Streams polluted with sewage became dangerous areas of infection for unwary bathers and, of course, made the water unfit for other uses, even to support fish and other aquatic animals.

In addition to health hazards, these methods of disposal of sewage and garbage were tremendously wasteful. These waste products represent tremendous amounts of organic matter which originally came from the soil and should be returned to the soil. Some cities burn garbage in an equally wasteful manner. The best method of garbage disposal consists of converting it into useful fertilizer to be distributed to the agricultural regions for use on the fields. In the same way, sewage may be treated and either reduced to valuable fertilizer or treated to stimulate the growth of bacteria of decay in order to destroy it rapidly before it is piped into rivers and streams.

Factory and housing conditions. The strongest constitutions cannot endure dark, ill-ventilated, or crowded homes and factories. Laws, inspection, and information have combined to bring about better conditions.

In most states child labor is forbidden or restricted, housing conditions are looked after to some extent, and fire protection is usually provided.

To carry out these many lines of civic biology, cities and towns usually have Boards of Health, inspectors, and the assistance of the police. In large cities public laboratories are maintained where examinations of food, milk, water, and disease cultures are made. There may be one or more city physicians, city chemists, and visiting nurses who help enforce and carry out the regulations.

Then there are the street cleaning and fire departments and the city engineers, who look after the drains, sewers, and parks.

The federal government devotes much of the work of the Department of Agriculture and the Departments of Commerce and Labor to matters pertaining to national health and the conservation of natural resources. They carry on investigations along varied lines of civic biology, and distribute quantities of valuable literature sent out on request.

Patent medicines. The consumption of patent medicines costs the people of the United States $300,000,000 per year. This would be well enough if the people were benefited by their use, but this is rarely the case. Many of them are fakes, some are positively dangerous, all are outrageously expensive, and in many cases their use delays proper treatment till too late. The Federal Food, Drug, and Cosmetic Act prevents any claims to " cure " unless they can prove their claims and this rule has practically removed that word from their vocabulary of fiction. No patent medicine ever *cured* consumption, nor " kidney trouble," nor catarrh, and they now are more careful in the wording of their advertisements, though many still try to convey the same impression.

" Consumption cures " are mainly opiates which lull the sufferer into false security until he is past all help. Tonics and some medicines frequently depend upon alcohol for their effect. " Soothing syrups " for helpless babies may be opium or morphine mixtures and frequently lay the foundation for drug habits in later life, if indeed the baby is not " soothed " into the sleep that knows no waking. Read the labels for yourself.

Headache remedies often contain heart-depressing drugs which deaden the pain but do not remove the cause, of which the pain was merely a warning.

Catarrh cures were usually cocaine or opium mixtures and often led to drug addiction; under recent laws they are much restricted.

The Federal Food, Drug, and Cosmetic Act does not forbid the sale of these medicines but it does oblige the maker to do two things:

1. He must put on the label the amounts of alcohol, morphine, cocaine, opium, or other harmful drug in his medicine.

2. He must not " make any false or misleading statement " as to the virtues of his particular " remedy."

This is one of the chief values of the law and applies to foodstuffs as well as medicines, so the only way to obtain the protection which the law affords is by reading the labels before you buy.

One can often judge of the character of a newspaper or magazine from the number and kind of patent medicine advertisements which it carries. A reputable periodical will not now open its columns to the false and misleading claims which some medicine manufacturers offer. Look over the available literature and draw your own conclusions.

Other agencies concerned with the fight against infectious disease. To some extent, disease is an individual problem. But the effects of disease are much more far reaching. The life of every individual has a direct bearing upon his community, his state, and even the nation as a whole. The entire economy of any nation is reflected in the health and living conditions of all of its citizens. Thus, the matter of public health has gradually become the concern of the nation, the states, and the communities in which people live.

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

In 1912, the United States Public Health Service was established as a national agency to assist in the control of disease. It grew out of a much older organization, the Marine Hospital Service, which was established by an act of Congress in 1798.

One of the earliest functions of the service was the control of the health aspects of immigration by means of the authority to quarantine immigrants and to restrict immigration from disease-infested areas. In addition to this international control, the U. S. Public Health Service co-operates closely with the states to prevent the spread of infectious disease from one state to another. Valuable data concerning all types of infectious diseases are available to all health organizations. These data are especially valuable since they are based upon national figures.

The National Institute of Health, a research division of the U. S. Public Health Service, is one of the foremost research centers in the world. It is now located in buildings near Bethesda, Maryland. By means of funds provided for in the Social Security Act of 1935, the National Health Institute works in close co-operation with state health agencies. Research includes investigation of disease, sanitation, and other phases of disease prevention.

In addition to national and state agencies, numerous local and private agencies are doing an extremely important work in the control and prevention of disease. Insurance companies have made exhaustive studies in connection with the life expectancy of their insured. This information is available to the public in the form of numerous pamphlets and is extremely valuable in health education. The Rockefeller Foundation maintains an extension program of research in the fields of medicine and prevention of disease. Public Health Nursing Associations, both privately and in connection with the local Boards of Health, provide nursing care to those who might not otherwise be able to afford it. In most cities, Public Health nurses are available for people of all economic circumstances. If an individual is unable to pay for his care, the nursing service is paid for out of other funds. No one is denied proper care during illness because of inability to pay for such care.

Organic and functional diseases. These diseases present quite a different problem from infectious diseases. They are not due to microorganisms and cannot be treated in the manner of infectious diseases. In many respects, they are even more of a problem than infectious diseases because they are slower in developing and, usually, are of much longer duration.

With the conquest of infectious disease, many former leading killers have been brought under control to the extent that they are of almost secondary importance. For example, tuberculosis, which was once a leading cause of death, has now been reduced to eighth place and is the cause of less than five per cent of all deaths. Diphtheria, likewise, has been tremendously reduced as a cause of death among children. With the improved methods of treating and preventing infectious diseases, the life expectancy of the average person in the United States has been increased from slightly over 49 years in 1901 to more than 60 years at the present time.

These life expectancy figures may be misleading, however, unless they are studied carefully. Remember that life expectancy figures are determined by averaging the length of life of all individuals. The figures include infant mortality which, naturally, reduces the total figure tremendously. With the exception of malformations present at birth (*congenital*), infant mortality is due to infectious diseases, for the most part. Most infectious diseases of infancy and childhood have been brought under control. Thus, a child has a much greater chance of surviving to become an adult than ever before. As a result, more people live to become victims of diseases which make their appearance later in life. Furthermore, large numbers of adults are spared infectious diseases, and die later of some other ailment.

This explains why organic and functional disorders are on the increase today. These diseases have now assumed prominent places among the leading causes of death. At the present time, diseases of the heart are the leading cause of death. Cancer and other malignant tumors, cerebral hemorrhage, arteriosclerosis (hardening of the arteries), and diseases of the nervous system, likewise, have become exceedingly prominent. We hear that they are constantly increasing. Perhaps they are somewhat, but certainly not in the proportion which figures would seem to indicate.

Regardless of explanation, however, these diseases represent a real problem today. Furthermore, they are of a more personal nature. They cannot be prevented through the efforts of public agencies in the manner of infectious diseases. The individual must understand these diseases and use every possible precaution against their occurrence.

Diseases of the heart and related organs. Heart disease, today, leads all other diseases as the cause of death, especially among people of middle and old age. We usually think of heart disease as occurring suddenly, because death from this ailment is often almost instantaneous. Actually, however, heart disease develops over a long period of time and, frequently, involves other organs of the body.

The blood vessels and kidneys are closely associated with the heart and have a direct effect upon its activity.

Consequently, diseases either of the blood vessels or the kidneys closely concern the heart. Frequently, these three organs are linked in the term *cardiovascular-renal diseases*, the term referring to the heart, blood vessels, and kidneys in the order named.

High blood pressure, the leading cause of heart disease, has been found in the majority of cases to be due to diseased kidneys. The relationship between the kidneys and blood vessels is extremely complicated and not thoroughly understood. Hardening of the arteries, another cause of heart trouble, may be due to several factors. One theory suggests that as arteries become old, their walls become rigid and lose their flexibility. As a result, they do not expand when blood gushes through them from the heart, thus increasing the pressure in the entire blood circuit. Another theory is just the opposite. According to this idea, the arteries harden to withstand the increase in blood pressure caused from another source. Regardless of the exact cause, however, high blood pressure places the heart under a strain and greatly increases the possibility that smaller capillaries, especially in the brain, may burst, resulting in a cerebral hemorrhage. Other common heart diseases include *coronary occlusion, coronary thrombosis,* and *angina pectoris.*

Cancer, one of the chief killers today. Cancer seems to be increasingly prevalent as more people live to reach the dangerous cancer age. Probably no disease is more feared by the average person. As yet, there is no cure for the disease except complete removal of the cancerous growth or the retarding of its activity by means of X ray and radium treatments.

The difficulty in dealing with cancer is that it is a "normal abnormality." It seems to be a mass of tissue in which cell division has gone wild, resulting in an abnormal growth which soon invades other organs. As the mass enlarges, cells near its center become cut off from food which is absorbed into the mass and begin to disintegrate, pouring poisons into the system. Because of its abnormal nature, a cancerous mass has no connection with the circulatory system and, thus, must absorb its nourishment.

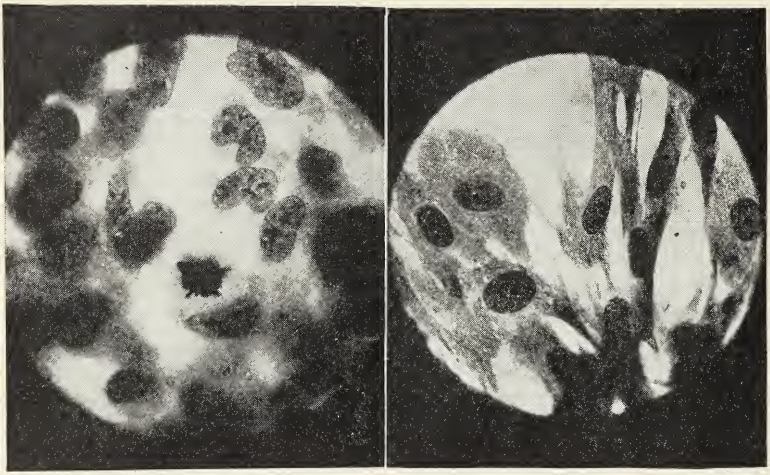
Cancers seem to develop as a result of bruises or irritations. They appear most frequently in the colon, stomach, throat, and liver, and, in the case of women, in the uterus and breasts. Cancer is rare in people under 30 and seems to be most common between the ages of 40 and 60.

The disease may be treated effectively if found in its early stages. Consequently, one should report any suspicious symptoms to the doctor immediately. The following symptoms *may* mean cancer, although they are not necessarily indications and should not cause undue alarm.

1. Any sore that does not heal within a few weeks
2. Bleeding from any body opening
3. A lump on the surface of the body which changes shape or enlarges
4. Stomach distress after eating which becomes continual
5. Alternate periods of diarrhea and constipation
6. Sudden loss of weight without any apparent reason

Bear in mind that the above symptoms do not necessarily indicate cancer. They should, however, be reported to the doctor.

Diagnosis and treatment of cancer. External cancers of the skin are readily diagnosed and treated. However, internal forms are often very difficult to detect. X ray is used to determine the extent and location of the growth, al-



CANCEROUS AND NORMAL TISSUE. Left: Cancer cells, showing the characteristic disorderly growth and arrangement. Right: Healthy tissue, showing regular cell outlines and orderly distribution.

though even this method is not positive evidence. The proof of cancer is based upon the presence of characteristic giant cells in the abnormal growth.

There are only three recognized methods of treating cancer. The entire growth may be removed, in many cases, by means of *surgery*. *X rays* may be used to destroy the rapidly dividing cells. In addition, *radium* and other radioactive substances emit powerful rays which destroy cells upon exposure. Numerous "quacks" have misled the public into believing that cancer may be cured by other methods. However, according to the U. S. Public Health Service, X ray, radium, and surgery are the only present cures for the condition.

Cancer cannot be transmitted from person to person because it in no way involves microorganisms. It cannot be inherited directly, although statistics seem to indicate that certain types of cancer are more prominent in some families than in others. An individual may inherit a constitutional make-up which tends toward cancer, although the disease is never inherited as such. Furthermore, cancer tendency in a family may be altered in offspring through marriage with individuals in which the tendency is not present. The relation of inheritance to cancer tendency needs much more investigation before definite conclusions may be drawn.

Mental diseases. This group of disorders is, without a doubt, increasing in prevalence today. Perhaps this is because many forms of diseases of the nervous system are recognized today which were not classed as disease formerly. But even this explanation does not account for the tremendous number of mental patients which crowd our hospitals and institutions.

The average individual today lives under great stress and strain which is likely to affect his nervous system in some way or other. Although mental disorders may result from disease in other parts of the body or from organic conditions such as tumors, by far the greatest number of cases are the result of purely functional disturbances.

We have only recently begun to regard mental and nervous illnesses in their proper light. Only a short time ago, people afflicted mentally were regarded as possessed by some evil spirit. Accordingly, they were shunned by society and isolated cruelly. Later, extensive institutional facilities were provided over the nation to house unfortunate victims of mental disorders and remove them from normal society. They constituted a group of " forgotten people " left to survive as best they could in an asylum.

Fortunately, mental illness is now regarded in a different light. We look upon it as we would any other disease, except that in affecting the nervous system it necessarily influences the actions of the individual. We know now, also, that by far the majority of cases may be cured and restored to normal life if treatment is begun early. While some forms of mental disorders may require institutional care for long periods of time, it is estimated that seven out of ten patients could avoid institutional commitment if treated in time. The great need in the country now is for mental hospitals with emergency wards where critical mental cases of short duration may receive extensive treatment. Shock therapy, a treatment consisting of passing strong currents through the nervous system, may frequently cure a mental patient within a few days or weeks. Baths, hydrotherapy, occupational therapy, and other forms of treatment, likewise, are very beneficial. If the patient who has " cracked " suddenly under heavy strain could be hospitalized immediately and placed under the skilled care of a psychiatrist, he would probably never require admittance to a mental institution. If treatments failed and he progressed into a condition which would indicate long term care, then he could be sent to the institution. Our trouble has been in disregarding early symptoms of mental and nervous disease and then committing the patient to an institution when he advanced beyond private care. Consequently, the patient failed to receive treatment at a time he needed it most and was thrown upon an overcrowded mental hospital or state or local institution. In time, this condition will be corrected, but not until the public realizes fully the difficulty and ceases to think in terms of institutional commitment. Funds to build many more mental hospitals and special wards in general hospitals and to employ adequate numbers of skilled psychiatrists and specially trained nurses and attendants are badly needed. They must be raised, willingly, from the public.

Wide World Photos

OCCUPATIONAL THERAPY. The patient is being taught how to tool leather.

Prevention of mental disease. Everyone of us has five chances out of one hundred of becoming a mental patient some time in life. The chances of suffering from some milder nervous disorder are much greater. Yet, most cases of mental illness could have been avoided had the individual understood something of the cause of these disorders. Frequently, mental disease begins with attitudes on the part of the individual. These attitudes, in turn, place a strain upon the nervous system which may affect the mental processes. Even as high-school pupils you should guard against these damaging attitudes and types of behavior. Study the following list and see if you are tending toward any of the attitudes which may lead to serious trouble in later life.

1. Avoid thinking too much about yourself. Think in terms of other people and make their happiness your chief goal. Avoid selfishness and self-pity.

2. Do not allow all of your activity to center around one thing. The person with varied interests may change activities from time to time and rest his mind considerably.

3. Strive to derive satisfaction from the work you do. Do not look upon things you must do as "chores," but rather as opportunities for accomplishment.

4. Maintain hobbies and avocations which have little to do with your routine life. These activities are almost as important as your chief occupation.

5. If possible, engage in sports and other outdoor activities which tend to tire you physically.

6. Develop adaptability. Learn to adjust yourself readily to new friends and situations. Do not exclude new acquaintances and prefer to live in a routine "rut."

7. Learn to accept disappointments willingly and cheerfully. Always look beyond present reverses toward future success.

8. Develop admiration for those who are more successful in certain things than you happen to be. Avoid, especially, the attitude that some people get all of the breaks and that you have more than your share of bad luck.

9. If you happen to have handicaps of one type or another, disregard them and develop superiority in some other line. If you are fortunate enough to have no handicaps, disregard them in others.

10. Be conscientious in what you do, but do not worry excessively. If you must worry, worry about someone besides yourself.

Perhaps this age will bring about a new era in the treatment of nervous disorders and mental diseases. Perhaps the public will cease looking at those with mental afflictions as objects of curiosity and instead will offer them assistance in their recovery. When nervous and mental disorders are treated with the same high degree of efficiency as infectious diseases we will have reached a high standard in the conquest of disease, not only mental diseases, but also social diseases.

Summary

Preventive medicine is concerned primarily with the prevention of disease before it occurs. In addition to the members of the medical profession, this important phase of medicine is carried on by national, state, local, and private agencies. The U. S. Public Health Service carries on work of a national scope. The states, in turn, have Boards of Health which carry on the work in their respective areas and in co-operation with the national organizations. Local Boards of Health administer the affairs of the communities. Numerous special agencies, such as the Tuberculosis Associations, likewise, carry on work of tremendous importance in the control and prevention of disease.

Public health activities include research, compiling of statistics on disease, quarantine and isolation, inspection of food and water supply, sewage and garbage disposal, and other activities.

Functional and organic disorders present quite a different problem from infectious diseases. They are not due to microorganisms and cannot be transmitted from person to person. With the present control and methods of treatment of infectious diseases, organic and functional disorders have assumed their places as leading causes of death. Heart diseases, closely associated with vascular diseases and kidney disorders, cancer, and mental disorders represent challenges to modern medicine. The conquest of these diseases requires full co-operation of the entire population.

Using Your Knowledge

1. Distinguish curative and preventive medicine.
2. Explain how the cottage or rest cure for tuberculosis was accidentally discovered.
3. Enumerate ways in which preventive medicine functions in the case of tuberculosis.
4. List some of the activities of your local Board of Health.
5. Mention some of the ways in which the water supply is guarded closely.
6. Enumerate some of the activities of the Federal Food and Drug Department.
7. In what manner do functional and organic diseases differ from infectious diseases?
8. Account for the fact that, while the average life expectancy has increased eleven years, the average adult today cannot expect to live eleven years longer than formerly.
9. In terms of the control in infectious disease, explain why heart disease and cancer seem to be increasing rapidly.
10. Enumerate the three recognized treatments for cancer.

Expressing Your Knowledge

preventive medicine	public health	quarantine
curative medicine	organic disease	watershed
sanitarium	functional disease	filter
Trudeau	cardiovascular-renal	cancer
Saranac Lake	arteriosclerosis	radium
nutrition camp	hemorrhage	surgery

Applying Your Knowledge

1. Obtain figures showing the five leading causes of death today. Prepare a block graph indicating each cause of death and the percentage of mortalities from each cause per year. In each case, indicate whether the disease is organic, functional, or infectious.
2. Visit your local water plant. Find out what measures are taken to safeguard your water supply and report your findings to the class.
3. Find out the methods used in the disposal of sewage and garbage in your community. If possible, make suggestions for improvement.
4. Confer with a member of your Board of Health to find out what kind of practical co-operation students can give him.

Increasing Your Knowledge of This Unit

Bauer, William W. *Contagious Diseases.* Alfred A. Knopf, New York. 1934

De Kruif, Paul. *The Fight for Life.* Harcourt, Brace and Co., New York. 1938

De Kruif, Paul. *Men Against Death.* Harcourt, Brace and Co., New York. 1932

De Kruif, Paul. *Microbe Hunters.* Harcourt, Brace and Co., New York. 1932

Dietz, David. *Medical Magic.* Garden City Publishing Co., Garden City, New York. 1942

Epstein, Samuel and Williams, Beryl. *Miracles from Microbes; The Road to Streptomycin.* Rutgers University Press, New Brunswick, New Jersey. 1946

Fishbein, Morris. *Common Ailments of Man.* Garden City Publishing Co., Garden City, New York. 1945

Fishbein, Morris. *Frontiers of Science.* D. Appleton-Century Co., New York. 1933

Flexner, J. *Doctors on Horseback.* The Viking Press, New York. 1937

Galdston, Iago. *Behind the Sulfa Drugs; A Short History of Chemotherapy.* D. Appleton-Century Co., New York. 1943

Haggard, H. W. *Devils, Drugs and Doctors.* Harper and Brothers, New York. 1944

Haggard, H. W. *The Lame, the Halt and the Blind.* Harper and Brothers, New York. 1932

Harpole, James. *Behind the Surgeon's Mask.* (New Home Library Series) Garden City Publishing Co., Garden City, New York. 1944

Heiser, Victor. *An American Doctor's Odyssey.* W. W. Norton and Co., New York. 1936

Hertzler, Arthur E. *The Horse and Buggy Doctor.* Harper and Brothers, New York. 1938

Montague, Joseph Franklin. *Nervous Stomach Trouble.* Blue Ribbon Books, Garden City, New York. 1940

Nelson, Nels A. and Crain, Gladys L. *Syphilis, Gonorrhea and the Public Health.* The Macmillan Co., New York. 1938

Park, William H. and Williams, Anna W. *Who's Who Among the Microbes.* D. Appleton-Century Co., New York. 1929

Parrin, Thomas. *Shadow on the Land Syphilis.* Reynal and Hitchcock, New York. 1937

Ratcliff, J. D. *Modern Miracle Men.* Dodd Mead and Co., New York. 1939

Rice, Thurman B. *Textbook of Bacteriology.* W. B. Saunders Co., Philadelphia. 1942

Robinson, Victor. *The Story of Medicine.* (New Home Library Series) Garden City Publishing Co., Garden City, New York. 1943

Roseneau, Milton J. *Preventive Medicine and Hygiene.* Sixth Edition. D. Appleton-Century Co., New York. 1927

Silverman, Milton. *Magic in a Bottle.* The Macmillan Co., New York. 1941

Singer, Charles. *A Short History of Medicine.* Oxford University Press, New York. 1941

Snyder, Garfield. *Your Arthritis: What You Can Do About It.* William Morrow and Co., New York. 1943

Taylor, Sherwood. *The Conquest of Bacteria from Salvarsan to Sulphapyridine.* The Philosophical Library, 15 E. 40th Street, New York. 1942

Vaughn, Warren T. *Strange Malady: The Story of Allergy.* Doubleday, Doran and Co., New York. 1941

Ward, Harold (Editor). *New Worlds in Medicine: An Anthology.* Robert M. McBride and Co., New York. 1946

Wilson, Charles Morrow. *Ambassadors in White.* Henry Holt and Co., New York. 1942

Pamphlets:

Little, Clarence C. *The Fight on Cancer* (Public Affairs Pamphlets No. 38), New York. 1939

Little, Clarence C. *What You Should Know About Tuberculosis.* National Tuberculosis Association, 1790 Broadway, New York.

Unit 10 ~~

Like Begets Like—the Biology of Heredity

HAVE you ever heard the expression, " like father, like son," or " a chip off the old block "? Have you ever wondered why dogs always produce puppies rather than kittens, and why setters and pointers are natural hunters? Or, perhaps, why War Admiral, the famous race horse, inherited the qualities of his sire, Man O' War?

The answer to these, and other similar questions lies in the study of the specialized branch of biology called *genetics* [*je net'ticks*]. The science, genetics, has been explored extensively in recent years. Knowledge of the heredity or inheritance of plants and animals is exceedingly important in many phases of modern life. The agriculturist makes use of genetics in the breeding of livestock for special purposes. The gardener and horticulturist apply the principles of heredity to plant breeding in the production of new varieties of garden flowers, crops plants, and fruit trees. The application of genetics to human inheritance has given explanation to numerous problems confronting the human race.

Chapter 54

The Basis of Heredity

Had you ever stopped to consider that there has never been another hand just like your right hand — except your left hand, and that there will never be another face just like yours, or a body, or a personality like the one you possess? Did you ever wonder how you came to be as you are and why you are different from everyone else?

At one time, it was generally believed that all characteristics were controlled by the blood. You have probably heard people speak with pride of a blood relationship with some prominent individual of a few generations ago. Or you have heard breeders of dogs, cats, or farm animals refer to blood lines. Actually, the blood has absolutely nothing to do with the hereditary characteristics of an individual. A child's blood often bears no similarity to that of its parents. Nor are characteristics of an individual altered by administering a blood transfusion.

As scientists, we must look much more closely at an individual to discover the manner in which his heredity is controlled. You have learned that an organism is composed of cells. Furthermore, each cell is a unit. Consequently, the factors of heredity must be present in every cell. If you could analyze the controlling factors of heredity which lie within your cells, you would discover that every cell in your make-up is identical in that respect. You are a unit, composed of millions of cells which are all related, all alike in heredity make-up, and all different from those of anyone else.

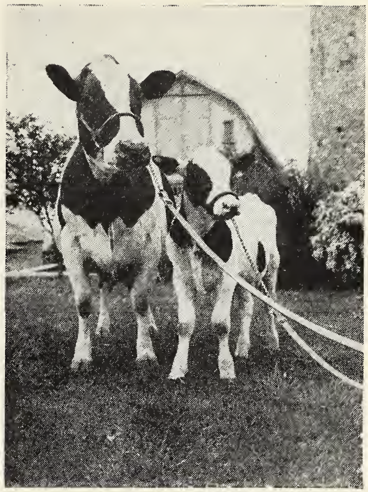
You will learn, in this chapter, how the characters of heredity are included in every cell, how they are passed to new cells during cell division, and how the characteristics of one individual are paired with those of another in the formation of a new organism.

Heredity and environment as controlling factors. Two great sets of influences determine the make-up of an individual. The first of these is *heredity.* Such characteristics as size, hair color, skin color, eye color, and even personality traits may be inherited. They are part of the physical make-up, controlled by factors of heredity. In addition to these influences, *environment* plays an important role in determining the nature of an individual. Just where one influence ends and the other begins is difficult to determine. Biologists and sociologists have been debating this question for years. It seems that no distinct line can be drawn between the two. For example, size may be controlled by heredity, but is not size determined, also, by the diet and other factors of the environment? Intelligence may be inherited, but to what extent? How would you determine intelligence? A mind which has been exposed to activity in an ideal environment will usually function in a manner far superior to one which has been deprived of learning opportunities in an unwholesome environment. Similarly, we speak of born criminals, but is one actually born with the tendency or is it developed because of bad social influences in a poor environment? Perhaps these arguments seem rather pointless, but they are really of tremendous importance because environment may be altered, while heredity is fixed.

For the present, we shall deal only with heredity. After you have become acquainted with the manner in which heredity operates, we shall return to a discussion of environment.

What sorts of characteristics are inherited? In certain respects, all members of a single species are alike. For example, man normally inherits the characteristics of the human race which make him like all other human beings. These *species characteristics* include hands with fingers for grasping, the ability to walk erect, a highly developed nervous system including brain development superior to all other organisms, and other characteristics of the entire human race. In addition to species characteristics, he inherits *individual characteristics* which make him different from all other people. These individual characteristics are transmitted from parent to offspring, with the result that the individual resembles his parents, but differs from each because he bears the heredity of both.

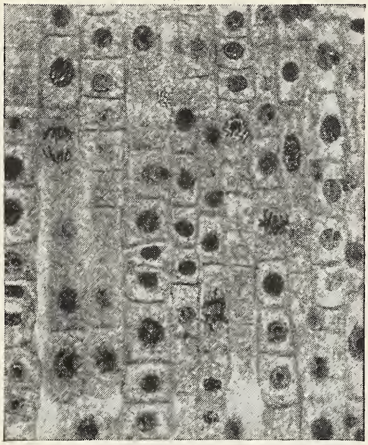
The cell, the unit of heredity. You know that the cell is the unit of structure, for you found that all living things are composed of cells. Similarly, the cell is the unit of function, for it is the seat of all the activities of the organism. We now come to the cell as the center of another phase of the life of an organism — the unit of heredity. The characteristics of an organism are expressed through its cells — that is, every cell is controlled individually by the factors of heredity. If you happen to have inherited musical ability, the characteristic is expressed in the cells of the nervous system, the ears, and all other parts of the



CHAMPION COW AND HER CALF. The calf resembles her mother.

body which are concerned with this special ability. Similarly, if you come from a long line of athletes, you may have inherited unusual muscular development and co-ordination through characteristics expressed in the cells of your nervous system and muscular system. Again, it is difficult to separate heredity and environment. To a certain extent these abilities may be developed through constant practice and in some instances they seem to be inherited. If the characteristic is inherited, it is expressed through large numbers of cells functioning together in the make-up of the organism.

The nucleus, the center of cell heredity. As you recall, the nucleus is a spherical body of protoplasm lying, usually, near the center of the cell. It consists of a *nuclear membrane,* one or more small bodies called *nucleoli,* and a mass of living substance called *nucleoplasm.* When special stains are added to the nucleus, a twisted mass of thread-like

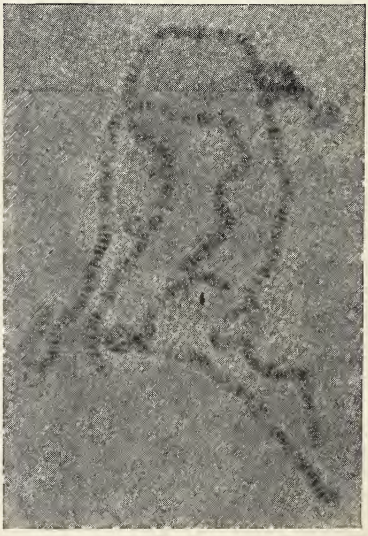


Cells of the Onion Root Tip. Note the chromosomes in the nuclei. Different stages in cell division are shown.

material may be seen in the nucleoplasm. This material is called *chromatin,* the substance of heredity. The mass of of threads is termed the *chromatin net.* This strange substance seems to control the characteristics of the individual cell as well as the organism as a whole. Furthermore, the chromatin in all of the nuclei of a single organism is identical. Thus, the individual functions as a single unit and carries the same hereditary characteristics in all parts of his make-up.

Chromosomes and genes. The chromatin material in the nucleus becomes much more apparent during division of the nuclear substances prior to division of the cell. The chromatin then becomes modified to form several rod-shaped bodies called *chromosomes.* Chromosomes appear as dark, elongated bodies within the nucleus when treated with special stains. They frequently vary in shape. When chromosomes are photographed under the extremely high powered electron microscope, numerous small granules are visible. Thus, the chromosome consists of great numbers of tiny particles arranged in strands, somewhat like a string of beads. The individual particles are called *genes* [*jeens*], which have been proved to be the bearers of heredity.

The number of chromosomes sometimes varies in different species, but is constant for every organism in that species. For example, the corn plant has twenty; the cat, sixteen; the frog, twenty-six; and man, forty-eight. Furthermore, chromosomes always appear as pairs. Man has forty-eight chromosomes which represent, actually, twenty-four pairs. A pair consists of duplicate chromosomes and genes. Thus, not one but two genes control each hereditary characteristic. Perhaps you have figured out already that one chromosome of each pair came from one parent, while the other came from the other parent.



Chromosomes. Can you see the bearers of hereditary characters in this highest magnification of the chromosomes?

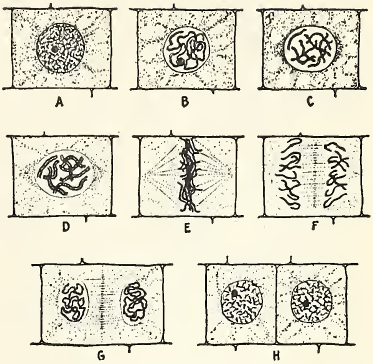
Formation of body cells (mitosis). The cells of an organism divide regularly and add to existing tissues and replace injured or worn-out cells. Each time a new cell is formed, the chromatin material of the nucleus is divided in order that the two new cells resulting from the division of the old one will have identical hereditary make-up. Division of the chromatin and other contents of the nucleus occurs during a complicated process termed *mitosis* [*my toe'sis*]. Mitosis always precedes division of a body cell. It may be observed in any plant or animal tissue, especially in rapidly growing embryonic tissue such as the tip of a root or stem or in an animal embryo. Mitosis begins with the formation of the chromosomes from the chromatin net in the nucleus of a body cell. Then the chromosomes split longitudinally down the middle into two equal halves. Each half migrates to opposite ends of the cell. Mitosis ends with the formation of two new daughter nuclei, each one containing the same chromatin material, and each one exactly like the nucleus of the body cell from which it was formed. Mitosis is divided into four distinct stages as follows:

1. *Prophase,* which includes the formation of the chromosomes from the chromatin net, and their arrangement along the center or "equator" of the cell.

2. *Metaphase,* which is marked by the longitudinal splitting of each chromosome down the middle.

3. *Anaphase,* during which the two halves of each chromosome migrate to either end of the cell.

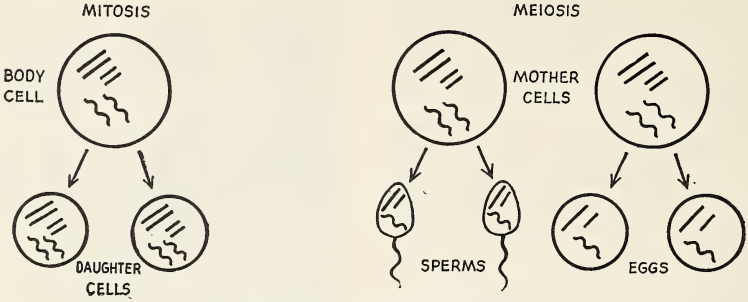
4. *Telophase,* during which the two daughter nuclei are reorganized. The chromosomes unite and form a chromatin net, and both nuclei again enter the resting stage.



The Stages in Mitosis. A is a cell which is about to divide; B, C, and D represent the first, or prophase stage; E shows the second, or metaphase stage; F is the third, or anaphase stage; G is the final, or telophase stage. H shows the two new daughter cells which have been formed from the original cell, A.

Each of these stages will be discussed in more detail in the following paragraphs, which will include, also, the manner in which cell division occurs following division of the nucleus by mitosis.

The first evidence that nuclear division is to occur is the gradual condensing of the fine threads of the chromatin net into a ribbon called the *spireme.* This stage is called *early prophase,* the first of the mitotic stages. The spireme then breaks up into short lengths called *chromosomes.* In many species, the chromosomes form directly from the chromatin net, omitting the spireme stage. With the formation of the chromosomes, the nuclear membrane begins to disappear and numerous fine threads composing the *spindle* form from poles above and below the nucleus. During *late prophase,* the nuclear membrane and other parts of the nucleus are no longer visible. The chromosomes move to the center of the cell and arrange themselves in a row along the equator, midway be-



COMPARISON OF MITOSIS AND MEIOSIS

tween the two poles marked by the ends of the spindle threads. The chromosomes now appear differently than they did originally, for each one seems to be double. Actually, the genes of each chromosome have divided and are about to separate from each other.

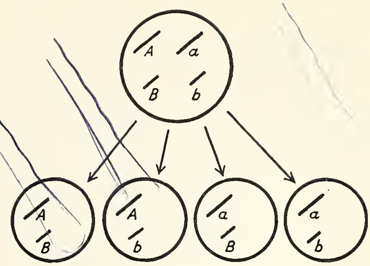
The second stage, called *metaphase,* begins with the separation of identical halves of each chromosome. As though some mysterious force were pulling from each of the opposite poles, the chromosome is actually separated into two pieces, much as you might peel off the skin of a banana in two pieces. Finally, the division which has started at one end of each chromosome continues to the other and the halves become completely separated. The metaphase stage is now complete.

The third stage, called *anaphase,* starts with the movement of the chromosomes in opposite directions. Each set moves along the threads of the spindle toward the respective poles. Bear in mind that each group of chromosomes is a full set, identical with the set which is moving in the opposite direction toward the other pole. The anaphase stage continues until the chromosomes have reached their respective poles.

The final or *telophase* stage consists of the formation of two daughter nuclei. The spindle fibers disappear gradually and the chromosomes of each of the two daughter nuclei form a chromatin net, characteristic of a resting nucleus. The other nuclear content reappears and becomes surrounded by a nuclear membrane. At about the same time as the spindle fibers disappear, a new cell membrane forms along the "equator," midway between the new nuclei. In the case of a plant cell, the membrane becomes covered on either side with cellulose and forms a cell wall. In animal cells only the membrane remains to separate the two new cells.

After mitosis and cell division, the daughter nuclei are about half the size of the original body cell from which they were formed. They grow to their mature size and are then capable of division into two more new cells.

Formation of sex cells (meiosis or reduction division). New organisms may be formed in a number of ways. *Sexual reproduction,* which is common to both plants and animals, is the only method by which higher animals reproduce their kind. Sexual reproduction is accomplished by the union of specialized sex cells during the process termed *fertilization.* Male sex cells are called *sperms,* and, in higher animals, are formed in special organs called *testes.* Female sex cells develop in organs called *ovaries,* and are termed *eggs.* Eggs and sperms are formed by the division of special cells in the reproductive organs which are called *mother cells.* The division of a sperm mother cell results in the formation of two sperms. Similarly, an egg mother cell divides to form two eggs. The manner in which these cells are formed is, however, somewhat different from the formation of ordinary body cells during mitosis.



Chance Distribution of Chromosomes and Genes During Reduction

When cells are formed by division following mitosis, both daughter cells have the exact nuclear content and the same number of chromosomes as the original body cell. Thus, all cells of the human body have forty-eight chromosomes and the number is kept constant by the division of the entire set of chromosomes during mitosis. If sperms and eggs were formed in the same manner, and each received forty-eight chromosomes from the mother cell, union of a sperm and an egg would result in a fertilized egg containing ninety-six chromosomes. It is hard to say just what an individual with this chromosome number would be like. Furthermore, the number would continue to double with each succeeding generation until the nucleus would be unable to hold all the chromosomes.

The manner in which this situation is avoided is quite logical. If the cells of both parents have forty-eight chromosomes and the offspring likewise must have but forty-eight, the egg and sperm must contain only twenty-four chromosomes each. Man, while he has forty-eight chromosomes in each cell, has only twenty-four different kinds of chromosomes with a pair of each kind present. In the formation of eggs and sperms, chromosome pairs of the mother cell separate, one of each kind going into one sex cell and the other into a second cell. This process is termed *meiosis* [*my oh' sis*] or reduction division, since the original chromosome number is reduced by exactly one-half.

Chance distribution of chromosomes during reduction. We know that the same parents may produce several offspring with quite different characteristics. It is evident, therefore, that eggs or sperms formed by a single individual may differ. This is due to the chance distribution of chromosomes in the germ cells. For example, if a mother cell has two pairs of chromosomes, designated as *Aa* and *Bb,* the pairs may separate in several ways in the formation of eggs and sperms. *A* may pair with *B,* resulting in *AB;* or *Ab* may pair, or *aB,* or *ab.* In every case *A* and *a* have separated, as have *B* and *b.* When you consider that man has forty-eight chromosomes and that each chromosome has numerous genes, the possibilities in distribution of chromosomes and genes during reduction are almost without limit. It is upon this chance distribution of genes and the characters they control during reduction, that the science of inheritance is based.

Fertilization restores the original chromosome number. We might consider an egg or a sperm as only half of an

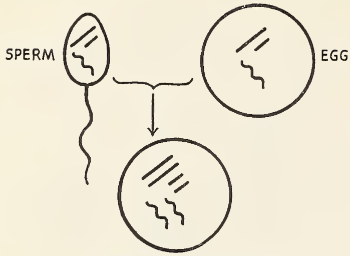


Diagram to Show Fertilization. A sperm unites with an egg and forms a zygote. If each sperm and each egg contains three chromosomes, the zygote will contain six.

individual. Either is powerless to develop further without the other, for it possesses only half of the chromosomes characteristic of the organism it represents. During the process termed *fertilization,* a sperm and an egg unite to form a *fertilized egg* or *zygote.* While the fertilized egg may not appear different from an ordinary egg, it represents a one-celled stage of a new individual. The chromosomes have been restored to their original number and the zygote goes through cell division by mitosis, as it grows into a mature organism.

From fertilized egg to many-celled organism. Immediately after fertilization, the egg begins a period of rapid growth. The cell divides following mitosis to form a two-celled stage. Since chromosomes are split in the process, both cells of the two-celled stage have identical chromosome make-up. Soon these cells divide to form a four-celled stage, then an eight-celled stage, and so on until millions of cells may have been formed. All of the cells are directly related to the original zygote cell from which they have descended by division. Each division is preceded by a mitotic division of the nucleus and each new cell receives part of the chromosomes which were present in the original fertilized egg. Since half of these chromosomes came from one parent and half from the other parent by means of the egg and sperm, we can readily account for "like father, like son," "a chip off the old block," or "a mother's own daughter."

Summary

The make-up of an individual is determined by two sets of factors; those of his heredity, and those of his environment. The factors of heredity are controlled by a substance called chromatin which is present in the nucleus of every cell. During nuclear division, the chromatin changes form and becomes chromosomes which are, in turn, composed of numerous genes arranged in strands. The genes are the determiners of heredity. They are visible only with an electron microscope.

When the nucleus of a body cell divides by mitosis, all of the chromosomes split lengthwise, the halves of each migrating to opposite ends of the cell where they are then organized in two new daughter nuclei. The daughter nuclei are identical, since they both contain part of the original chromosomes of the body nucleus. In the formation of eggs and sperms, however, the chromosome pairs separate and the total number is reduced to one-half the content of body cells. During fertilization, however, the egg and sperm unite with the result that the original chromosome number is restored. Further divisions of the fertilized egg, resulting in the new organism, are by mitosis. Thus, all cells of the organism carry the same chromosome make-up as the original fertilized egg.

Using Your Knowledge

1. Distinguish between environmental and hereditary characteristics.
2. Explain why the cell is the unit of heredity.
3. Discuss the relationship between chromatin, chromosomes, and genes.
4. Explain why body cells, formed following mitosis, have the same nuclear content as the body cell from which they came.
5. Define meiosis and explain the process by which it occurs in the formation of eggs and sperms.
6. Explain the difference between an egg and a fertilized egg in regard to chromosome content.
7. Explain the manner in which the fertilized egg develops into a new organism.

Expressing Your Knowledge

heredity	mitosis	mother cell
environment	meiosis	egg
species characteristic	prophase	sperm
individual characteristic	metaphase	fertilization
chromatin	anaphase	ovaries
chromatin net	telophase	testes
chromosome	spireme	zygote
gene	spindle fibers	

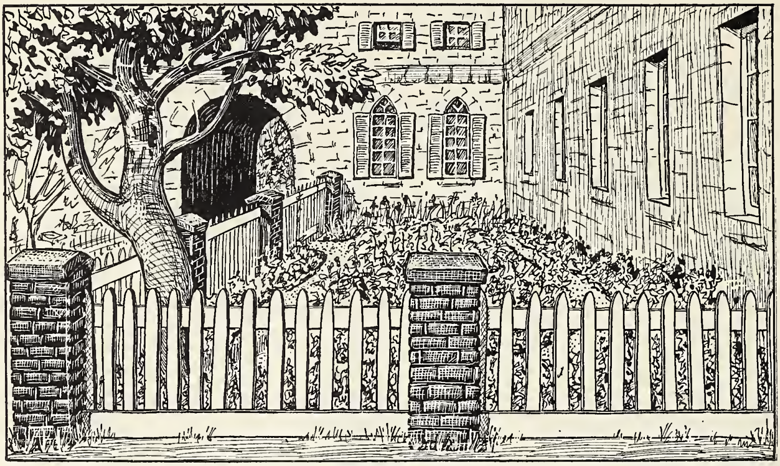
Applying Your Knowledge

1. Make a list of ten of your individual characteristics and indicate which ones have been controlled largely by heredity and those which have been determined largely by environment.
2. Prepare a series of eight sketches to show successive stages in mitosis.
3. Construct a drawing of an imaginary cell containing four pairs of chromosomes. Diagram the formation of two cells by mitosis and either eggs or sperms by meiosis. Show the chromosome content in both cases.
4. Make drawings of two pairs of greatly enlarged chromosomes to show the genes. Make the genes different colors and indicate with a key the imaginary characteristics each gene controls. Be sure that you have two of each kind of genes, that they are located on corresponding chromosomes, and that they are located in corresponding places on the chromosomes.

Chapter 55

The Principles of Heredity

In 1865, Gregor Mendel, an Austrian monk, published the results of a masterful piece of work on the laws of heredity. His was not the first experimentation in the field of inheritance, but his findings were the first of any scientific consequence. His paper, representing years of experimentation with garden peas, was contributed to the Natural History Society of Brünn, Austria, where it re-



Mendel's Garden

mained totally unnoticed for thirty-five years. Mendel had been dead for sixteen years when three other scientists discovered his work and began to make use of his findings. It is indeed unfortunate that Mendel could not have lived to see his work acclaimed, and tragic that the results of such a wonderful piece of scientific research should have gone unnoticed for so long. It is, however, the greatest tribute to Mendel that the laws he formulated from his experiments with garden peas stand today, practically unchanged, as the basis of the science, genetics.

Mendel's paper is a model of accuracy and simplicity. It could be read with ease and pleasure by any interested boy or girl of high-school age. In dealing with the principles of heredity, you will hear of several of Mendel's experiments and the laws he formulated from results which he obtained. More recent discoveries will be included as well, but you will find in all cases that they fit the principles of heredity as discussed by Mendel.

Since the discovery of Mendel's paper in 1900, genetics has grown rapidly and has become a highly specialized science For this reason, the demonstration of the principles of heredity in this chapter must be limited to rather simple illustrations. To learn the first principle of heredity, we shall study one of the experiments in crossbreeding which Mendel performed in his work with garden peas.

Mendel's experiments with the garden pea. There were several reasons why Mendel selected the garden pea as the basis for his experiments on heredity. Other investigators had tried pigeons with little success because their inheritance was so complicated that no definite conclusions could be drawn. But Mendel had noticed that garden peas differed in certain definite characteristics. Some plants were short and bushy, while others were tall and climbing. Some produced yellow seeds, some green seeds; some had colored flowers, some white. Altogether, Mendel discovered that garden peas differed in seven principal respects. Furthermore, he found that the characteristics of any one kind of pea were preserved in generation after generation because the plants normally carried on self-pollination. However, cross-pollination could be performed easily by transferring pollen from the stamens of one plant to the pistil of another. With seven different characteristics to follow, and cross-pollination easy to perform, Mendel had selected an ideal subject for the demonstration of basic principles of heredity.

His first task was to determine whether the seven different characteristics which he had observed were always carried from parent to offspring. To establish this fact, Mendel collected plants of all types and arranged them in his garden. He collected seeds from each different type in order to establish a second generation. The second generation proved that the seven characteristics he was considering were transmitted from parent to offspring. Tall plants produced other tall ones and those with yellow seeds produced others with yellow seeds. He called each of these characteristics " pure " because they were carried from one generation to another.

Mendel illustrates the Law of Dominance. The next step was to determine what would happen if two plants with contrasting characters were crossed. Accordingly, he selected one tall parent and one short one. He took pollen from the tall one and placed it on the pistil of the short one. When the seeds matured on the short plant, he sowed them to determine the results of his cross. Would they be short like one parent, tall like the other, or of medium height, with characteristics of both? He discovered that all of the plants were tall, like the plant from which he had taken the pollen in making the cross. His next step was to determine if it made any difference which plant was used for pollen and which was used to produce seeds. Accordingly, he reversed the process of pollination, using a short plant for pollen and a tall one for seed production. The results were as before — all of the second generation were tall.

Mendel then proceeded with experiments involving other characters. He crossed plants which had yellow seeds with varieties which had green seeds and found that all of the second generation had yellow seeds. Similarly, he found that round seeded varieties crossed with plants with wrinkled seeds produced a generation with round seeds. These experiments were repeated until all seven characters had been tested. Then, he drew his first conclusion. One character *dominated* over the other. The offspring resembled *one* of the parents but not both. In drawing this conclusion, Mendel established the first of his famous laws of heredity, the *Law of Dominance.*

Mendel called the trait that appeared in the first generation of offspring the *dominant* trait and the one that seemed to be lost, the *recessive* trait. In keeping track of his generations of crosses, he designated the parent generation in which the characters were *pure* as P. The second generation, resulting from the cross, he called F_1, which stands for *first filial.* The individuals in the F_1 generation appeared like the parent possessing the dominant characteristic. Actually, however, they were not identical. The plants of the second generation were not *pure* tall because they had been crossed with a short parent. Rather, they were *hybrid* tall peas, as we shall discover in referring to another of Mendel's experiments.

The table on page 588 shows the results of Mendel's crosses of parent plants with

The Seven Pairs of Contrasting Traits	Dominant Trait in Offspring (F_1 Hybrids)
1. Round seeds, wrinkled seeds	Round seeds
2. Yellow seeds, green seeds	Yellow seeds
3. White seed coat, colored seed coat	Colored seed coats
4. Inflated pod (unripe), constricted pod	Inflated pod
5. Green pod, yellow pod	Green pod
6. Axial flowers, terminal flowers	Axial flowers
7. Tall stem, short stem	Tall stem

each of the seven sets of contrasting characters with which he established the Law of Dominance.

Mendel experiments with hybrid tall peas. Having produced tall peas as a result of crossing pure tall and pure short parents, Mendel's next step was to determine what would happen if he crossed two of the F_1 hybrid tall peas. Would they produce all tall plants like the pure tall parent, or would the recessive character for shortness again appear? To determine this, he selected two F_1 hybrid tall plants, cross-pollinated them and planted the seeds to establish another generation which he called F_2. The results of this cross were quite striking. Some of the plants were tall, while others were short. None were intermediate. Furthermore, ¾ were tall, while only ¼ were short. He later found that ¼ of the plants were pure tall and always produced tall plants when crossed with each other, ½ were hybrid tall, and ¼ were short. Exactly the same results were obtained in crossing hybrids showing other traits. The yellow peas which had been produced by crossing pure yellow and pure green, when crossed with each other, produced peas which were ¼ pure yellow, ½ hybrid yellow, and ¼ pure green.

This sorting out and reappearing of the seemingly lost recessive trait in the offspring of hybrids Mendel called *segregation*. The principle is referred to as the *Law of Segregation*.

The chart and table below illustrate the laws of *Dominance* and *Segregation*, based upon Mendel's crossbreeding of tall and short peas.

In the study of genetics, special charts resembling checkerboards are used to determine the results of various crosses. Mendel's work with tall and short peas may be made very graphic by diagraming his various experiments.

You will recall that chromosomes are always present in pairs and that each parent contributed one of each pair. In dealing with tallness and shortness in peas, Mendel was actually concerned only with one pair of genes. If we let the letter *T* stand for a gene for tallness, a

Table to Illustrate Dominance and Segregation

Parents	Pure tall	Pure short	
F_1 Generation	Tall hybrids		
F_2 Generation	¼ pure tall	½ tall hybrid	¼ pure short

pure tall plant would be written *TT*, indicating that both of its genes for this character were tall. The capital *T* indicates that tallness is dominant over the contrasting character, shortness. In like manner, *s* may stand for short, and a pure short individual would be designated as *ss*. While all of the body cells contain full sets of chromosomes and genes, you remember that reduction division occurs only during the formation of sex cells. Consequently, the egg cell in the pea ovule and the sperms formed from the pollen grain have only one gene for each character. When eggs or sperms are formed by a pure tall pea plant, one sperm receives one *T* and the other receives the other *T*. In like manner, the *ss* genes present in all of the body cells are separated in reduction division to *s* and *s* in the formation of eggs or sperms. Therefore, a cross between pure tall, *TT* and pure short, *ss*, may be diagramed as follows:

TABLE TO SHOW RESULTS OF CROSSING *TT* AND *ss*

Female→ Genes Male ↓	*s*	*s*
T	*Ts*	*Ts*
T	*Ts*	*Ts*

All of the offspring are hybrids, with a gene for tall, *T*, and a gene for short, *s*. They appear tall, however, because tall is dominant over short.

If the *Ts* hybrids are bred together it is easy to see that four possible combinations of genes may occur.

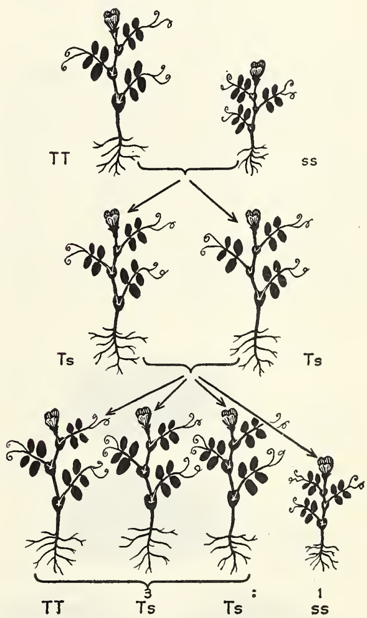
Egg with gene *T* may meet sperm with gene *T*
" " " *T* " " " " " *s*
" " " *s* " " " " " *T*
" " " *s* " " " " " *s*

Thus the chance combination of the genes of hybrid parents make it logical that the offspring should be ¼ pure dominant (*TT*), ½ hybrids (*Ts, Ts*), ¼ pure recessive (*ss*).

TABLE TO SHOW RESULTS OF CROSSING *Ts* AND *Ts*

Female→ Genes Male ↓	*T*	*s*
T	*TT*	*Ts*
s	*Ts*	*ss*

The same scheme explains the other ratios.



MENDEL'S LAW OF SEGREGATION. A tall pea crossed with a short one produces an F_1 generation in which all plants are tall. When these tall plants are crossed with each other, the plants in the F_2 generation will show the ratio of three tall to one short.

Table to Show Results of Crossing *TT* and *Ts*

Female→ Genes Male ↓	*T*	*s*
T	*TT*	*Ts*
T	*TT*	*Ts*

Table to Show Results of Crossing *Ts* and *ss*

Female→ Genes Male ↓	*s*	*s*
T	*Ts*	*Ts*
s	*ss*	ss

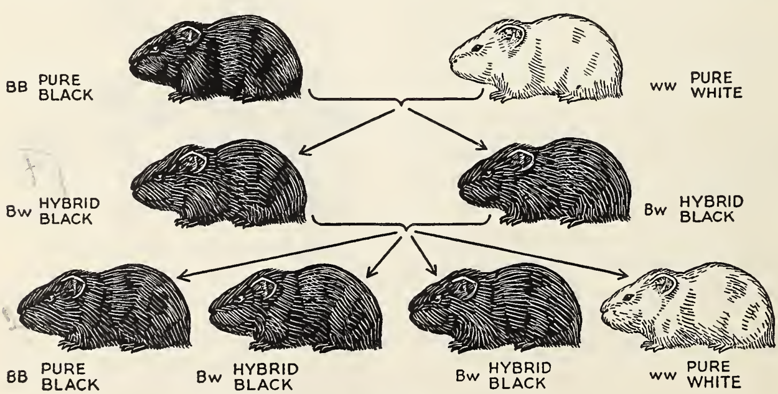
Dominant and recessive genes in guinea pigs. The same results Mendel obtained in crossing tall and short peas are shown in the inheritance of color in guinea pigs. In this case, black is dominant over white. If a pure black guinea pig (*BB*) is crossed with a pure white (*ww*) one, all of the offspring in the F_1 generation are black. They differ in genetic make-up, however, in that they are hybrid blacks (*Bw*). When two hybrids are crossed, the F_2 generation will show a ratio of ¼ pure black (*BB*), ½ hybrid black (*Bw*), and ¼ pure white (*ww*). The cross between two hybrids of the F_1 generation to produce the F_2 generation may be diagramed as follows:

Table to Show Results of Crossing *Bw* and *Bw*

Female→ Genes Male ↓	*B*	*w*
B	*BB*	*Bw*
w	*Bw*	*ww*

The same applies to the crossing of rough and smooth-coated guinea pigs. In this case, rough coat is dominant over smooth coat.

Crosses involving two characters. Crosses involving two traits become much more complicated than simple crosses in which only one pair of contrasting characters is considered. The same principles apply, but the possible



Inheritance of Color in Guinea Pigs

gene combinations are increased. When two sets of characters are involved, the individuals possessing mixed genes for both characters are called *dihybrids*.

If a pea bearing round, green seeds (two unit characters) is crossed with a pea bearing wrinkled, yellow seeds, all members of the F_1 generation are round and yellow, the recessive characters of greenness and wrinkledness being overshadowed by the two dominant traits. The F_1 hybrids would all possess the genetic make-up *RwYg*, a gene for round (*R*) having come from one parent and a gene for wrinkled (*w*) having come from the other. In like manner, one parent supplied a gene for yellow (*Y*) while the other supplied a gene for green (*g*).

When two hybrid round, yellow peas are crossed the situation becomes more complicated. Each hybrid, with the genetic make-up *RwYg* may produce four kinds of eggs or sperms. During reduction, the pairs *R* and *w* and *Y* and *g* must separate and go into different cells. *R* may pair with *Y* to form *RY*, or *R* may pair with *g*, resulting in *Rg*. Similarly, *w* may pair with *Y* to form *wY* or with *g* to form *wg*. The nature of the offspring in such a cross depends upon which eggs and sperms happen to unite during fertilization. The possible offspring which may result from such a cross and the ratio of their occurrence may be diagramed as in the case of a single character, except that space must be provided for more possible crosses. The diagram above shows the result of such a cross, beginning with the parents one of which was pure round green (*RRgg*), while the other was pure wrinkled yellow (*wwYY*). You will note that all of the F_1 generation are alike, being hybrid round, yellow (*RwYg*). In the F_2 generation, however, four different kinds of individuals have been produced as follows:

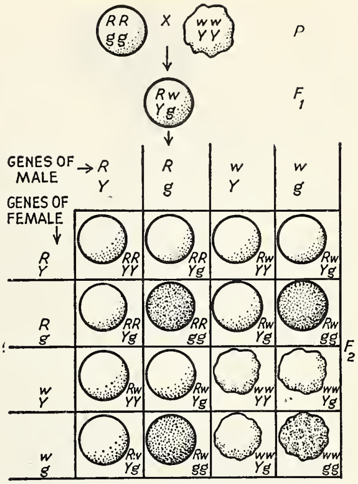


Table Showing Two Generations from Dihybrid Parents

Nine have seeds which are round and yellow (both dominant traits)

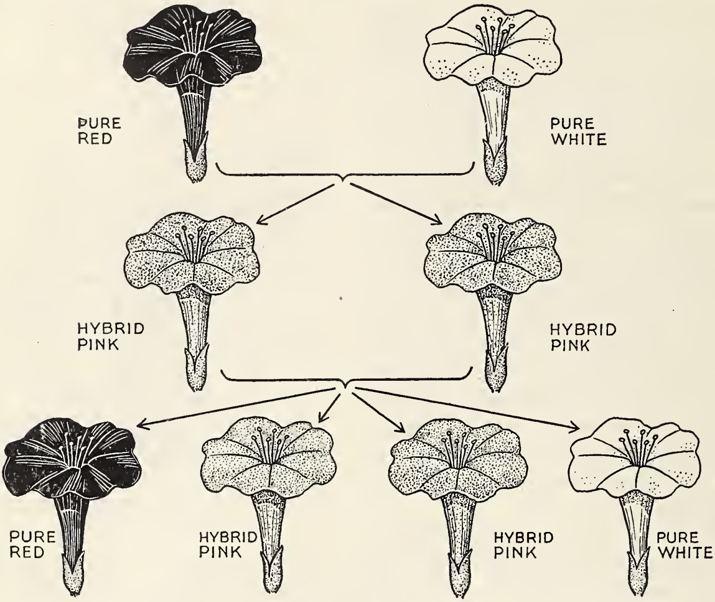
Three have seeds which are round and green (one dominant and one recessive trait)

Three have seeds which are wrinkled and yellow (one recessive and one dominant trait)

One has seeds which are wrinkled and green (both recessive traits)

You will note that yellow seeds may be either pure yellow or hybrid yellow; also that round seeds may be either pure round or hybrid round. The only case where a recessive character shows is when both genes for the recessive character are present. Both recessive characters appeared only once in the sixteen possibilities.

When hybrid black, rough-coated guinea pigs are crossed (black and rough are dominant), similar results are obtained. Nine are black and rough, three are black and smooth, three are



Inheritance of Color in Four O'Clocks

white and rough, and one is white and smooth.

Mendel's Law of Unit Characters. In working with more than one set of contrasting characters, involving more than one pair of genes, Mendel found that genes are units and that different genes bear no relationship to each other. For example, a pair of genes controlling color, as yellow and green in pea seeds, operates entirely independently of the genes which control tall and short or wrinkled and smooth. In other words, a pea which is hybrid for color but pure for tall (*YgTT*) will show a 3:1 ratio for color, when crossed, even though all individuals will be tall. Thus, the individual genes, and not the genes as a whole, illustrate dominance, segregation, and ratios of appearance. Mendel established this fact in his *Law of Unit Characters.*

Blended characters. *Genes* are not always dominant or recessive. In some cases, different genes of a pair may both appear in a blended character. This *blending* or *incomplete dominance,* as it is sometimes called, may be illustrated in crossing the flowers of four-o'clocks.

When pure red four-o'clocks (*RR*) are crossed with pure white (*ww*) varieties, all of the first generation are pink (*Rw*). Neither red nor white is completely dominant. The result is that both colors appear in the hybrid F_1 as a blend, which is pink. However, when two of these hybrid pink (*Rw*) flowers are crossed, the next generation includes ¼ red, ½ pink, and ¼ white individuals. The fact that red and white genes actually did not mix in the pink hybrid is indicated in the fact that both appear again as pure genes in the second generation.

SHORTHORN CATTLE. Red, roan, and white animals are shown in the picture.

In diagraming a cross between two pink (*Rw*) four-o'clocks as two hybrid tall (*Ts*) garden peas were diagramed, you will note that the results are the same. The ratio was 3:1 in the peas, rather than 1:2:1 as in the four-o'clocks, because of the complete dominance of tall over short.

Blending occurs in other kinds of crosses in the same manner as in four-o'clocks. In the case of the Andalusian fowl, which is a breed of chickens, a pure black mated with a white speckled produces offspring that are blue. When two blue fowls are crossed, ¼ of the offspring are black, ½ are blue, and ¼ are white speckled. Similarly, the color in shorthorn cattle is inherited in this manner. A pure red animal crossed with a pure white results in a mixture of red and white called *roan*. When two roans are crossed, ¼ of the offspring are red, ½ are roan, and ¼ are white, illustrating the same 1:2:1 ratio.

Ratios are averages. The ratios in heredity are averages and not fixed numbers. They are accurate only when large numbers of individuals are considered. For example, two roan shorthorns bred four times will not necessarily produce one red calf, two roan ones and a white one. Similarly, two hybrid black guinea pigs will not always produce one pure black, two hybrid blacks and one white. If only four eggs and four sperms were involved in the process, the ratio would work out. But, actually, the eggs may be fewer or greater than four in number and the sperms are usually many thousands in number. Thus, it becomes a matter of chance as to how the eggs and sperms will unite during fertilization.

Chance ratios may be best illustrated with two coins. If you flip two coins, they will light in three possible combinations: two heads, one head and one tail, or two tails. There is twice the chance of one head and one tail appearing as two heads or two tails. Consequently, if you flip them a great many times, they should appear in a ratio of 1 (two heads): 2 (one head and one tail): 1 (two tails). The exact ratio will appear, however, only after the coins have been flipped a great number of times.

Application of Mendel's laws to other organisms. In 1900 when Mendel's laws were rediscovered, scientists began to experiment with other organisms to see if the laws were universal in their application. Professor E. C. Castle of Harvard University found that they applied to guinea pigs, in the manner we have referred to them in this chapter. The late Professor T. H. Morgan of the California Institute of Technology did extensive work with small fruit flies, belonging to the genus *Drosophila,* and discovered that the laws also applied to them. For example, he found that when he crossed purebred, winged flies with wingless varieties all of the offspring had wings. Similarly, gray bodied individuals crossed with black bodied ones produced gray bodied hybrids. Since his work with fruit flies, this tiny insect has been the subject of more study of inheritance than any other organism.

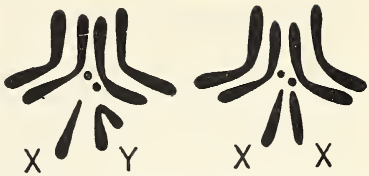
Other scientists have worked with numerous traits of plants and animals, and the universality of the Mendelian laws is beyond question. There is overwhelming evidence that in humans, too, inheritance of traits follows the Mendelian laws. Because of the impossibility of experimenting on humans, the difficulty of finding purebreds and of knowing what traits are the contrasting ones, the limited number of offspring, and the

Organism	Dominant Trait	Recessive Trait
Corn	Yellow grain	White grain
"	Black "	Yellow "
Tomato	Tall stem	Short stem
"	Spherical shape	Oval shape
Wheat	Late ripening	Early ripening
"	Susceptibility to rust	Immunity to rust
Fowls	Black plumage	Yellow plumage
"	Crest	No crest
Cattle	Hornless	Horned
"	Black coat	Red coat
Horses	Trotting	Pacing
Human	Brown eyes	Blue eyes
	Curly hair	Straight hair
	Normal fingers	Fused fingers
	Normal digits	Extra digits
	Normal growth	General dwarfing
	Normal pigmentation	Albinism
	Normal sight	Color blindness
	Normal mentality	Feeble-mindedness
	Normal hearing and speech	Deaf-mutism
	Normal sight	Blindness at birth

long period of youth, information concerning human inheritance is of a less definite character than for other organisms. The table on page 594 lists some of the observations which have been made concerning characteristics of various organisms.

Determination of sex. Formerly it was thought that diet or other special treatment might produce the desired male child to continue the royal line or be a warrior for his clan or country. Many people still believe that the sex of a child may be controlled by thoughts during its development or by some other means. Sex is determined at the time fertilization occurs and cannot be altered. This is demonstrated by the fact that identical twins, which began life as one individual, but became separated in the two-celled stage, are always of the same sex.

Determination of sex is purely a chance union of sperm and egg. Actually, it is determined by the sperm alone. The chromosome arrangement in the cells of females is like that of males except that the male usually has one less chromosome than the female. Two of the chromosomes of the cells of females are called *X* chromosomes. The cells of males, however, have only one *X* chromosome. Sometimes they also have what is called a *Y* chromosome. When egg mother cells form eggs in the female, reduction of the chromosome number occurs by meiosis and each egg cell receives one *X* chromosome. Similar reduction occurs when sperms are formed. Since the sperm mother cells contain but one *X* chromosome, half of the sperms will receive an *X* chromosome while the other half will lack the *X* or, in some species, will receive the *Y* chromosome. If the egg is fertilized by a sperm with an *X* chromosome, the fertilized egg will



Sex Chromosomes of *Drosophila*. In the fruit fly, *Drosophila*, there are two groups of sex chromosomes. The sex cells of the female (right) include two straight X chromosomes. The sex cells of the male (left) have one straight X chromosome and one bent Y chromosome. In mating, combinations of XX chromosomes produce females; combinations of XY chromosomes produce males.

have two *X* chromosomes and will be female. If, however, the sperm happens to be lacking an *X* chromosome, the fertilized egg will be male. Thus, the nature of the chromosome make-up of the sperms alone determines the sex of the individual.

Sex determination may be shown easily by means of a diagram.

Female→ Chromosomes Male ↓	*X*	*X*
X	*XX*	*XX*
Y	*XY*	*XY*

Under certain unusual conditions, sex may be altered by stimuli called *primary sex determiners.* Destruction of an *X* chromosome would certainly determine sex. Sometimes chemical changes occur in the egg due to variations in temperature, nutrition, or other causes which affect an *X* chromosome, and thus change the sex. Occasionally sex reversal occurs in animals during embryonic development, or even later, due to changes in the sex glands or variations in hormone production. These instances are, however, quite rare.

Sex-linked characters. Certain characters seem to be carried in the *X* chromosome by means of genes which are recessive in the presence of a normal *X* chromosome. These characters may be carried in a female without appearing because only one of the *X* chromosomes is carrying the gene. In the male, however, such a gene causes a characteristic to appear because only one *X* chromosome is present. Color-blindness, baldness, and "bleeder's disease" or hemophilia are examples of sex-linked characters. They appear much more frequently in males than in females. These sex-linked characters of the human race will be discussed more fully in Chapter 57, dealing with the applications of heredity to the human race.

Mutations. Occasionally an offspring appears with a characteristic which was not inherited, but which will be passed on to future generations. This strange occurrence is called a *mutation*. The individual possessing the mutation is called a "sport" or a *mutant*.

One of the most common forms of mutation is illustrated in albino organisms, which are entirely lacking in color. Apparently the genes for color were destroyed or altered in such a manner that they do not function. This characteristic will remain and will be passed on to new generations, although it may not reappear immediately because it is a recessive character.

Albino animals are always white and have pink eyes. The white body covering is normal except that it lacks any pigmentation. The eyes, likewise, are normal but lack coloring in the iris. You have seen albinos in the form of white rabbits, white rats, and white mice. All of these animals, if they are true albinos, have pink eyes. In addition to these common forms which are well known, albino squirrels, woodchucks, raccoons, deer, robins, sparrows, and other kinds of animals have been found, although they are very rare. Albino humans are characterized by having very light skin, pure white hair, and pink eyes.

Other mutations have occurred from time to time in cattle. Occasionally a calf of a horned breed is born without horns. From such mutations, hornless or polled breeds have been developed, including the Aberdeen-Angus and polled shorthorn. Other mutations include tailless dogs, and hogs with "mule feet" or single hoofs rather than normal split hoofs.

The exact cause of a mutation is not clear. It may be due to the number or arrangement of genes in the chromosomes. Another cause is the increase in chromosome number. Mutations have been found in which the chromosome number has doubled. Occasionally genes are destroyed or are altered in their chemical nature, resulting in a mutation.

Scientists have caused mutations experimentally by means of X rays and radium treatment upon chromosomes. Certain chemical preparations have also been used to double chromosome numbers and to produce a mutation. This field of research in heredity may produce many interesting new varieties in the future.

Lethal genes. Occasionally charactertеristics appear which result in death of the organism. For example, geranium and corn seedlings have been discovered which are entirely lacking in chlorophyll. Normally, they could not live because the lack of chlorophyll means, also, lack of the ability to make food by photosynthesis. However, if such colorless seedlings are woody and can be grafted to normal plants as in the case of the geranium, food may be obtained and the colorless plants may even bloom. This lethal character has been proved always to be recessive.

Other lethal characteristics have been found in animals. When they appear, usually during its period of development, the animal dies suddenly. The characters are transmitted as recessive characters and appear only when both parents are carrying recessive genes for the character and the offspring happens to receive a recessive gene from each parent.

Lethal characteristics have been discovered in mice, in chickens, in swine, and in certain breeds of cattle. Particularly, the English breed known as the Dexter-Kinney is susceptible to lethal factors.

Summary

Gregor Mendel established the laws of heredity in his brilliant work with garden peas. He discovered that purebred tall peas crossed with purebred short varieties produced a generation of tall plants. In checking six other contrasting pairs of characters in peas he found that the same principle applied; one character was dominant while the other was recessive. From these conclusions, he formulated the Law of Dominance.

When two hybrid peas were crossed, recessive characters reappeared in the second generation. This principle led to the formulation of the Law of Segregation. Mendel found, also, that individual genes are not influenced by other genes and that they always function as units. Upon this discovery, he based the Law of Unit Characters.

Mendel's work has served as the basis for the modern science, genetics. Other investigators have applied Mendel's laws to many other organisms. They serve to explain the determination of sex, sex-linkage, and other phenomena of heredity.

Using Your Knowledge

1. Why does an organism always have a pair of genes for each characteristic?
2. Explain dominant and recessive genes.
3. Black is dominant in guinea pigs. Explain the difference between a pure black and a hybrid black.
4. When two hybrids are crossed, pure dominant, hybrid dominant, and pure recessive individuals appear. How does this illustrate the Law of Segregation?
5. Under what conditions does a 9:3:3:1 ratio of types of individuals appear?
6. Why may blending or incomplete dominance be said to be the exception that proves the rule?
7. Explain the determination of sex in terms of *X* and *Y* chromosomes.
8. Show how a mutation may be responsible for an entirely new variety of plant or animal.

Expressing Your Knowledge

Mendel	contrasting character	*Y* chromosome
dominant	dihybrid	determination of sex
recessive	unit character	primary sex determiner
Law of Dominance	Law of Unit Characters	sex-linked
purebred	ratio	mutation
hybrid	blended character	mutant
segregation	incomplete dominance	albino
Law of Segregation	*X* chromosome	lethal gene

Applying Your Knowledge

1. Diagram a cross between two hybrid rough-coated guinea pigs with the genetic make-up *Rs* and with rough coat (*R*) dominant over smooth coat (*s*). What percentage of the offspring will be rough-coated?

2. Make a similar diagram but follow two characteristics. For example, cross two dihybrid black, rough-coated guinea pigs (*BwRs*). Your diagram should include sixteen squares. The sperms and eggs should contain the genetic formulas; *BR, Bs, wR,* and *ws*.

3. To illustrate blended characters, cross a pure red (*RR*) shorthorn female with a pure white (*ww*) male. The first generation should be all roan individuals (*Rw*). Now cross two roan individuals and determine the character of the next generation.

4. Flip two coins fifty or one hundred times and keep track of the way they fall each time. See how near your results come to a 1:2:1 ratio.

5. Indicate the genetic make-up of eggs or sperms produced when three characters are followed in a hybrid pea (trihybrid). As an example, use a hybrid tall, round seeded, yellow seeded plant (*TsRwYg*). There are eight possible ways in which genes may combine when contrasting pairs are split in reduction.

6. Investigate your family line and see if you can discover any traits which seem to be dominant.

Chapter 56

Plant and Animal Breeding

Selective breeding of plants and animals is a practice much older than the science, genetics. For centuries, man has made a constant effort to improve the varieties of plants and animals which supply his daily needs. Wheat was grown as a cereal crop by the early Egyptians. Garden flowers, fruit trees, domestic fowls, sheep, goats, cattle, and many other plants and animals have been domesticated longer than man has recorded history.

Genetics originated, largely, to explain the phenomena which resulted from plant and animal breeding. Selective breeding was, and to a great extent still is, a practice of chance selection rather than scientific application of principles. With the development of genetics as a science, however, established laws have greatly improved the efficiency of the process. The modern farmer, horticulturist, and gardener can make use of many of the established principles of genetics in the development of new varieties and the improvement of old ones.

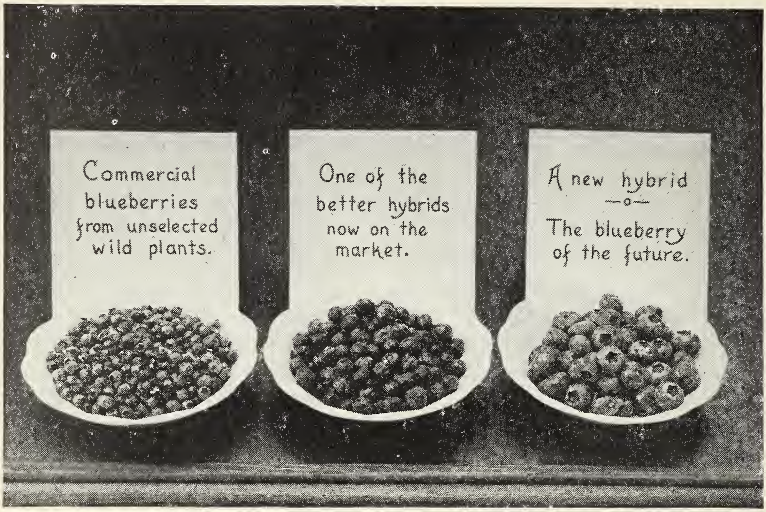
The laws of heredity when applied directly to plant and animal breeding are not always exact because of the extreme complexity of the inheritance of organisms. Not one or two, but hundreds of different characteristics are involved in each cross. Nevertheless, even a consciousness of the fact that genes are passed from one generation to another, that certain characteristics dominate over others, and that high quality offspring can be produced only from parents possessing the desired traits has brought tremendous improvement in the methods used in plant and animal breeding. One need only drive through the country and see the highly productive livestock, fields of grain, and orchards to appreciate the importance of a basic knowledge of heredity in the breeding of plants and animals.

Luther Burbank, the "wizard" of California. Plant breeding will always be associated with the genius and wizardry of Luther Burbank. Numerous, indeed, were the "biological miracles" wrought on his farm in California in the form of strange and different plants of Burbank variety.

Burbank's brilliant work in plant breeding began in the summer of 1873 in his native Massachusetts. While a young man, he was examining a crop of potatoes one day and happened to notice a fruit maturing on one of the plants. This was a rather unusual occurrence, for while the potato plant flowers, it seldom bears fruit. New plants are grown from cuttings made from "seed" potatoes rather than from actual seeds. Burbank saved the fruit and, when the seeds matured, planted each one in a separate hill. When the plants matured, he dug the potatoes from each hill and discovered that those from each plant were different. Some were large, some were small; some hills had many tubers, while others had but few; some were good quality, and some were poor. One hill had potatoes of far better quality than any of the others. These potatoes were large, smooth, and numerous. Burbank sold them to a gardener for $150 — his first profit from plant breeding. They were named Burbank potatoes in honor of their discoverer and were the first of a strain which was destined to become popular all over the country.

With the profit from his first achievement, Burbank bought a ticket to California, where he established a farm that was to make him famous. From his experimental gardens came such varieties as the Shasta daisy and a new strain of poppies. By combining various fruits, he produced the plumcot, pitless plum, "Primus berry," and the improved beach plum. Another of his famous developments is the thin-shelled walnut. The spineless cactus, which can be used as fodder for cattle, is still another of his achievements. Just before his death, Burbank was working on a grafting cross between a potato and a tomato which would bear fruit above the ground and tubers below the ground — a most profitable combination!

Objectives in plant breeding. The plant breeder has several purposes in producing new strains or varieties of plants. One of the chief objectives is the production of *more desirable varieties.* Such characteristics as large fruit, large and abundant seeds, vigorous growth, early maturation of fruit, large leaf area in leafy vegetables, and vigorous root growth in root crops are highly profitable. Plant breeders work constantly to improve the quality and quantity of the yield of all crop plants. In addition to the nature of the yield, resistance to disease is highly important. Plant breeders have been able to produce many varieties of *disease-resistant* crops. *Extension of crop areas* through the production of new varieties is another objective of the plant breeder. Wheat is a good example of the extension of crop areas through plant breeding. Varieties of spring wheat grow well in the northern section of the nation, while winter wheat favors the climate of the central states. Wheat growing has been extended even to the Great Plains with the production of va-



HYBRID BLUEBERRIES

rieties of hard wheat. In similar manner, other crops which were once limited to small areas because of climatic requirements or soil conditions have now been extended to many other regions in the form of new varieties.

By means of hybridization, entirely *different kinds of plants* have been developed. The hybrid may be the result of crossing two strains or varieties or two closely related species.

Several methods are employed to obtain these desired results in plant breeding, and in animal breeding as well. We shall consider some of these methods, first as they apply to plant breeding, and later to the production of improved varieties and new kinds of animals.

Mass selection. This method is widely used in obtaining desirable varieties or strains of both plants and animals. *Mass selection,* as the name implies, consists of the careful selection of parent plants from a great number of individuals. Burbank practiced mass selection when he discovered his famous potato. He selected the most ideal plant from all that he grew from seed. In like manner, the farmer who selects seed from his own corn, tomatoes, or other crop, always picks the most desirable plants for propagation. Thus, he takes advantage of natural variations which may occur. Many productive strains have been produced in this manner. By "weeding out" undesirable individuals generation after generation, the productive qualities of the strain are gradually increased.

Mass selection is important, also, in the production of disease-resistant strains of plants. To illustrate how mass selection operates in this respect, let us assume that a cabbage disease has swept into an area, resulting in the destruction of the entire crop. Field after field of cabbages lie victims of the disease. As we examine the acres of diseased plants, we find a single plant which, for some unknown reason, has withstood the dis-

Disease-Resistant Plants. The stunted, shriveled appearance of the diseased plants which the men are examining is in marked contrast with the disease-free plants in the background and foreground.

ease. We carefully preserve the seeds from this plant and sow them the following season. Disease again strikes the crop, but a few more plants remain than the year before. Again, we use these plants for the seed of the following season. Each year, more and more plants withstand the disease. The character of disease resistance, present in the original plant, is becoming more and more prominent in the offspring. Finally, an entire strain is developed in which this character appears. Cabbage has again become a crop in the disease-infested area due to our efforts in plant breeding.

Actually, this situation has occurred many times, and plant breeders have used these same methods in establishing disease-resistant varieties. Wilt-resistant asters bloom in flower beds and rust-resistant strains of wheat grow in fields where their ancestors died of disease. Perhaps some day, plant breeding will re-establish the chestnut tree on the eastern hills where its forests once thrived — before the blight.

Hybridization. *Hybridization* is similar, in many respects, to mass selection in that desirable hereditary traits are sought in new varieties. However, hybridization is a much more rapid method of obtaining the desired results than selection of natural variations. In hybridization, characteristics of two unlike but closely related parents are combined in one individual by artificial crossbreeding. In the production of a new hybrid strain, one parent might be selected because of vigorous growth; the other because of the quality of fruit or some other characteristic. Often, the hybrid possesses a characteristic not found in either parent. Another advantage of hybridization is the production of *hybrid vigor* in the offspring. Often the crossing of two varieties or strains of plants or animals produces a vigor not found in either parent.

Monkmeyer Press Photo Service

Line Breeding. A plant breeder produces seed from a pure line of the onion variety, Creole. For self-pollination, he ties small bags over the heads of certain plants. This keeps out the pollen from other plants.

Generations of hybrids must be watched carefully, for the combination of unlike characters may result in either desirable or undesirable traits. Undesirable characteristics are more inclined to appear than desirable ones. One thing is certain, however; the hybrid will be different from either parent. It then becomes a matter of mass selection to sort out individuals with desirable traits.

Most varieties and breeds of crop and garden plants and farm animals today are the results of artificial crosses between unrelated strains or varieties. The Concord grape, Baldwin and Jonathan apples, golden bantam, Ried's yellow dent and Leaming corn, red Fife wheat, and Duram wheat are a few of the varieties produced by means of hybridizing and mass selection.

Some of the most striking examples of hybrid plants in which entirely different species were used as parents include the Shasta daisy, produced by Burbank in a cross between a native ox-eye daisy and a European variety; the plumcot, which he developed by grafting a plum and an apricot; and the cross between the squash and the pumpkin.

Line breeding. After the desired characteristics have been obtained by selection or hybridization, it then becomes a matter of propagating these new and different individual plants. This is a simple matter when vegetative methods may be used, for vegetative multiplication in no way affects the hereditary make-up. Once Burbank had discovered his potato, propagation was simple. He used cuttings from the potato in order to produce more plants exactly like the parent. Had he been forced to grow more potatoes from seed the situation would have been entirely different. In the same manner, a new variety of apple, peach, iris, or rose may be multiplied by cuttings, grafting, or budding without altering the hereditary make-up.

In the case of plants like corn and wheat where seeds must be used for propagation, the problem is much more difficult. Seed production involves a mixing of numerous characters. Plants produced from seeds are not necessarily like the parent, especially when they are crop plants which have been crossed by man for centuries. This difficulty can be overcome only by generations of *line breeding,* the opposite of hybridization. Self-pollination is carried on to avoid introducing any new characteristics from a new parent. Seeds resulting from self-pollination are planted and all individuals of the new generation are carefully sorted. Only those with the desired characteristics of the parent are selected as seed plants for the next generation. Again, self-pollination is carried on, after which the resulting plants are carefully sorted. As this process is repeated, generation after generation, more and more seeds bear the desired characteristics. Finally, a hybrid strain which will be true to seed is established and is ready for the market. Even then all seeds may not produce the true hybrid characteristics, but these individuals can be sorted out readily.

Animal breeding. The principles used in plant breeding apply also to animal breeding. Mass selection has long been a method of producing highly desirable animal breeds. Today, we have numerous breeds of poultry which have been developed for different purposes. The Leghorn, for example, has been bred as an egg machine. All of its energies have been directed toward egg production rather than body flesh. The Plymouth Rock has been developed as a dual purpose fowl and is ideal both for egg production and meat. Large breeds like

Philip D. Gendreau, N.Y.

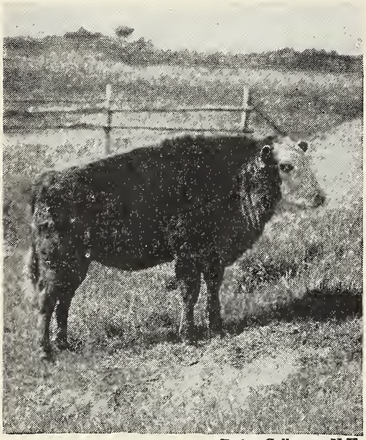
A 300-Egg Hen. This bird is the result of mass selection and line breeding.

the Brahma and Cochin are famous for their table value rather than for egg production.

Heavy laying strains of several breeds have been developed by keeping records of egg laying and using only high production females mated with males from high production strains. In this manner, strains with production records of over 300 eggs per year have been developed.

By the same methods, dairy and beef breeds of cattle have been developed. Beef breeds, like Aberdeen-Angus and Hereford are improved constantly for the nation's market. Only sires and dams with the most desirable characteristics are used for breeding purposes. In the case of dairy breeds, records of milk production are kept for all members of a herd. Cows with the highest records and the best characteristics of the breed are bred to sires produced from correspondingly good strains.

In animal breeding, the records of outstanding individuals used in breeding are kept in pedigrees and registra-



Ewing Galloway, N.Y.

THE CATTALO. The result of a cross between the bison and the cow.

tion papers. Purebred animals may be registered at the headquarters of their respective breed. Registration papers must include the names and numbers of the parents and part of the ancestry. In this manner, different strains of the same breed may be crossed without danger of introducing undesirable characteristics or losing existing good qualities.

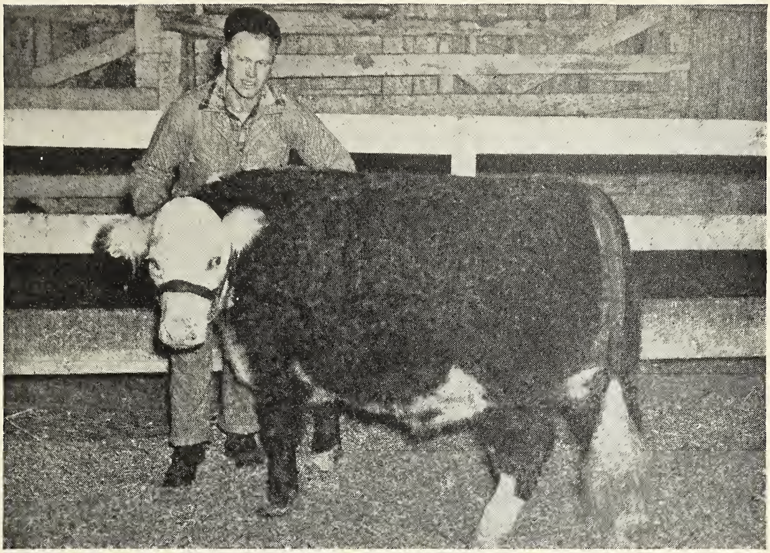
Hybrid animals. The term " hybrid " is used rather loosely in plant and animal breeding. It is frequently used to indicate crosses between different strains or varieties of the same species as, for example, hybrid corn. A true hybrid is the result of the crossing of two different species of plants or animals.

The mule is an example of a true hybrid animal. This useful animal is the result of crossing a female horse with a male donkey. It possesses some of the characteristics of one parent and some of the other. The size is inherited from the horse. From the donkey, it inherits long ears, sure footedness, great endurance, and the ability to live on rough food and to endure hardships. Thus, this product of artificial breeding has combined characteristics which surpass those of either parent.

Other hybrid animals include the cross between the Aberdeen-Angus and Hindu cattle which results in a black animal, somewhat like the Aberdeen-Angus but with the large size and shoulder hump characteristic of the Hindu cow. Another cross of true hybrid nature is the cross between the domestic cow and the bison (buffalo) with some of the characteristics of both animals. This unusual animal is called a *cattalo.* The cattalo might prove a useful range animal with great endurance, were it not for the difficulties in breeding it. The breeder of cattalo must raise both bison and cattle as parent stock for the cross.

Extension of plant and animal breeding. Plant and animal breeding is carried on in numerous centers today. Agricultural colleges and universities carry on extensive programs of education in which young agriculturists are acquainted with the most desirable varieties of crop plants and farm animals. Advanced students have the opportunity to do research in the development of new strains and varieties. The United States Department of Agriculture through numerous research laboratories and experiment stations is, likewise, carrying on extensive research programs in the field of plant and animal breeding. With the latest scientific equipment and the talents of leading investigators, interesting discoveries are made public each year, and new varieties of plants and animals are developed.

The high quality of crop plants and farm animals is maintained and improved, to a great extent, by the modern scientific farmer. Many such farmers gain extremely valuable experience



A Hereford Champion

while young in one of the many 4H clubs which are organized throughout the nation. In these young organizations, boys and girls learn the principles of plant and animal breeding, in addition to many other phases of farm life, and have an opportunity to enter their products in county and state fairs and 4H club shows. Many of the fine cattle, sheep, hogs, poultry, grains, fruit, and other products of the farm which attract so much interest at fairs and other agricultural exhibits are the results of application of principles of plant and animal breeding applied by young members of these worthy organizations.

Summary

The application of principles of heredity to plant and animal breeding has improved the methods used in producing more desirable varieties of plants and animals. The main objectives in plant and animal breeding include: improvement of existing varieties, production of disease-resistant strains, extension of crop areas, and development of new kinds of crop plants and farm animals.

Mass selection and hybridization are the principal methods used in obtaining new strains and varieties. When desirable traits have been produced, line breeding is practiced to hold the characters in the offspring, and self-pollination is used.

Plants and animals produced by crossing different parents are called hybrids. Usually, the parents are of the same species and differ only as to variety. A few "true" hybrids, involving parents of different species, have been produced. Plant examples include the Shasta daisy and plumcot, while animal examples include the mule and the cross between the domestic cow and the bison.

Using Your Knowledge

1. Explain how mass selection operates in producing disease-resistant strains of plants and animals.
2. Why is hybridization a more rapid method of developing new strains than mass selection?
3. Compare the processes of hybridization and line breeding as to both principle and practice.
4. Why, do you think, hybridization can be carried on only between varieties of a single species or, in some cases, closely related species?
5. Explain what is meant by "hybrid vigor."
6. Enumerate characteristics which a mule inherits from the horse; from the donkey.
7. Name three different agencies or organizations concerned with the improvement of plants and animals through the practice of scientific breeding.

Expressing Your Knowledge

Luther Burbank	hybridization	strain
disease-resistant	line breeding	hybrid vigor
crop area	species	4H club
mass selection	variety	experiment station

Applying Your Knowledge

1. Prepare a report on the life and work of Luther Burbank.
2. Select any hybrid plant, such as the plumcot, king orange, or Shasta daisy and see if you can obtain information explaining how it was produced by hybridization.
3. Consult a breeder of pedigreed dogs or other livestock and find out how line breeding is practiced.
4. Ask to see some pedigree papers of a pet animal and make a record of the information which appears. Explain how this information may be used in both line breeding and crossbreeding.

Chapter 57

Genetics Applied to Human Inheritance

It is rather surprising to observe that people, for the most part, pay much less attention to human inheritance than they do to the inheritance of their cattle and hogs, chickens and dogs, or corn and wheat. Yet, this condition can be explained easily. Each individual is born with an hereditary make-up which cannot be changed. He has no choice but to make the best of it. Furthermore, the heredity of man cannot be manipulated in the manner of plants and animals. A human life is too valuable to be used in scientific experiments to demonstrate phases of human inheritance. For these, and other reasons, science knows much less about the heredity of man than that of other organisms.

Even with these limitations, however, much attention has been given human inheritance in recent years. A specialized branch of genetics called *eugenics,* dealing with human inheritance, has become an organized science. Today, knowledge of human inheritance is of tremendous importance to society as a whole.

This chapter will acquaint you with some of the principles and a few of the problems of human inheritance.

Sir Francis Galton, the founder of eugenics. Eugenics dates it birth to 1883, when Sir Francis Galton, an English scientist, pointed out the need for such a science. He even gave it the name, eugenics, which means, literally, "good birth." Galton himself defined it as "the science which deals with all influences that improve the inborn qualities of a race."

He studied the family records of a large number of English families and concluded that mental ability, scholarship, moral strength and weakness were subject to heredity just as were physical traits such as size and eye color. He based these ideas upon the results of numerous case history studies and upon investigations he had conducted in the field of heredity. Today, we know that many of Galton's ideas were incorrect since he did not have the benefit of Gregor Mendel's work. It is interesting to note that during the period of Galton's investigations, Mendel had completed his experiments and had published his brilliant paper. But his publication was lying unnoticed in the files of the Natural History Society at Brünn.

While Galton was mistaken in some of his conclusions concerning human inheritance, he was correct in others. His work resulted in the birth of a new science, which has grown remarkably since his time. In the United States today, several organizations are carrying on extensive investigations in the field of heredity and eugenics. One of the most famous is the laboratory and record office at Cold Spring Harbor, Long Island, New York. This institution was established in 1904 by Dr. Charles Benedict Davenport, one of the most famous of American eugenists. It is interesting to note that Davenport's interest in the study of heredity began with a lecture given by Galton at Harvard University, where Davenport was a student. Davenport served as director of the Cold Spring Harbor Laboratory from its beginning in 1904 until his retirement in 1934. In addition to this famous organization, the American Genetic Society in Washington, D. C. and other organizations are active in research in the field of eugenics.

The nature of human heredity. The heredity of man is essentially like that of any other organism. Characteristics of the human race are carried by genes which are borne in forty-eight chromosomes present in every cell. Furthermore, the genes are always paired in the same manner as chromosomes are paired, a pair of genes concerned with a particular characteristic being located in identical places on corresponding chromosomes.

Human inheritance is difficult to trace, however, for several reasons. For one thing, human characters are frequently not controlled by a single pair of genes as were color in guinea pigs and tallness and dwarfness in peas. In the human eye, for example, two colors seem to be involved. The infant's eye is blue, but in many individuals a brown layer appears later, resulting in a change in eye color. It seems that the number of genes for brown present determine the shade of the eyes. They may range from deep brown, through shades of hazel and greenish-blue to pure blue. This would indicate the presence of numerous genes, all exerting an influence upon the color of the eyes.

Similarly, skin color in the human race is controlled by several pairs of genes. In the case of crosses between members of different races, one color does not dominate over another. Genes for different colors result in blending. The fact that many genes are involved in the same characteristic is indicated in the number of color shades between the pure color of one race and the pure color of the other.

Another complicating factor in human inheritance is the fact that most people derive from very mixed ancestry. This means that few, if any, characters are pure. It is, therefore, almost impossible to trace any one characteristic through a family. Each time a marriage occurs, two families of entirely different genetic background are combined in the offspring. While this practice has made the study of human inheritance difficult to follow, it has been extremely healthy for the human race. Most undesirable characters are recessive and are not apt to appear in two unrelated individuals. However, when two closely related individuals combine their characters, the offspring is likely to receive two recessive genes for an undesirable character due to similarity in genetic make-up of the parents. This condition was illustrated in certain of the ruling families of the Middle Ages. Marriages between first cousins were not uncommon as a means of preserving royal blood lines. Undesirable recessive traits appeared frequently in the forms of body defects, low vitality, and mental defects. From the standpoint of eugenics, marriages with peasant folk would have improved tremendously the kings and queens of that era. The fact that man is hybrid in nearly all of his characters may explain why the human race becomes better with each generation and is not inclined to be static in the manner of the pure line animal species.

Methods of studying human inheritance. In addition to the genetic complexity of the human race, other problems add to the difficulty in studying human inheritance. Mendel was able to trace the inheritance of peas through many generations within a few years. Other investigators have used fruit flies and guinea pigs since their life is short and many generations can be obtained in the space of two years. But any one individual may observe three or not over four generations of any one family in his lifetime. Many times that number of generations would be required to demonstrate the principles governing human inheritance.

For this reason, the eugenist must resort to case history studies to determine inheritance in a family. Eugenics is a young science, and a case history soon outdates the science itself. Observations which were recorded concerning individuals of several generations ago may or may not have been scientific. Thus, much of the data obtained in this manner may be unreliable.

Much light has been thrown upon the study of human inheritance through the study of *identical twins*. There are two distinct types of twins. *Fraternal twins,* the more common type, are two entirely different individuals. They developed from separate eggs, which were fertilized by different sperms. They are no more closely related than brothers or sisters. But *identical twins* are the same individual in duplicate. They started life as a single fertilized egg. During

Wide World Photos

IDENTICAL TWINS

early development, for some reason, the cells separated and grew into two individuals. Having begun life as one individual, their genetic make-up is identical. Thus, similarities in identical twins would indicate characteristics controlled by genes. These individuals show marked similarity not only in physical appearance, but in such characteristics as temperament, aptitudes, likes and dislikes, and many other personality traits.

Heredity and environment as influencing factors have been studied in the case of identical twins who, for some reason, have been separated at birth or at a very early age. Even when they are reared in completely different surroundings they continue to remain like each other in certain respects, even though environment, naturally, causes certain obvious differences. It has been concluded that such twins remain more like each other than they differ from each other.

Can acquired characteristics be inherited? Man, more than any other organism, adjusts his life to his surroundings. High mentality makes these adjustments possible. The complex nature of human society requires that each individual develop his inherited abilities in the form of trades, skills, and professions. One may become a lawyer, a doctor, a musician, a carpenter, or a mechanic as a result of a long period of training and practice. The question is whether these acquired skills are transmitted to the offspring in any degree. To answer this question, we must examine very carefully the nature of the skill. Certain individuals inherit tendencies which lead them toward a particular kind of activity. Musical ability is probably inherited, but a musician is the product of long hours of practice. Only the inherited or native ability may be passed on to the next generation. If such an ability is inherited and, for

Press Association Inc.

Six Fingers. This characteristic is inherited, and is due to two recessive genes bearing this characteristic. When both genes occur in the same individual, the trait also appears.

some reason, is never developed further during life, the same ability may be transmitted to the next generation. If, on the other hand, the individual uses his inherited ability to become a great musician, he will have in no way improved the inheritance of his children in that respect. In like manner, the acquired skills of great lawyers or expert mechanics cannot be passed on to the next generation, although certain inborn characteristics which had an important influence upon the success of these individuals may be passed on.

Can a child's heredity be changed during development? You have, no doubt, heard of cases where a child was supposed to have been "marked" because of some occurrence during the period of its development. Such episodes are entirely without scientific basis. Thoughts and emotional upsets of the mother can in no way alter the heredity of the child. This heredity was determined with the union of the egg and sperm prior to development and cannot be altered in any way except in rare instances where genes may become diseased. These changes would have occurred long before the mother was aware that she was to bear a child.

Inheritance of desirable and undesirable traits. We have mentioned certain traits which are known to be inherited in the human race. Among these are eye color, size, and skin color. Other physical traits include hair color, the length of the limbs, shape of the hands, finger length, facial features, and other factors determining the form of the body. In addition to these physical traits, there is evidence that personality traits, native intelligence, and aptitudes are likewise inherited. These characteristics are much more difficult to determine and, therefore, to trace than physical traits.

Finger deformities, including extra fingers, fingers grown together, and fingers with missing joints tend to run in families. Other undesirable defects include blindness from birth and deaf mutism. These characteristics are carried by recessive genes. Thus, they may be carried from one generation to another without appearing, as long as a normal gene is present. Only when two recessive genes bearing one of these characters are present does the trait appear. The chances of this happening are small, unless marriages occur between closely related individuals.

Sex-linked characters in the human race. Certain *sex-linked* characters appear more frequently in the human race than other undesirable traits, especially in males. These characters are called sex-linked because they are carried on the *X* chromosome which functions, also, in the determination of sex.

Color blindness is such a characteristic, appearing much more frequently in males than in females. The gene for color blindness is carried in an X chromosome, but is recessive to a normal gene in another X chromosome. Thus, a female may carry a gene for color blindness (X') on one chromosome and a normal gene on the other (X). Such an individual ($X'X$) will not possess the character, but will transmit it to offspring. In the case of the male, however, only one X chromosome is present. Hence, a single color-blind gene combined with a Y chromosome in which no gene for the character is present ($X'Y$) will produce the defect.

Inheritance of color blindness may be demonstrated by means of diagrams. The following diagram shows how a female parent, carrying a gene for color blindness but not showing the trait, may produce color-blind sons even though the male parent is not color-blind.

Female→ Sex chromosomes Male ↓	X'	X
X	$X'X$	XX
Y	$X'Y$	XY

The ratio in such a cross will be one female carrying color blindness; one normal female; one color-blind male; one normal male.

If a color-blind male is crossed with a normal female, color blindness will not appear in any of the offspring, although all of the females will carry the trait as a recessive gene. This cross is diagramed at the top of the page.

Female→ Sex chromosomes Male ↓	X	X
X'	XX'	XX'
Y	XY	XY

By diagraming a cross between a color-blind male and a female carrying a recessive gene for the character, you will discover how color blindness may appear in a female. Similarly, a color-blind female crossed with a normal male will produce all color-blind males, but no females showing the trait, although all are carrying it. Two color-blind individuals will have all color-blind offspring.

Baldness seems to be another sex-linked character. It appears frequently in males, but is very rare in females.

Hemophilia [*heem oh fill'ia*], or "bleeder's disease," operates in the same manner as color blindness. Hemophilia is much more serious than either color blindness or baldness. Consequently, its appearance in families must be checked most carefully.

Hemophilia is the result of an inherited abnormality in the character of the blood. Normally, blood will clot when it is exposed to the air in a wound. Clotting causes formation of a scab which halts the flow of blood through severed blood vessels. But the blood of a hemophiliac does not clot properly, and bleeding may continue for a long period of time. Death from loss of blood may occur as a result of serious wounds.

Hemophilia tends to run in families and to appear in males. There is little possibility of the disease appearing in females, although they may transmit the disease to new generations of males. Hemophilia can appear in a female only when the father has the disease and the mother happens to be the daughter of a man who is also a bleeder. It is unlikely that such a marriage would occur, especially since both individuals would realize the circumstances.

Hemophilia has been prominent in certain of the royal families of the past. The Russian royal family, dethroned in the Russian Revolution, carried hemophilia, as did the royal family of Spain. In both cases, close marriages greatly increased the prevalence of the characteristic.

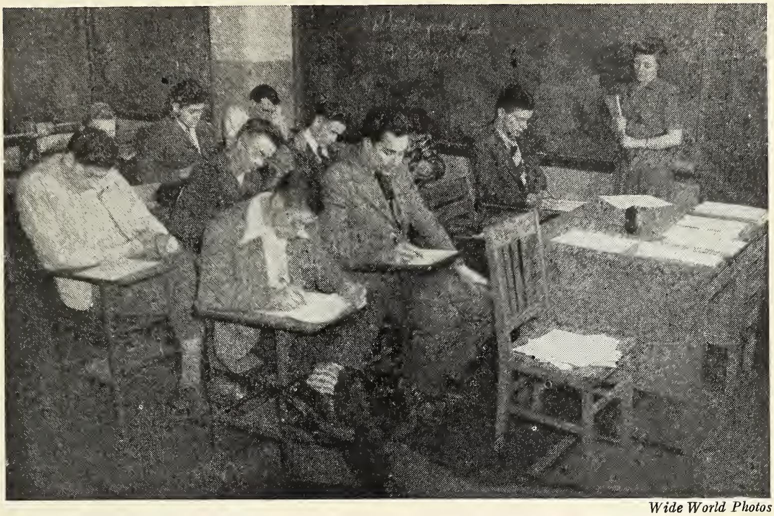
Inheritance of the Rh factor. One of the most recent applications of genetics to human inheritance is the discovery of the *Rh factor* in blood. The discovery of the factor itself, as well as the fact that it may be inherited, has explained several strange phenomena concerning childbirth.

Until recently, science has been unable to explain why certain infants died of a strange blood condition soon after birth, and why certain mothers lost all but their first born during the period of development. The answer to this strange occurrence was found in 1940 by two scientists, Landsteiner and Wiener, who were studying the blood characteristics of the *Rhesus* monkey. They discovered that the blood of a certain rabbit which had been immunized against blood from the *Rhesus* monkey contained a substance which would agglutinate (cause to clump) the corpuscles of eighty-five per cent of the people tested in the city of New York. This particular agglutinin was distinct from the common agglutinins referred to as *O, A, B,* and *AB* in the typing of blood.

Further investigations revealed that the blood of eighty-five per cent of all people contains a protein substance or *antigen* which has been called the *Rh* factor. Those persons who possess the factor are called *Rh positive;* those lacking it, *Rh negative.* The difficulty arises when *Rh* positive and *Rh* negative blood are mixed. The negative blood produces an antibody in the form of an agglutinin against the *Rh* antigen of the positive blood, much in the manner in which blood reacts against the products of bacteria with the formation of antibodies. This agglutinin causes the corpuscles of *Rh* positive blood to clump together or agglutinate. Thus, if an *Rh* negative patient receives *Rh* positive blood in a transfusion, his blood produces agglutinins against the *Rh* antigens present in the positive blood. His blood becomes sensitized against the *Rh* factor. The next transfusion involving positive blood will result in immediate agglutination of the added blood with serious reactions which may even cause the death of the patient.

Probably the most important application of the *Rh* factor is in regard to childbirth. When an *Rh* negative mother has a child who has inherited *Rh* positive blood from its father, she may produce agglutinins against the *Rh* factor of the child's blood, due to diffusion of small quantities of the child's blood into her circulatory system. For some reason, this seems to occur in only about five per cent of such blood combinations. If such a condition results, the first child is usually born before agglutinins in the mother's blood have been produced in a quantity sufficient to damage the child. However, a second child with *Rh* positive blood has little chance to survive until birth. Powerful agglutinins from the mother's blood diffuse into the child's circulatory system, causing agglutination, hemorrhage, anemia, and, usually, death during development or soon after birth.

The *Rh* factor operates as a dominant character in the human race. This accounts for the fact that eighty-five per cent of all people have *Rh* positive blood. If the mother is *Rh* negative and the father has both genes for positive factor, all the children will be positive. Under



Wide World Photos

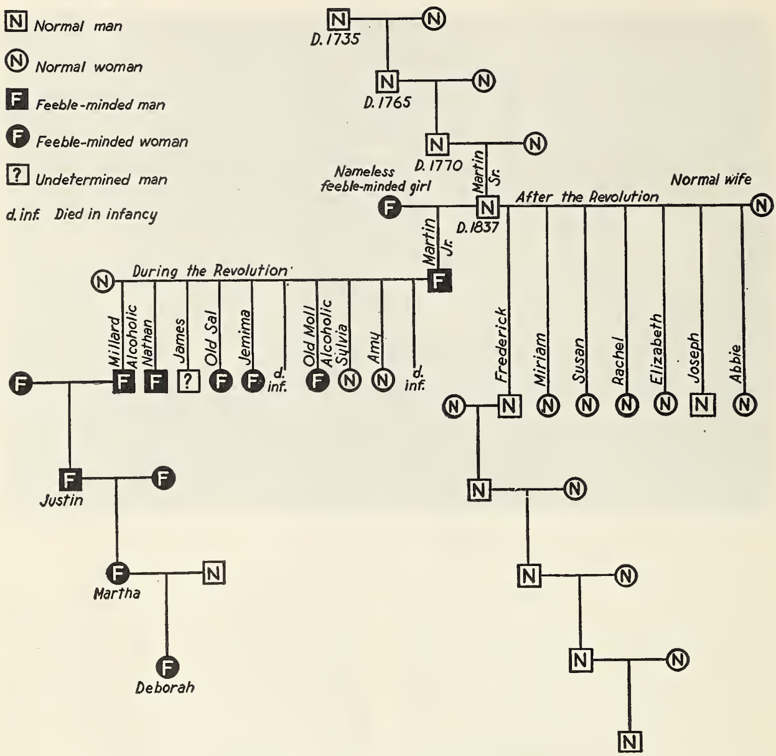
Group of Students Taking an Intelligence Test

these conditions, the mother's blood forms antigens against *Rh* positive blood during the development of her first child with the result that she can have only one child without serious danger. If the father has one *Rh* positive gene and one *Rh* negative gene, the child could inherit *Rh* negative blood.

Inheritance of mental ability. One of the most vital phases of eugenics is the study of inheritance of mental ability. This phase of the science is, also, one of the most complicated. For one thing, mental ability is extremely difficult to determine. Just how much of what we call intelligence is hereditary and how much is due to surroundings is difficult to determine.

One of the modern methods of determining mental ability is by the administration of tests. These tests, called *intelligence tests,* are intended to evaluate the mental processes of the individual in various manners. The score on the intelligence test is used to calculate the *mental age.* Intelligence is then determined by dividing the mental age by the actual or *chronological age.* The result multiplied by 100 is the *intelligence quotient,* or *I.Q.* A normal or average I.Q. is 100. Theoretically, this method is sound. Actually, however, it contains many flaws due to variable factors. The general physical and mental condition of the person taking an intelligence test may affect his mental processes temporarily. Slight illness or mental strain will invariably reduce the score. Furthermore, no test has yet been devised which will eliminate completely the effects of environment upon the individual. A child from a home in which excellent learning opportunities have been provided will always outrank a less fortunate child who has been deprived of these opportunities. In such a case, the I.Q.'s of the two children may vary widely, while actual inherited mental ability is the same.

The most reliable studies of inherit-



Inheritance in the Kallikak Family

ance of mental ability have been made concerning individuals of extremely high or extremely low intelligence. The caliber of these individuals lies beyond the control of environment alone. Genius cannot be acquired; nor can the lowest forms of intelligence as expressed in the idiot, the imbecile, or the feeble-minded.

One family in which extremely high intelligence has been traced through many generations is the family of Jonathan Edwards. Jonathan Edwards was a distinguished New England preacher who, later, became president of Princeton University. Needless to say, he was a fine, upright, intellectual man. His descendants in the year 1900 numbered more than 1,300 persons. Among this number were 100 clergymen, about the same number of lawyers, 295 college graduates, 65 college professors, and 13 college presidents. There were 60 doctors, 60 prominent authors, 75 military officers, 80 public officials, and 30 judges. Among this notable list were one vice-president, several senators, governors, foreign ministers, and eminent businessmen. So far as is known, no member of the whole six generations was ever convicted of a crime.

Many such examples have been traced through varying lengths of time. Such are the Lee family of soldiers, the

Ewing Galloway, N.Y.

CITY SLUMS

Hutchinson family of musicians, and the Lowells, noted for literary ability.

Families of inferior ability. Examples of opposite types of heredity are, unfortunately, not rare. In the notorious Juke (the name is fictitious) family, six generations numbering 1,200 persons have been traced. Of this number, 7 were convicted of murder, 130 were found guilty of other crimes, 60 were thieves, 310 professional paupers, and 440 immoral persons. Every grade of viciousness and idiocy was represented in the descendants.

Another family was traced and the results published by Dr. H. H. Goddard, who formerly directed the home for feeble-minded at Vineland, New Jersey. It is one of the cases which has now become internationally famous. It is the story of Deborah Kallikak (the name is fictitious) who was admitted to the institution in 1897 as a little, seven-year-old, feeble-minded girl. By a thorough investigation, her ancestry was traced for six generations and disclosed 480 members. Of this number, only 46 were found to be normal, while 143 were feeble-minded. Data concerning the other members was incomplete or lacking. The Kallikak family is especially significant because two groups of descendants have been traced to the same individual. Martin Kallikak was a soldier in the Revolutionary War. While a soldier, he had a son by a feeble-minded girl. From this feeble-minded individual, called Martin, Jr., the long line of feeble-minded individuals, including Deborah, descended. Society has paid and paid, and will continue to pay for this unfortunate occurrence.

After the war, the same soldier married a girl from a fine and respected family. From this marriage, 496 descendants have been traced. In no instance, has feeble-mindedness occurred.

Effect of environment on mental development. Statistics indicate that low-grade heredity was very prominent in both the Juke and the Kallikak families. What, do you suppose, was the environment of these families? What chance would a normal child have had in the sort of homes feeble-minded parents would provide? Probably many of the criminals of the Juke family could have become good citizens if their surroundings had been different. While feeble-mindedness cannot be corrected, children with normal intelligence may sink to become worthless individuals if they are forced to tolerate the squalor of the homes of these social outcasts. They soon become branded as low-grade and have little chance to improve their heredity through marriage with people of higher caliber.

Crime in America today presents a challenge to the biologist and the sociologist alike. Some criminals are victims of hereditary low-grade intelligence. Others are victims of poor environment. Most of these could have been saved from their criminal tendencies if the environment in which they grew up had been better. It is the responsibility of every citizen to see that he does his share in seeing to it that places which are natural hang-outs for criminals are done away with. Regardless of cause, the situation must be corrected. Slums are breeders of criminals and social misfits. We cannot afford to have them. The cost involved in eliminating slums is trivial, compared to the cost of maintaining institutions of confinement. In actual dollars and cents, we cannot afford to have slums. Normal individuals living under such conditions must be given a chance through education and betterment of living conditions. Those of low-grade mental ability who have settled to this lowest level of society must be provided for in decent surroundings. Improvement of environment is a problem we must face and face soon!

Summary

The name, eugenics, is applied to the phases of heredity dealing with human inheritance and the improvement of the human race. It began with the work of Sir Francis Galton and has grown into an extensive field of scientific investigation.

Because of difficulties in tracing human inheritance, most of the data concerning human inheritance has been obtained from studies of family histories. Certain characteristics have been observed in studies made of identical twins.

Many undesirable human characters are recessive, and do not appear in the presence of a normal gene. Usually, the appearance of such traits is avoided in the combination of unlike genes in the offspring of entirely unrelated parents. Sex-linked characters include color blindness, baldness, and hemophilia. Since they are carried on the *X* chromosome and are recessive to a normal gene, they are less likely to appear in females than in males. Another dominant character in the human race, only recently discovered, is the presence of the *Rh* factor in blood. This factor is present in the blood of eighty-five per cent of all individuals.

Mental ability appears to be inherited in man, although general intelligence seems to be influenced greatly by environment. Biological investigation reveals that this character involves the improvement both of the heredity and of the surroundings of the individual.

Using Your Knowledge

1. Account for the fact that many of Sir Francis Galton's ideas concerning heredity were not in accord with present knowledge of the science.

2. Explain how several pairs of genes may control one characteristic and give an example of such a character.

3. Distinguish between identical and fraternal twins and explain how the former are valuable in the study of heredity.

4. Distinguish between hereditary and acquired characteristics.

5. Explain, in terms of undesirable recessive characters, why marriages between closely related individuals should never be allowed to occur.

6. Explain the operation of a sex-linked character with an example.

7. If a child with *Rh* positive blood is born with serious anemia due to the reaction of the mother's antigens against its blood, would you administer *Rh* positive or *Rh* negative blood in an effort to save its life? Explain.

8. Describe the manner in which an I.Q. is determined.

9. What are some of the limitations in the present method of determining the I.Q.?

10. How could the figures obtained in the study of the Juke family be influenced by environment in addition to heredity?

Expressing Your Knowledge

eugenics	hemophilia	chronological age
Galton	*Rh* factor	I.Q.
Davenport	antigen	genius
undesirable character	*Rh* positive	idiot
identical twins	*Rh* negative	imbecile
fraternal twins	agglutination	feeble-minded
acquired character	mental ability	Juke
color blindness	intelligence	Kallikak
baldness	mental age	slum

Applying Your Knowledge

1. Prepare a report on the study of eugenics in the United States and include the activities of the center at Cold Spring Harbor, New York, and the American Genetic Society in Washington, D. C.

2. Make a study of eye color of the members of your class. Group all individuals as to eye color and determine the ratios of occurrence of each color.

3. Make a list of some of your own characteristics which you think are acquired rather than hereditary.

4. Prepare a similar list, but include characteristics of your parents or other close relatives.

5. Prepare a report on the improvement of certain areas in your own locality and explain how this action would greatly improve the living standards of the entire community.

6. Outline what you consider to be the best method of dealing with the significant and important problem of inherited mental deficiency.

Chapter 58

The Changing World of Life

This is a changing world. It changes from day to day, from year to year, and from age to age. Rivers deepen their gorges as they carry more land to the sea. Mountains rise, only to be leveled gradually by winds and rain. Continents rise and sink into the sea. Such are the gradual changes of the physical earth as days add into years and years combine to become ages.

During these ages, species of plants and animals have appeared, have flourished for a time, and then have perished as new species took their places. It is as though nature tried different schemes to provide a plant and animal population for the changing world. As surroundings changed, life also changed. When one race lost in the struggle for survival, another race appeared to take its place. We might liken these changes to the development of the automobile. Each model has its day when it represents the ultimate in mechanical perfection. But each year brings new developments to outmode all previous models. Perfection of yesterday is only a step toward tomorrow. A few old models continue to cruise on the boulevards, but their numbers are few compared with current super deluxes which stream past them.

Such has been the drama of life through the ages. Each period is marked by the prevalence of more perfect organisms. We, who represent the current "super deluxe" form of life, are fascinated by the story of life through the ages. We are not sure how certain parts of the story should be written. It is like a picture puzzle and we are hunting for pieces. Each piece fits somewhere, and each time a new piece is found the picture become clearer. The complete picture will be a map of the progress accomplished by changes.

Men have searched the earth for pieces of the puzzle. Some have been found in rock; others in telltale characteristics of living organisms. As the picture began to form, scientists offered various possible explanations for the story it told. A final interpretation can be made only when the picture is complete. This chapter will present several important pieces of the puzzle in the form of evidence gathered by scientists. You will study, also, several theories which have been offered to explain the changing world of life.

How old is the earth? This is a question that intrigues everyone. It probably doesn't matter too much, and certainly will never be settled. Scientists have expressed its age in rather staggering figures. We, who appear for only a brief scene in the total drama, are inclined to underestimate the length of time our planet has existed. We think in terms of ancient civilizations which actually flourished only yesterday when compared with the age of the earth.

There are several methods used by science in determining how long the earth has existed. For one thing, the rate at which materials are deposited to form *sedimentary rocks* can be measured. We can also measure the thickness of the layers of these rocks which build up the

Philip D. Gendreau, N.Y.

Ausable Chasm, N. Y. This is a perfect example of layers of sedimentary rock.

crust of the earth. Scientists have found that sedimentary layers are often ten miles thick. To form such a layer would require nearly two billion years. In such calculations, of course, a mistake of a million years or so is trivial! Whatever of its actual age, we may be sure that the earth is extremely old, that it has changed from age to age, and that these changes are continuing very gradually.

Evidence that living things have changed through the ages. Science has turned to various sources to obtain evidence that organisms have become more complex through the ages and that plant and animal populations have changed with time. These sources include:

1. Fossils
2. Homologous structures
3. Vestigial organs
4. Evidence in embryology
5. Physiological similarities
6. Geographical distribution
7. Results of breeding
8. Experimentation in genetics

Fossil evidence. Perhaps the best indication of the nature of plants and animals of past ages has been found in the form of fossil remains. Fossils might be likened to "footprints in the sands of time" except that the footprints may be entire organisms or their parts and the sands are hardened sediments. Each age, from the beginning of life, has left evidence of its existence in the sediments of the earth. These sediments are found, originally upon the surface of the land in the form of mud or other soft material. As plants and animals die, their remains sink into the soft sediment. As layers of sediment are formed, one above the other, these plant and animal remains are gradually replaced by mineral matter to remain for all time. The sediment gradually changes form to become deposits of rock, arranged in layers. This process has been going on for ages. As one breaks through successive layers of sedimentary rock, each new layer he reaches represents an era older than the

Fossil Plants and Animals in Sedimentary Rock

one immediately above. Fossils embedded in these sedimentary layers are, thus, arranged in their order of existence. Where streams have cut through layer after layer to form deep canyons, rock layers millions of years old are exposed in the stream bed. Fossils exposed in these deep layers are remains of some of the oldest forms of plant and animal life.

The deepest layers, which probably represent the earliest era of life, contain few fossil remains. Evidence of life is rare except in indications that one-celled plants and animals existed in abundance. Above these most ancient layers, fossils may be found in considerable number in the form of marine invertebrates such as sponges, jellyfish, and long extinct creatures called trilobites. Among the most common fossils of this period are various kinds of mollusks in the form of brachiopods [*brack'ee oh pods*] and gastropods [*gas'tro pods*]. In some sections of the country these fossil forms may be gathered by the bushel. Through the next higher layers appear fossils of invertebrates somewhat resembling forms of our seashores of today. Insects, armored fish, and Amphibia appear in higher strata, together with traces of tree ferns whose stems and leaves have for the most part been converted into coal. In later sedimentary rocks are found the remains of huge dinosaurs and other reptiles. As we approach more recent sedimentary rocks, land reptiles seem to be giving place to flying reptiles and to true birds, while plants and trees are beginning to resemble living forms of today. In the most recent strata are found fossils of mammals, the highest form of animal life.

Each of these layers of rocks is so definitely characterized by the remains of certain predominating forms of life that scientists name the rocks by definite periods and ages, no matter where that particular rock is found in the world. This helps to determine what animals and plants lived at the same time. Although the fossil remains are very in-

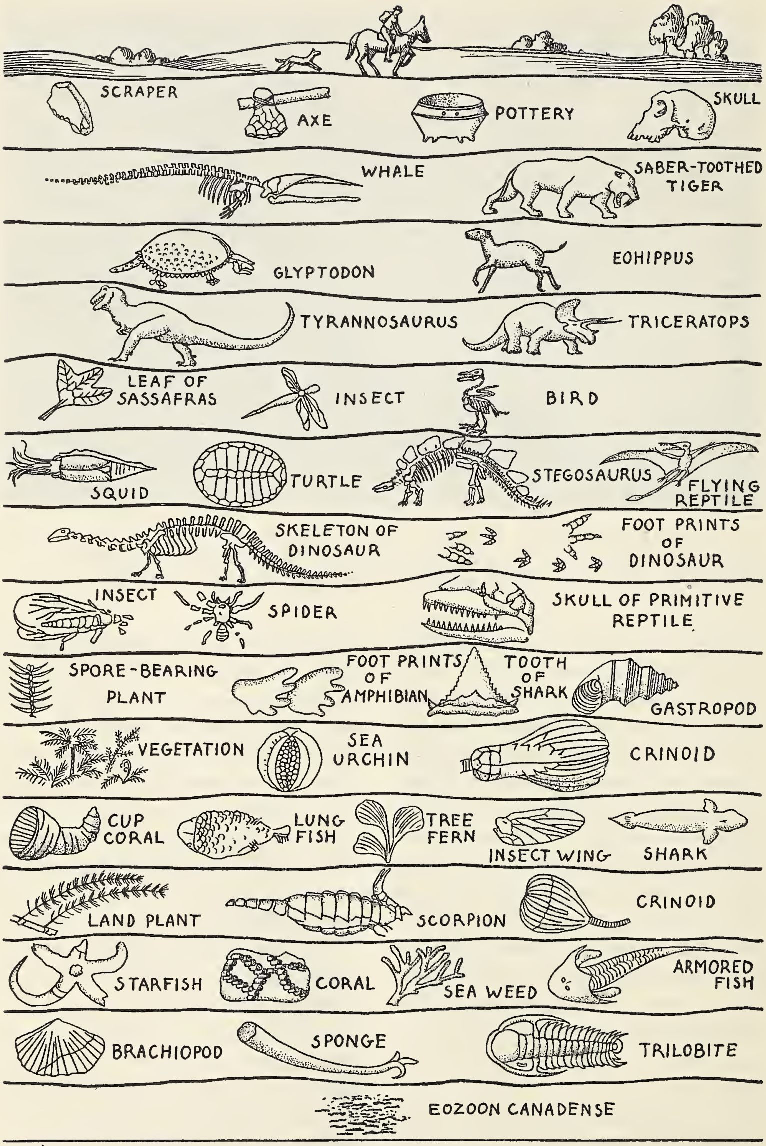
Eocene Life. According to the records of the rocks forty-five million years ago in the Eocene Period, horses were about the size of collie dogs and walked on four toes. The large horned animal is one of the strange mammals which died out during the period.

complete, since most fossils still lie buried in the rocks, nevertheless many series have been assembled. This is notably true of the horse, whose ancestors have been traced in fossil skeletons back to a small form, the size of a collie dog, with four toes in the front feet and three in the hind feet. (A five-toed form seems indicated but it has not yet been found.) Gradual but profound changes in size, bones, teeth, and toes tell an eloquent story. Other relationships, just as important as the family tree of the horse, concerning the camel, rhinoceros, certain reptiles, fish, and other animals are constantly being revealed by new discoveries.

This geological story of the rocks, showing fossil gradations from simple to complex organisms, is what we should expect to find if there had been racial development throughout the past.

Certain new species probably came into existence very gradually. Scientists estimate that such profound changes as the development of our modern two-toed camel from the smaller four-toed form or the modern horse from its diminutive ancestor must have taken many millions of years. From the probable rate of deposition of the particles which later turned into sedimentary, fossil-bearing rocks, from their thickness and depth, from the rate of cooling of the earth, and from other facts, scientists think that life has been on the earth for an inestimably long time.

There are resemblances as well as differences between modern animals and fossil organisms. The question arises: Are these prehistoric creatures the ancestors of modern animals? Each animal we see today had parents, grandparents, great-grandparents, and so on to remote ancestry. We know that some strains or races of animals perished in



THE GEOLOGICAL TIMETABLE

	PSYCHOZOIC ERA — 26,000 years (.00001%)
Recent Period	Beginning of man's dominance; domestication of animals
	CENOZOIC ERA — 106,000,000 years (4.1%)
Pleistocene Period	Ice ages; extinction of mammoth and mastodon; rise of modern horse; man uses fire and makes implements
Pliocene Period	Rise of man; Pliohippus
Miocene Period	Saber-toothed tiger; Protohippus; whale
Oligocene Period	Primitive Anthropoids and Mesohippus
Eocene Period	Primitive forms of modern mammals: sloths, armadillos, marsupials, Eohippus, rhinoceros
	MESOZOIC ERA — 283,000,000 years (10.9%)
Cretaceous Period	Tyrannosaurus and other dinosaurs become extinct
Comanchean Period	Flowering plants; true trees; modern insects; true birds
Jurassic Period	Giant dinosaurs dominant; birds with teeth; turtles and flying reptiles; egg-laying mammals
Triassic Period	Rise of dinosaurs
	PALEOZOIC ERA — 780,000,000 years (30%)
Permian Period	Rise of insects, spiders, and primitive reptiles; extinction of trilobites and other forms; glacial period
Pennsylvanian Period	Spore-bearing plants; sharks and large amphibians (first land vertebrates); coal formed
Mississippian Period	Rise of crinoids, brachiopods, and sea urchins; dense vegetation on land
Devonian Period	Tree ferns and other land plants; lung fish and primitive amphibians; fish and invertebrates dominant
Silurian Period	First air-breathing animals; crinoids; primitive sharks; scorpions; first land plants
Ordovician Period	Corals; armored fish; starfish; first seaweeds
Cambrian Period	Marine invertebrates: sponges, jellyfish, trilobites

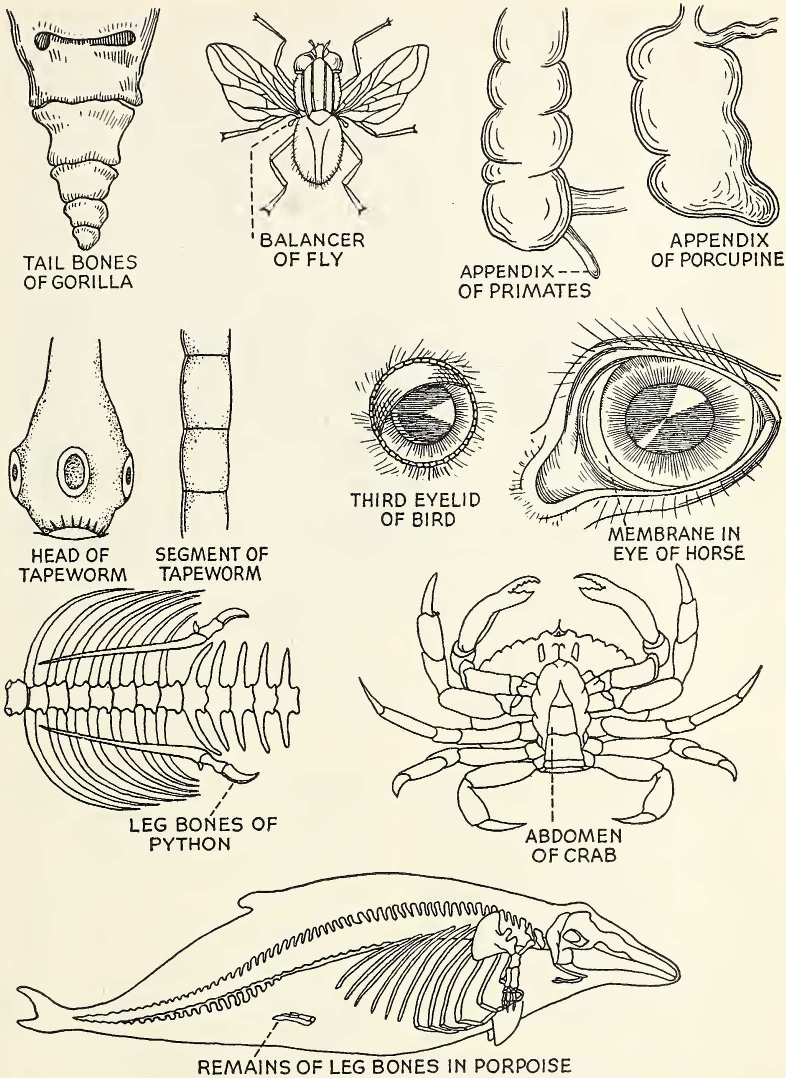
PROTEROZOIC ERA AND ARCHEOZOIC ERA — 1,430,000,000 years (55%) — Origin of life in form of one-celled organisms; few fossil remains

Total number of years since life began — 2,600,000,000 years the struggle for existence. That ended their line but those groups which lived must have been the forebears of modern organisms. These are thereby the descendants of those remote forms which we know only from fossil evidence. When we can find likenesses it shows relationship. The differences found in comparing organisms of today with their remote ancestors reveal how nature has shown a constant tendency toward a more complex development of her offspring.

Homologous structures. In both plants and animals we find parts evidently of similar origin and structure, developed for very different purposes in different species. Leaves can be altered to become petals, tendrils, or thorns. Roots may act as organs for climbing, anchorage, or storage. Epidermal tissue of animals may be modified as hoofs, scales, nails, claws, feathers, and hair. The various appendages of the crayfish are greatly changed for different functions in its relatives, yet the correspondence of these parts is evident. The bones of the wing of a bird, the front leg of a horse, and the paddle of a whale are so similar that, with slight exceptions, they are given the same names. Likewise the muscles and internal organs of mammals are, with certain modifications, practically identical. The manner in which comparative organs are modified for different uses throughout the animal kingdom indicates clearly how new species have resulted from structural variations.

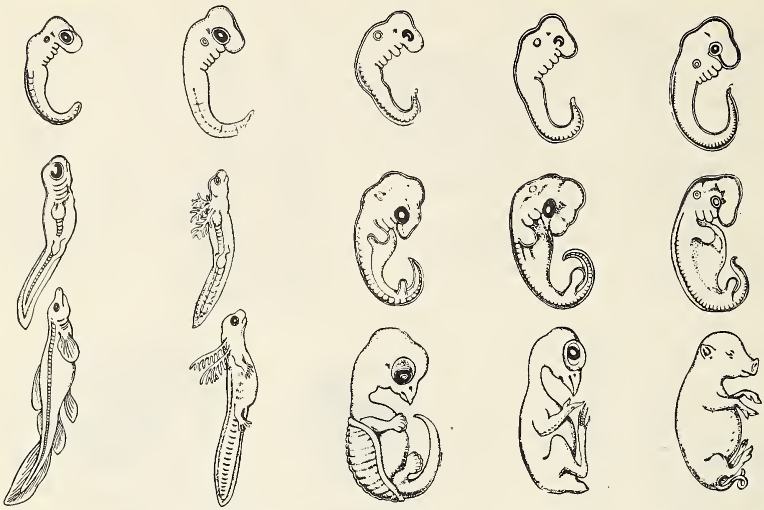
Vestigial organs. In the preceding paragraph reference was made to some of the obvious ways in which animals resemble each other in structure. In certain animals structures may be well developed yet in one of its relatives the corresponding structure may be very inadequate. For example, the abdomen of the crayfish and lobster is the largest division of the body, yet in the crab the abdomen has been reduced to a V-shaped part so tiny that it is sometimes entirely overlooked. In the foot of the horse there are unused bones which in its ancestors were used to support separate toes. The theory is that such inadequate structures are vestiges of corresponding organs well developed in ancestors or living relatives. These are called vestigial [*vest ih'jee al*] organs. They are somewhat like the remains of scaffolding of construction left in a completed building, showing thereby the process of its development. In tailless Primates there are, nevertheless, distinct tail bones at the end of the spinal column. The owl has a third eyelid called the *nictitating membrane.* In the horse this has been reduced to an immovable crescent of skin. In the porpoise all that remains to indicate the possession of hind legs in its ancestors is a group of tiny useless bones buried under the blubber. In rodents the appendix is the largest part of the intestine, while in Primates it has become a small and apparently useless vestige. The ostrich and penguin have wings so reduced that they are useless, yet the presence of flightless birds, such as species of rails, on remote islands too far from other land to be reached by swimming implies descent from ancestors who could fly. Likewise, sightless fish found in underground streams indicate an ancestry having eyes. Insects of the order *Diptera* have the hind wings reduced to mere "balancers."

Degeneration may go so far as to wipe out structures completely. With the exception of the huge regal python, whose twenty-five foot body has tiny leg bones perhaps one-half inch long, legs have



Vestigial Structures Are Widespread among Animals

gone out of style among snakes, though there is every reason to believe that snakes are descendants of reptiles with legs. The tunicate, a small sea animal, when young has a well-developed nervous system and supporting "backbone," yet as it develops it loses the backbone completely and the whole nervous system is reduced to a mere ganglion. The tapeworm has lost its mouth and diges-



EMBRYOS OF FIVE TYPICAL VERTEBRATES. From left to right: fish, salamander, turtle, bird, and pig. Note the long tails and gill slits in the earliest stages, as well as other structural resemblances.

tive system. It hangs in the intestines by hooks and suckers. Each segment resembles the next and is mostly a reproductive organ. The organs of locomotion have completely disappeared.

Evidence from embryology. It is amazing that the embryos of mammals which are never aquatic, such as cows and dogs, nevertheless possesses gill arches. As mammalian embryos develop, the gill arches are modified or obliterated, but two of them later become the Eustachian tubes in the adults. Tailless as well as tailed mammals possess a distinct tail in early embryo stages. All vertebrate embryos have a two-chambered heart and circulatory system like that of a fish, even though later they may have a heart with three or four chambers.

The evidence seems to be that each animal in its individual development passes through stages which resemble its remote adult ancestors. The similarity of vertebrate embryos shows relationship through common ancestry. With this in mind we can understand the embryological evidence showing that vertebrate lungs have developed from the swim-bladder or air-bladder of fishlike animals. It explains the presence of teeth in the embryos of the whalebone whales, which as adults do not possess teeth. It explains the fact that though the cow has front teeth only in the lower jaw, its embryo calf has teeth in both jaws, apparently starting out on its ancestral plan. The breast of the young robin is spotted like a thrush, as students of ornithology would expect, because of its known relationship to thrushes.

The presence of temporary teeth in the embryos of certain birds would imply descent from toothed ancestors. This can be checked from fossil evidence, as we know that the earliest true bird—the *Archaeopteryx*—did possess teeth.

Physiological similarities. Not only do the various classes of vertebrates resem-

GEOGRAPHICAL DISTRIBUTION. Song sparrows are affected by environmental conditions sufficient to produce different varieties. Those along the coast are darker than those inland. Those in the dry, arid southwest parts of the United States are particularly light colored. There are also noticeable differences in size among the various geographical varieties.

ble one another in structure, as the three preceding statements have portrayed, but in functions there is also marked similarity. For instance, internal secretions of mammals show a striking resemblance.

The digestive enzymes are so similar that many commercial products such as pepsin, extracted from cows, sheep, and pigs, are used in medicine. The tremendous use of insulin, thyroxin, adrenin, ductless products taken from animals for use in human treatment, suggests relationship. The blood of the horse is successful material in immunity treatments for diseases like diphtheria, scarlet fever, and pneumonia.

Two English scientists, Nuttall and Graham-Smith, have made extensive tests with blood to show the degrees of relationship between different animals. Many thousands of such experiments seem to point to a close relationship between all mammals. Blood tests of the reptiles indicate that lizards are related closely to snakes, and turtles to crocodiles. Birds are more nearly related to lizards and to snakes than to the other reptiles. Fossil evidence also corroborates this.

Evidence from geographical distribution. It is well known from the writings of Darwin and many other investigators since his time that animals on isolated islands usually differ from corresponding forms on the mainland. Yet both must have descended from common ancestors. Professor Crampton investigated snails on Tahiti, a South Sea island. He found that isolation seemed to produce special varieties. These differed from the crosses or hybrids that developed on the mainland where they had a chance to breed with snails possessing many characters different from their own.

Animals which find themselves in an environment markedly unfavorable face three possibilities: migration to new territory, death, or survival of individuals which through mutations can "adapt" themselves to new conditions. Presumably there have been many cases in prehistoric times where marine fishes, for instance, became land-locked and died out in fresh water. Yet a few mutants must have lived on to give rise to types of fishes observable today, such as the fresh water herring and Miller's thumb. These living forms are distinctly different from, though necessarily the descendants of, their marine ancestors.

Comparisons of all the variations of any widely distributed organism reveal unmistakable relationships. Relationship means common ancestry.

Results of breeding. Domesticated plants and animals are eloquent examples in favor of racial development. The known facts show that over twenty-five kinds of dogs have been developed by man from wild wolflike progenitors. A dozen kinds of pigeons have been originated from the rock pigeon of England. As many kinds of hens have a common ancestor in the jungle fowl of India. Do-

Origin of Domestic Animals

Animal	Progenitor
Dog	An animal resembling the wild wolf, jackal, or possibly the fox. The first animal to be domesticated
Horse	Diminutive, five-toed Eohippus, progenitor of the Orohippus
Ox	Sacred cattle of India
Sheep	Domestic so long that previous history is lost; probably some type in Asia, possibly China
Goat	Of uncertain origin. Wild relatives still alive: Angora of Asia Minor, Kashmir of Tibet, Egyptian goat of Nile
Pig	European wild boar; Indian wild boar
Cat	Some wild type like European wild cat
Hen	Jungle fowl of India, a kind of pheasant
Goose	Graylag goose of north British Isles. Long domesticated
Dove, Pigeon	Rock pigeon of England
Duck	Original wild progenitor unknown. Many wild species still living
Turkey	American wild turkey
Peacock	Some pheasant, in Asia

mestication preserves variations arising as mutations or as the result of hybridization. The Percheron horse has been bred for draft purposes and the Arabian steed for riding. In these cases the skeletons show striking differences in size and weight of bones and hoofs.

Horticulturalists produce new flowers and plants every year. Luther Burbank gave the world dozens of new "creations."

The story of plant and animal breeding, while it does not prove that similar developmental changes have taken place in past ages, does prove the possibility of such changes in nature.

Experimentation in genetics. Rapid growth of the knowledge of the science, genetics, has established heredity as one of the chief causes for the modification of life forms. During 1927, Professor Muller of the University of Texas announced the results of experiments in which he had exposed the eggs of fruit flies to X rays, producing alterations in the flies which subsequently hatched from the treated eggs. As more of this work is carried on with X rays and cosmic rays more knowledge will become available concerning the artificial alteration of heredity.

In 1937, Dr. Albert F. Blakeslee, at that time working at the Cold Spring Harbor Laboratory of the Carnegie Institution, showed that spraying plants or seeds with a chemical called *colchicine* [*kol′chee sin*] resulted in the doubling or quadrupling of the cell chromosomes. This treatment resulted in artificial mutations in the form of strange, new varieties We learned in Chapter 55 that mutations occur naturally from time to time. It is quite likely that new varieties and species may have originated quite suddenly as a result of this hereditary phenomenon.

Theories proposed to explain racial development. As evidence was accumulated, indicating that living things have changed through the ages, scientists turned to the problem of explaining such an occurrence. The first theory was presented by the French biologist Jean Baptiste Lamarck, in 1801. Later, in 1859, the famous English scientist, Charles Darwin, published his theories. In 1901, just one hundred years after Lamarck's publications, a third great scientist, Hugo de Vries announced yet another explanation for racial development. The theories of these three men differ considerably. Perhaps it is a reflection of the scientific knowledge of their day. One might expect that De Vries, the most recent of the three, would have based his theory upon the science, genetics, which had originated at that time. Perhaps all of these men are right in some of their ideas. Perhaps all are incorrect. We may, someday, find a positive explanation. Until then, we must consider all of the theories for what they may be worth.

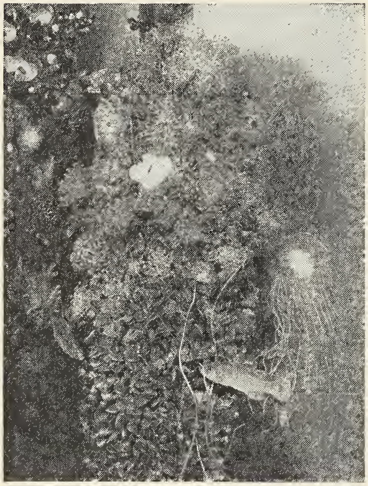
Lamarck's theories. Lamarck proposed three "laws" or theories in lectures delivered in 1801, and again in 1809. His book, *Philosophie Zoologique,* described his ideas as follows:

1. *Theory of need.* The production of a new organ or part of a plant or animal results from a need.

2. *Theory of use and disuse.* Organs remain active as long as they are used, but disappear gradually with disuse.

3. *Theory of inheritance.* All that has been acquired or changed in the structure of individuals during their life is transmitted by heredity to the next generation.

While some of Lamarck's ideas are still acceptable, most of his theory has been discarded. We know, today, that organisms cannot develop new organs



OVERPRODUCTION. Note the hordes of marine organisms which crowd this wharf pile. Mussels below and hydroids above occupy literally every inch, and even attach themselves to each other.

as they are needed. Some people still cling to the idea that organisms adapt themselves to their surroundings. This is a rather interesting way to look at life, but the vast numbers of plants and animals which have perished because they were not suited to their environment are sufficient evidence to refute it. Rather, it seems that variations occur and the organism seeks surroundings favorable for its new characteristic. If such conditions are found, the organism survives; otherwise, it perishes.

Another fallacy in the Lamarckian theory is in regard to inheriting acquired characteristics. As organisms change, gradual modifications seem to be passed on to new generations, but not in the manner that Lamarck suggested. No environmental variation which has occurred within the lifetime of a single organism is inherited.

Lamarck's idea of use and disuse may have scientific basis. In our own body, for example, the appendix has no present use and seems to be disappearing. The same may be said of the third molars or wisdom teeth. However, this disappearance of an organ due to disuse is much more gradual than Lamarck supposed.

Darwin's theory of natural selection. The year 1859 marks an epoch in biological thought. In that year Charles Darwin, an English scientist, published his *Origin of Species by Natural Selection*. His theory is the cornerstone of all recent science. It is not confined to biology alone, but has influenced almost every branch of science. In its broader features it is accepted by every biologist, although there are many details still to be worked out.

Following is an outline of the chief factors assigned by Darwin to account for the development of new species from common ancestry:

1. Overproduction of individuals
2. Struggle for existence
3. Variation among individuals
4. Survival of the fittest
5. Inheritance of favorable characteristics
6. New forms better adapted to survive, thus "naturally selected" as new species

Darwin spent over twenty years of strenuous toil and study, accumulating facts upon which to base his theory. Many able men have since devoted their lives to the same end, but we can here only briefly review the argument, following the outline given above.

Overproduction. A fern plant may produce fifty million spores per year. If all matured they would completely cover North America the second year. A mustard plant produces 730,000 seeds annually, which in two years, if all matured, would occupy two thousand times all the land surface of the earth. The common dandelion would accomplish the same achievement in about ten years.

The English sparrow lays six eggs at a time and breeds four times a year. In the course of a decade, if all survived, there would be no room for any other birds. The codfish produces over a million eggs per year. If all survived this would fill the Atlantic solidly with fish in about five years.

Most amazing of all is the rapidity of reproduction in bacteria and Protozoa. One of the latter, if it reproduced unchecked, would make in thirty-eight days a solid mass of these microscopic animals, as large as the sun.

Struggle for existence. We know there is no such actual increase; in fact, the number of individuals of a species changes but little. In other words, only a small minority of these countless hosts reaches maturity. Each seeks food, water, air, warmth, and space, but only a few can obtain these necessities, and these only through an intense struggle in which those best fitted are generally the survivors.

Variation. It is a well-known fact that no two individuals of any plant or animal are exactly alike; slight variations in structure occur in all. This furnishes the material for nature to use in her selection; and those forms whose variations tend to adapt them best to their environment survive, while others perish.

Survival of the fittest. This expression was first used by another noted English scientist, Herbert Spencer, and almost explains itself. If, among the thousands of dandelion seeds produced, some have better dispersal devices, these will scatter to other soil, be less crowded, and so will survive, while those having poorer adaptations will perish by overcrowding. In so severe a struggle where only a few out of millions may hope to live, very slight variations in speed, or sense, or protection may turn the scale in favor of the better-fitted individual. Those with unfavorable variations sooner or later will be wiped out.

Inheritance. It is common knowledge that in general the offspring resemble the parents. If the parents have reached maturity because of special fitness, those of their descendants which inherit most closely the favorable variation will in turn be automatically selected by nature to continue the race.

New and better adapted species. A continuation of this process of natural selection will in time produce such differences in structure and habit that the resulting forms must be regarded as new species, genera, and finally higher groups. This process may be aided when the developing species are separated by distance, mountain ranges, bodies of water, or climatic differences, and so do not lose their favorable variations by interbreeding. This is the theory of geographic isolation which was developed by Alfred Russel Wallace, another Englishman and a contemporary of Darwin.

Conclusions from the theory. 1. *Cause of Adaptations.* It will be seen that natural selection is constantly tending to fit the individual more closely to its environment. This may account for the marvelous adaptations of structure which we continually find in all living things.

2. *Relationship of all Forms.* Carrying the theory to its logical conclusion it follows that all the species now on earth, or which have lived here in the past, are descended from other primitive original forms. The further back the variation begins, the greater will be the difference between the present forms, and

the more distant will be their relationship. Those more closely allied have separated from a common ancestor in more recent times.

3. *Classification.* This last fact provides for a natural method of classification, now universally used, in which relationship and descent are shown by the groups in which individuals are placed.

Thus members of a species are more closely related than those of a genus or order. A class includes forms which began to diverge further back than the members of a family. When we speak of any forms as " belonging to the same order " or genus, we are really expressing not only their likeness in structure, but the reason for it, namely, relationship and descent from common ancestry.

Natural selection, while recognized today as one of the most important factors in the development of plant and animal life, does not seem to account for all of the known facts. Scientists are turning to other theories to help explain certain things which natural selection does not cover. This does not mean disbelief in Darwin's general conclusions nor their abandonment. The main facts are being more strongly intrenched every year. The interpretation of these facts will continue to vary with new discoveries.

While Darwin was finishing his great work, a German named August Weismann was becoming known for his microscopic studies. He was an admirer of Darwin and supported the theory of natural selection. He was greatly interested in the nature of variations and performed many experiments. In one of his investigations he cut off the tails of mice for hundreds of generations with no resulting deformity in the offspring at any time. This and other experiments led him to feel that *any bodily changes which occur during the lifetime of an individual are not transmitted to the offspring.* In other words, not the body cells (*somatoplasm*) but the reproductive cells (*germ plasm*) are the true carriers of heredity. The physical basis of variation, he felt, lay in the chromosomes of egg or sperm. Environmental effects which changed only body cells were not hereditary, but any causal agency which made a change in germ plasm would bring about hereditable variations. He was thus the staunchest opponent of Lamarck's idea that acquired characteristics can be inherited. His theory, usually summed up as the "continuity of germ plasm," is generally accepted today.

Mutation theory. Hugo de Vries, the great Dutch botanist, in 1901 startled the scientific world by announcing his mutation theory, which in the light of supporting evidence since discovered may well be elevated to the Law of Mutation. As early as 1886, De Vries had found, among a group of evening primroses, two plants which were definitely different from the common type. He experimented for many years, finding that from 50,000 specimens of evening primroses at least 800 plants showed striking differences and that these characteristics were hereditary. To such new forms arising suddenly and breeding true, De Vries assigned the name of *mutants,* from the Latin *muto* meaning " to change." Such striking changes had been observed for centuries and the new specimens had been called " sports " on the theory that nature was just having a little fun, but no one had seen any scientific significance in them.

It should be noted that De Vries did not attempt to account for the striking variations he called mutants, any more than Darwin did for the lesser variations

Mutations in the Boston Fern

he included in his theory of natural selection. Modern experiments, however, seem to confirm the probability that changes in the numbers of chromosomes, or effects produced in their genes from various rays, may be the determining factors for mutations. The full solution to the puzzle of variation may be made only after more experimentation.

Mutations occur both among plants and animals. An example is the "Piersoni" fern, a variety with feathery fronds which originated from the Boston fern in the greenhouses of Mr. Pierson at Tarrytown, N. Y. An animal example is the rather well-known Ancon ram, born in New England in 1791. Although it had normal parents it was broad-bodied and had abnormally dwarfed limbs. Since a sheep of this kind would be less able to jump fences, the farmer who owned the herd used this ram in mating. From it has developed the famous breed of Ancon sheep, prized especially in Australia and England.

Similarly to the Ancon sheep, hornless cattle have been developed from a "sport" hornless bull which was born in Paraguay from normal horned parents.

It is true that, considered from the standpoint of the plant or animal concerned, most mutations are unwelcome innovations. The Ancon ram, unless protected by man, would soon have fallen prey to speedier enemies. Hornless cattle, likewise, have lost one of their best defenses against natural enemies.

Mutants are usually weaker than the normal stock and have less likelihood of surviving because their mutations are usually defects. By chance, however, operating through millions of years, it is quite possible that advantageous mutations might also occur. By the operation of natural selection it is easy to see how organisms possessing such beneficial mutations would be preserved and give rise to new types of plants and animals.

The mutation theory, like natural

selection, may seem somewhat inadequate, but biologists accept it today as a working basis for further investigations. Although it is imperfect for all cases, it explains others satisfactorily. Doubtless new theories will supplement, if they do not supplant, present ideas.

Science and religion. There is nothing in science which is opposed to a belief in God and religion. Those who think so are mistaken either in their science or their theology or both. Huxley was a contemporary of Darwin and one of the most eminent biologists. Note his opinion:

" Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before the fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses nature leads, or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved at all risks to do this."

Major W. W. Keen, M.D., whose professional training gives him a different point of view from that of Huxley, says, " With the passing years I am more and more impressed with the wonderful mechanism of nature, which to me bespeaks God."

Summary

Through periods and eras representing many millions of years, life on the earth has undergone constant and gradual changes. This modification of life forms is termed racial development. Evidence of racial development has been accumulated through the study of fossils, homologous organs, vestigial organs, embryology, physiological similarities, geographical distribution, results of breeding, and experimentation in the field of genetics.

Three famous theories have been advanced to explain the manner in which racial development occurs. Lamarck expressed the idea of use and misuse, in which the organism was thought to modify its structure to fit its needs and to pass these changes on to the next generation. This theory for the most part has been refuted. Darwin's theories, based upon overproduction, struggle for existence, and survival of the fittest is based much more on demonstrated facts than was Lamarck's theory. De Vries applied the knowledge of heredity in advancing his theory of mutations. His ideas, combined with many of Darwin's, offer the best explanation for racial development.

Using Your Knowledge

1. What methods have scientists used to determine the age of the earth?

2. Explain the manner in which fossils are formed.

3. What significance is attached to the order of the layers in which fossils are found in the earth?

4. How do homologous organs explain the wide variety of forms related organisms may assume?

5. Define the term vestigial organ and name several such organs.

6. How does embryology indicate the possible ancestry of organisms?

7. Name some of the ways in which vertebrate animals show physiological similarity.

8. How have the results of breeding clarified the idea that organisms may change because of variations in heredity?

9. Upon what improper conclusions were Lamark's theories based?

10. Explain the operation of Darwin's theories in nature.

11. Account for the fact that De Vries incorporated much more heredity in his theories than either Lamarck or Darwin included.

Expressing Your Knowledge

period	vestigial	Lamarck
era	sedimentary	Darwin
fossil	degeneration	De Vries
brachiopod	distribution	natural selection
gastropod	embryology	variation
homologous	overproduction	survival of the fittest

Applying Your Knowledge

1. Collect specimens of different fossils from your region if they are available. If not, visit a museum and report on the fossils on display.

2. Find out how sedimentary rocks are formed and what kinds of rocks are produced in this manner.

3. Make a list of organs which are, or are rapidly becoming, vestigial in man.

4. Count the number of dandelion flowers in a measured section of a lawn. Then estimate the number in the entire lawn. When the seeds mature (tufted fruits) count the number in one head, then estimate the total number in the entire lawn. Which of Darwin's principles has been illustrated?

Increasing Your Knowledge of This Unit

Burbank, Luther. *Partner of Nature*. D. Appleton-Century Co., New York. 1939

Campbell, Douglas Houghton. *Plant Life and Evolution*. Henry Holt and Co., New York. 1911

Chicera, Edward. *They Wrote on Clay*. The University of Chicago Press, Chicago. 1938

Conklin, Edward Grant. *Heredity and Environment in the Development of Man*. 6th Edition. Princeton University Press, Princeton, New Jersey. 1929

Fasten, Nathan. *Principles of Genetics and Eugenics*. Ginn and Co., Boston. 1935

Fenton, Carol Lane. *Our Amazing Earth*. Doubleday Doran and Co., New York. 1938

Goddard, Henry Herbert. *The Kallikak Family*. The Macmillan Co., New York. 1912

Guyer, Michael Frederick. *Being Well Born: an Introduction to Heredity and Genetics*. 2nd Edition. Bobbs-Merrill Co., Indianapolis. 1927

Harwood, W. S. *New Creations in Plant Life*. 2nd Edition. The Macmillan Co., New York. 1907

Howells, William. *Mankind So Far*. Doubleday Doran and Co., New York. 1944

Huntington, Ellsworth. *Tomorrow's Children*. John Wiley and Sons, New York. 1935

Hurst, C. C. *Heredity and the Ascent of Man*. The Macmillan Co., New York. 1935

Iltis, Hugo. *Life of Mendel*. W. W. Norton and Co., New York. 1932

Jewett, Mrs. Francis (Gulick). *Next Generation: a Study in the Physiology of Inheritance*. New Edition. Ginn and Co., Boston. 1928

Kellogg, Vernon. *Evolution*. D. Appleton Century Co., New York. 1924

Knight, C. R. *Before the Dawn of History*.

The McGraw-Hill Book Co., New York. 1935

Levine, M. I. and Selegman, Jean. *The Wonders of Life*. Simon and Schuster, New York. 1941

Lull, Richard Swann. *Fossils*. The University Society, Inc., New York. 1931

Mason, Frances. *Creation by Evolution*. The Macmillan Co., New York. 1928

Newman, Horatio H. *Evolution, Genetics and Heredity*. The University of Chicago Press, Chicago. 1932

Quennell, Marjorie and Quennell, C. H. B. *Everyday Life in the Old Stone Age*. G. P. Putnam's Sons, New York. 1922

Popenoe, Paul. *The Child's Heredity*. The Williams and Wilkins Co., New York. 1929

Rife, David C. *The Dice of Destiny*. Longs College Book, 1836 High Street, Columbus, Ohio. 1945

Romer, Alfred Sherwood. *Man and the Vertebrates*. 3d Edition Revised. The University of Chicago Press, Chicago. 1941

Schlinfeld, Amram. *You and Heredity*. Garden City Publishing Company, Garden City, New York. 1936

Walter, Herbert Eugene. *Genetics, an Introduction to the Study of Genetics*. The Macmillan Co., New York. 1938

Ward, C. H. *Evolution for John Doe*. Bobbs-Merrill Co., Indianapolis. 1936

White, Anne Terry. *Lost Worlds*. Random House, New York. 1941

Van Loon, Henry. *The Story of Mankind*. Garden City Publishing Co., Garden City, New York. 1936

Unit 11 ---

Safeguarding Nature's Inheritance

Conservation is a major problem in America, equal in importance to the conquest of disease. Our entire national economy is dependent upon our natural resources. Our land and waterways, mineral resources and wildlife are vital to the future of the nation. Regardless of the brilliance of our scientists, the wisdom of our statesmen, the ingenuity of our industrialists, and the skill of our workmen, our country cannot continue to be a great nation unless her natural resources are conserved.

In this unit we come to the problem of total conservation, which is a climax study of biology because it concerns all other branches of the science. Only under a total conservation program, supported by the nation, the states, and the entire population, can we win the war against the devastation of our land.

The Conservation Pledge, formally accepted in Washington, D. C., for the American people by Secretary of the Interior Krug in December 1946 is:

I give my pledge as an American to save and faithfully to defend from waste the natural resources of my country — its soil and minerals, its forests, waters, and wildlife.

Chapter 59

Conservation of Our Soil and Water Supply

In the mountains of the Black Forest of central Europe the beautiful blue Danube, famous in song and literature, starts its long journey to the Black Sea. In the Rocky Mountains of the northwestern part of the United States, the Missouri River starts its long flow to the Gulf of Mexico. On its journey, it combines with the muddy Mississippi, the muddy Ohio, the muddy Red River, and numerous smaller waterways, all muddy, and deposits the wealth of America in the Gulf. These rivers symbolize an abused and impoverished land.

It would seem that man cannot appreciate prosperity. Great wealth leads to waste. The land of the Danube is a poorer land than ours. It has supported human population for many more centuries than ours. Yet, the waters of this famous river are blue. They flow through forest lands and green fields where man learned long ago that he must respect nature or pay a terrific price. We are learning this lesson, too, but only after half of the battle has been lost. Half of our precious topsoil is gone and much of our land is already abandoned.

America is waking up. Soil and water conservation are now receiving national attention. Perhaps we can still win, but success depends upon an understanding of the problem by all of our population and the full support of the programs of national, state, local, and individual organizations.

The land as we found it. When the first settlers came to America, they found a land of almost unbelievable opportunity. Climate, geographical location, and soil were ideal for crop production. Trees in almost endless quantity were at hand to supply materials for building a new nation. The greatest problem was the clearing of the land for agriculture. For generations, it was man against nature. The eastern forests fell to the woodsman's ax. Trains of covered wagons bore pioneer families through the eastern forest lands, across the prairies and great plains, and finally across the Rocky Mountains to the Pacific Coast. Nature was generous in yielding the heritage of ages to these hardy families and America soon became a prosperous nation.

The soil was the basis of all this prosperity. It grew the forests and grasslands where game abounded. As planted crops replaced native stands, the soil yielded its fertility to fields of grain and vegetables. Herds of cattle and flocks of sheep fattened on the rich grasses of the prairies and plains. The fertility of topsoil was transferred into material wealth as fortunes began to grow.

The land today. What of our land today? Can our soil continue to support such a rapidly growing nation? Can it supply the demands of a nation in which the average citizen enjoys a standard of living far above inhabitants of any other country? The answer to these questions may be yes and may be no. It can if we rebuild it more rapidly than we deplete it and restore natural controls against its removal by forces of nature. Our task in rebuilding the land is doubly hard today, for we must not only guard against further depletion in our age, but must restore the damage caused by less informed generations which preceded ours. Unless large-scale conservation measures are taken immediately, the answer to these questions is definitely no!

The importance of topsoil. You may wonder how a nation can ever exhaust its soil. If water washes out an area, or if wind blows part of the soil away, new layers are exposed. Actually, however, we cannot assume that this newly exposed soil can support plants. Vegetation depends upon *topsoil,* which is quite different from the *subsoil* which lies below. Topsoil consists of mineral matter combined with organic matter. Mineral substances may exist naturally, but organic matter is formed from the remains of plants and animal substances which have lived upon the land for ages. Topsoil contains, also, numerous microorganisms which live in the upper layer of the earth and carry on the processes which give soil fertility.

A few inches of topsoil requires thousands of years for formation. The weathering of rock to form small particles is an extremely slow process. It requires the action of running water, wind, rain, snow, ice, and other forces of nature over a period of centuries. The decay of organic matter to form humus, likewise, occurs slowly. Thus, we cannot replace our topsoil readily. We must protect the existing supply. When the topsoil is gone, the land becomes a desert. Would it alarm you to know that you are now living within five inches of such a desert? Originally, the topsoil in America averaged nine to ten inches in depth. Now, it averages about five inches. Below this precious layer is several feet of subsoil, topsoil in the making, but entirely lacking in the qualities necessary to support the native vegetation and crops of America. This is what the conservationist means when he says that the battle is half lost already. Half of the topsoil is gone already. Some areas are still rich, but others are entirely ruined.

Ewing Galloway, N.Y.

A SOIL PROFILE. These soil technicians are taking samples from various depths in the profile.

What has happened to the topsoil? The answer lies in river beds, at the bottom of the oceans, and in the clouds of dust which blow across the land especially during the hot, summer months. The rich soils of the prairies and plains were once anchored by the soil-binding roots of native grasses. Winds now sweep across plowed or abandoned fields. Where vegetation once soaked up moisture during rainy periods, water now pours over exposed soil, washing away the top layers and depositing it as silt in streams and rivers, where it is carried to the ocean. In many areas, even where the soil has not been removed, year after year of crop production with no effort to replenish the removed fertility has exhausted the topsoil to the point that it can support only a few weeds.

What practices have led to soil destruction? The causes of soil loss and depletion are very apparent when past and present agricultural practices are examined carefully. *Overproduction* placed a terrific strain on the land as crops were grown year after year without giving the soil an opportunity to restore its fertility. The object seemed to be to produce as much as possible in as short a time as possible. After a few seasons, the loss of fertility began to show in reduced crop yield. Rather than heeding this danger signal, many farmers pushed the land even harder. When the soil finally became exhausted, the field was abandoned in favor of a new and more profitable area. Fortunately, the modern farmer understands the principles of crop rotation. He has found that he can produce more yield over a given period by resting his land during a crop rotation period than by using a field continually. Nevertheless, millions of acres of worn-out land lie idle in America.

Overcultivation has resulted in tremendous soil loss. With the rapid expansion of the agricultural industry, more and more areas were cultivated for crops. During World War I America was called upon to feed a large part of the world. Agriculture prospered more than ever before. In eagerness to make every inch of land pay, many farmers began cultivating hillsides, river bottoms, and every other available location rather than increasing yields from land already cultivated. Along the great rivers, fields were cultivated almost to the water's edge. Even in hilly forest lands where oak and hickory trees were thriving in shallow topsoil, the native vegetation was cleared to provide more tillable ground. Such lands were entirely unsuitable for crops and were soon abandoned to the ravages of erosion or were left for families to eke out an existence from a few patches of dwarfed, yellow corn and vegetables. These practices constituted one of our greatest mistakes. When riverbanks were cultivated and no backwaters were left to receive the swollen waters, floods began to rage. This destruction of large areas of forests left the land exposed to the ravages of wind and water.

The practice of growing *row crops* has been another important contributing factor to soil loss. Entire fields are cultivated with such crops as corn, beans, and tomatoes planted in rows. The soil between rows is laid open to wind and water unless special protective measures are used. As a rule, such crops are *cash crops,* upon which the farmer depends for a large portion of his income. Such extensive cash crops usually lead to overworking of the land.

Factors involved in soil loss and depletion. Loss and depletion of soil is due to three principal factors. The actual removal of soil from an area is called *erosion.* This is the greatest problem to be overcome. *Leaching* out of soluble minerals by running water is another serious problem. A third problem is *exhaustion* of soil minerals as a result of overproduction of crops. Soil conservation concerns all of these problems.

Wind erosion. Soil erosion concerns two chief forces of nature, wind and water. They may operate together or separately, depending upon the location of the erosion. *Wind erosion* is the greatest problem in the prairie and plains states. In the southwestern parts of the United States, particularly in west Texas, Kansas, and Oklahoma, wind

THE RESULTS OF A DUST STORM. An abandoned farmstead, showing the disastrous results of wind erosion.

erosion is a critical problem. Strong winds blow from the south, especially during the spring and summer months. Originally, native grasses and other plants bound the soil firmly with their extensive, shallow root systems. But much of this land was extremely fertile and suitable for growing cereal crops. As a result, extensive areas were plowed for agriculture. During the spring and early summer months the soil was moist enough to hold its place, but with the summer drought those strong, hot winds blew the topsoil away. This process of wind erosion increased. Entire fields were covered with fine particles of topsoil carried in dense clouds during a dust storm. Abandoned fields added to the growing desert. The farmer who was fortunate enough to hold his soil in check was powerless to stop the tons of soil which blew onto his land from other areas. There was nothing left but to abandon the homestead with its half-buried house and barns and join the procession of landowners out of the growing "Dust Bowl." This is wind erosion on a large scale, as anyone from that section of the nation can testify.

Water erosion. This is serious in other sections of the country. Especially where the land is sloping or hilly, raindrops fall upon exposed soil and dissolve small amounts of topsoil. The rain forms tiny rills or channels across the surface of the land. This is called *rill erosion* and is usually followed by a much more serious stage called *gully erosion*. Each time a rain falls, more water flows through rills, carrying away more soil and enlarging the channel much as a stream increases the size of its bed. Finally, each rill becomes a gully. Still the erosion continues. More and more rills pour run-off water into the gully, causing it to deepen and widen. Soon, the gully enlarges to almost canyon proportions. Cases have been found where

GULLY EROSION. This gully is still very active and will continue to grow larger until erosion is checked.

single gullies have covered many acres of land and have swallowed up trees, barns, and even houses as they grew wider and deeper. The soil removed during formation of the gully has been carried away in muddy streams and rivers.

Another type of water erosion, called *sheet erosion,* occurs when water covers an entire area of land during a flood. In this case, an entire sheet of land may be dissolved or washed away by the flood waters. When the waters recede, the land is left one sheet nearer the sterile subsoil. A few such occurrences may leave the land totally worthless.

Soil leaching. Water does not necessarily have to remove soil in order to cause damage to the land. Soil is cultivated to allow rains to soak into the ground to reach the roots of crop plants. As it runs through the soil it dissolves mineral matter and carries it downward. By such leaching action, minerals may be carried too deep into the soil, and well beyond the reach of roots. Thus, valuable fertility is lost. We have always assumed that fields should be cultivated frequently. In the light of present knowledge of soil leaching, the advisability of such practice is questionable.

Exhaustion of soil minerals. You learned that plants use minerals from the soil in forming protoplasm. Carbon, hydrogen, and oxygen are taken from air and water and are used in the production of carbohydrates during photosynthesis. But these elements alone cannot form protoplasm. To them must be added nitrogen, phosphorus, potassium, sulphur, and other elements. These substances must come from the soil as soluble minerals.

Crop plants, raised for food, remove large amounts of mineral matter from the soil in which they grow. This is the reason for their food value. Each season a crop is grown, the soil minerals are exhausted further. After a few seasons, certain types of minerals may be lacking. Unless they are added, future crops are much reduced in food value. Since crops are removed from the field and are not left to decompose naturally, minerals must be added in the form of fertilizer. Unfortunately, much of the land has been exhausted of critical minerals which have never been replaced, and old farms have been abandoned for new land.

Soils and health. It is only rather recently that science has become aware of the direct relation of soil to health. As soils vary in mineral content, the plants which grow in them also vary in chemical make-up and nutritional value. We cannot say, for example, that spinach and lettuce are necessarily rich in certain minerals. It depends entirely upon the mineral content of the soil in which they are grown. Similarly, wheat is especially rich in protein when grown in the highly fertile soil of the prairie states. The same crop grown in depleted soil would contain much less protein.

Soil depletion is most acute today in the South. Much of the land has been exhausted with extensive growing of cotton and other crops. Here, it is not uncommon to see cattle grazing in fields, knee-deep in grass, with their ribs bulging. The grass they are eating contains carbohydrates made from photosynthesis, but lacks proteins because the soil is depleted in mineral content. Such conditions are reflected in the human race. Some farm families, trying to make a living from worn-out land, become undernourished and ill because of the lack of vitamins and minerals in the crops they are able to grow. Dr. Jonathan Forman, editor of the Ohio State Medical Journal, has expressed the important relation between soil and health in his numerous publications and personal appearances before groups in connection with activities of the Friends of the Land Society.

Soil conservation. Soil can continue to play its vital role in the economy of America only if conservation measures are applied immediately and extensively. Such measures include:

1. Planting windbreaks, soil-binding plants, and other measures to control wind erosion
2. Contour farming
3. Strip cropping
4. Terracing
5. Gully control
6. Crop rotation
7. Application of lime and fertilizer

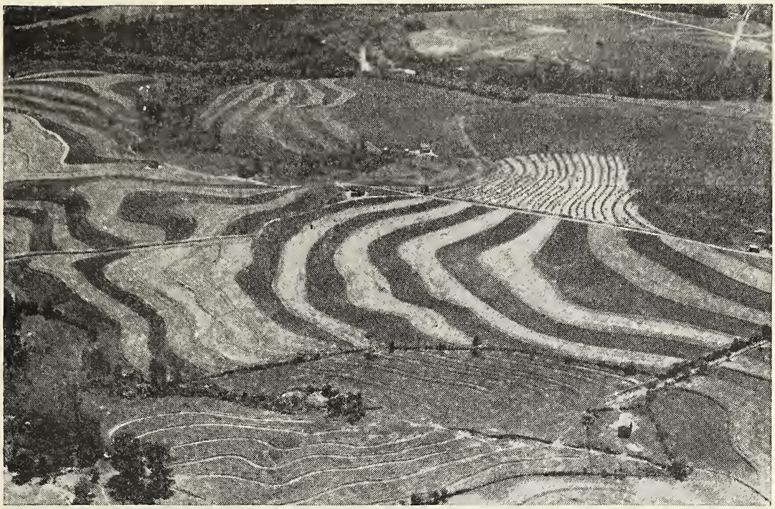
Control of wind erosion. Wind erosion is especially difficult because it involves such large areas. Any local wind erosion control could be wiped out in a single dust storm. Consequently, these projects must be undertaken on an extremely large scale and with the aid of the state and national agencies. One such measure is the planting of *windbreaks* or *shelterbelts*. Extensive experiments have been conducted to find trees which can be planted at intervals to break the force of the wind. In addition to windbreaks, plants are needed as *soil binders*. Every inch of exposed land not used regularly for crop production must be anchored firmly by the roots of grasses and other soil binding plants. When land is cultivated, furrows should be *plowed at right angles* to the prevailing wind. Thus, the wind does not blow down the furrows but blows across them. Each furrow helps to stop the movement of soil. In sections where *irrigation* is possible, diversion of water into the fields during dry periods will check wind erosion because moist soil does not blow.

An Excellent Shelterbelt Planting. These trees were planted in 1937. The photograph was taken in 1944. The crop in the foreground is wheat, and is being protected from strong winds.

Contour farming. One of the greatest problems in water erosion occurs when fields are plowed up and down slopes. The furrows between rows of plants make ideal places for rills and gullies to form. Each time it rains, water pours down the slope through the furrows, carrying away topsoil. The solution to this problem is quite logical. Plow around the hill rather than up and down. This method of cultivation is called *contour farming*. When furrows are plowed around the slope, each one serves as a small dam to check the flow of water. Water stands in each furrow and then soaks into the ground. If this simple practice had been followed long ago, our lands today would be richer and our rivers deeper and clearer.

Strip cropping. This extremely valuable soil conservation practice frequently combines two important measures. Broad strips are cultivated on the contour of a slope for growing *row crops* such as corn, cotton, potatoes or beans. These strips alternate with strips in which *cover crops* such as wheat, oats, clover, alfalfa, or grass are grown. These cover crops completely cover the surface of the soil and hold it securely. As water runs from the strip of row crop it is checked upon entering the strip of cover crop. Frequently, clover is used as a cover crop. In this way, strips may be rotated within a single field. Nitrogen-fixing bacteria, associated with the roots of clover, alfalfa, and other legume plants, replace the various nitrogen compounds in the soil. Strips may be alternated every few years with the result that water erosion is checked continually and fertility of the soil is maintained.

Terracing. Terracing is used extensively to check the flow of water on sloping land. A long slope is broken into numerous short ones by forming a series



STRIP CROPPING. Whole fields are not planted with a single crop. Cotton still grows on this South Carolina farm but it is planted in strips that follow the contour of the land. Small grain is sown in between the strips of cotton. How does this practice help in conserving the soil?

of banks. Terracing graders are used to form flat strips on the contour of the slope. Each strip is divided from another by a bank. Drainage ditches at the base of each bank conduct the water around the slope.

Gully control. When large gullies have already formed, measures other than those discussed must be employed. One of these is planting the slopes of the gully with trees, grasses, or other plants to act as soil binders and prevent further widening. Deepening may be prevented by building a small dam at the lower end. The dam stops the flow of water and soil gradually fills the gully.

Crop rotation. This conservation measure has already been discussed. It may involve an entire field or several strips when strip farming is practiced. Crop rotation is essential in maintaining soil fertility, especially in respect to nitrogen compounds. While crop rotation may seem a waste of valuable space, statistics show that the yield from a field grown in crops two years and rotated one is actually greater than a three-year yield without rotation.

Application of lime and fertilizer. Most field crops require alkaline soil. Lime adds sweetness or alkalinity to the soil. Each year a field is cultivated some of the lime is used up and some leaches down with water which penetrates to the water table. As soil begins to wear out, it becomes more and more acid. The answer is addition of lime to the soil.

Mineral deficiency may be restored by the addition of fertilizers. Phosphorus and potash especially must be restored to the soil in this manner. Commercial fertilizers, corn cobs, leaf and stem remains, and animal manures are among the most widely used fertilizers. With lime to maintain the alkalinity, crop rotation to restore nitrogen, and fertilizer to replace lost minerals, the soil may go on producing indefinitely.

Ewing Galloway, N.Y.

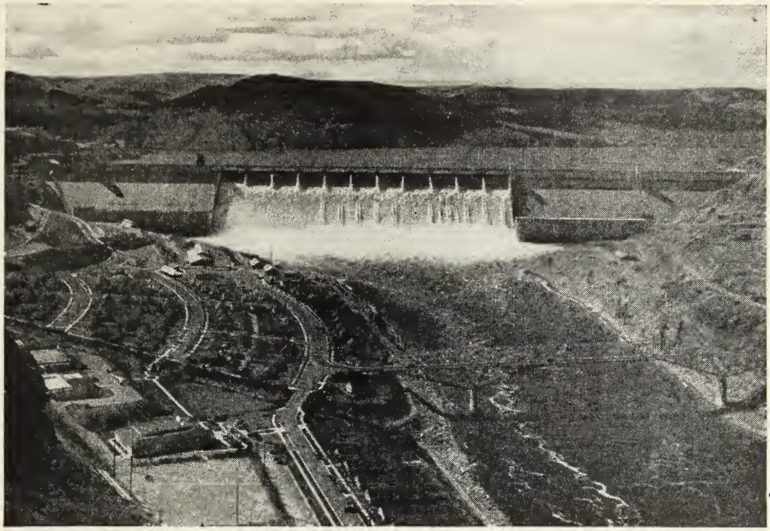
A SEVERE FLOOD. Millions of acres of fertile land are washed away each year by floods such as this.

Problems in administrating soil conservation. The greatest difficulty in administrating soil conservation is the fact that the majority of the land is privately owned. If a farmer chooses to refuse to practice terracing, strip cropping, or any other measure in controlling erosion on his land, he has a perfect right to do so. Thus, soil conservation must be sold to the public through education and a demonstration of its results.

In 1935, the United States Soil Conservation Service was established as part of the Soil Conservation Act. This agency became a permanent part of the Department of Agriculture. This division of the Department of Agriculture has embarked upon an extensive program of soil conservation. Expert agricultural engineers are investigating all phases of the problem. They travel through the country studying various problems and offering aid where needed. Farmers have the opportunity to examine demonstration farms where soil conservation measures are in operation. If the farmers of a community wish to employ these methods on their farms, they must first form a local soil conservation district under local control. Engineers from the U. S. Soil Conservation Service will then co-operate with the local district in applying soil conservation methods to the problem. It is still a matter for the individual to decide, but he will find his government always ready and willing to assist him.

In addition to national and local soil conservation organizations, many states are active in soil conservation. These state agencies work through the local Departments of Conservation.

A discussion of soil conservation would be incomplete without mentioning the Friends of the Land Society. This organization, composed of public-



Grand Coulee Dam

spirited members all over the nation, has been active for several years and is doing an extremely valuable service in promoting soil conservation through an extensive program of education. Meetings are held regularly in different sections of the country where farmers and city folks alike may discuss soil conservation problems. In addition to conducting special meetings, the Society sponsors publications containing articles written by outstanding authorities in the various phases of soil conservation.

Water conservation. The problems of water conservation are closely related to those of soil conservation. Floods and drought are both a result of improper use of land.

Rivers have always flooded their banks during periods of heavy rain, but not in the proportions nor the frequency of the present day. The failure of land to absorb water during rains sends this excess water into streams which cannot carry it. Consequently, floods occur during nearly every rainy period. Furthermore, a swollen river has no place to store its excess water. When a river rises it is just like filling a gutter. It spills over when it reaches the top. Formerly, swamps and backwaters held back enormous amounts of water. A great quantity was absorbed, also, by the swamp and lowland forests which grew along the riverbanks. If these reservoirs are removed, as they have been in far too many regions, the water has no place to go but downstream, or over the riverbanks.

The same situation applies to droughts. Water which should have fed the river through the dry season went down with the flood waters. When rains cease, small streams dry up and rivers become low. Most of this can be traced to the treatment of the land.

During the disastrous flood of 1937, heavy rainfall in the eastern section caused the upper Ohio River to rise rapidly. Muddy waters reached an all-time flood stage of 50 feet. This was higher than the river had ever risen before. Five hundred persons lost their lives and a million more were made homeless as flood waters washed out entire cities. Total damage was estimated at more than 500 million dollars.

Water conservation measures. Water conservation is a national problem. Rivers cross state boundaries and affect large areas of the nation. The federal government has been carrying on extensive flood control projects for many years and is planning many more for the future.

Flood control measures include the construction of high levees along the larger rivers. In other places, lowlands along the rivers are taken over to restore natural swamp forests and backwaters. Numerous reservoirs have been built to hold water during flood seasons and release it in controlled quantity during periods of drought. These measures hold down the crest of water during floods and maintain the level during rainless seasons.

As another means of controlling water, the government has constructed enormous dams in several sections of the country. These projects not only check the flow of water, but serve several other valuable purposes. The dams are the site of hydroelectric plants which use the water rushing over the dam to turn turbines attached to generators. This water power is changed into electricity and supplies large areas of the nation. In addition, the dams raise the water level in rivers and make them navigable for long distances. In the west, water from large dams is used for irrigation and has made many semi-desert areas ideal for crop production. Still another value of such dams is the provision of bodies of water for recreation. Deep, clear lakes are formed above the dam which are ideal places for swimming, boating, and fishing.

Summary

Soil and water conservation are two very important phases of the program of total conservation in America. Both problems have arisen largely from misuse of the land. Through forces of erosion, one-half of our topsoil has been removed and much existing land has been depleted as a result of leaching and overproduction. The planting of windbreaks and soil-binding plants and cross wind plowing are practiced in the Southwest in an effort to check wind erosion. Contour farming, strip cropping, and terracing have come into prominence as methods of checking water erosion. Crop rotation, liming, and application of fertilizer are methods of restoring lost fertility.

Water conservation deals with the effects of too much water at certain seasons and too little at others. As a means of checking flood waters, levees and reservoirs have been built. Other extensive projects include numerous dams, which serve not only to control flood waters, but to furnish hydroelectric power, water for irrigation, raised level for navigation and recreational facilities as well.

Using Your Knowledge

1. How does the character of topsoil differ from that of subsoil?

2. Explain how overproduction and overcultivation have created serious soil conservation problems.

3. Discuss the farming practices in the

Southwest which led to the formation of the Dust Bowl.

4. Explain the relation between rill and gully erosion.

5. What is leaching? How does cultivation increase leaching?

6. Explain how contour farming reduces water erosion.

7. Explain why control of erosion, crop rotation, liming, and application of fertilizer are all necessary in maintaining productive soil.

8. Enumerate causes for the extensive floods of today.

9. How do dams lessen the danger of floods?

Expressing Your Knowledge

topsoil	rill erosion	terracing
subsoil	gully erosion	rotation
fertility	sheet erosion	liming
overproduction	leaching	irrigation
overcultivation	windbreak	hydroelectric
row crop	soil binder	backwater
cover crop	cross-plowing	reservoir
depletion	contour farming	levee
wind erosion	strip cropping	silt

Applying Your Knowledge

1. Visit farms in your vicinity and report on any erosion projects in progress.

2. Using soil or plaster of Paris, construct models of slopes illustrating contour farming, strip farming, and terracing. Crops may be indicated with small straws or sticks or painted, in case plaster is used.

3. Make a collection of pictures or photographs which illustrate different kinds of wind or water erosion. Obtain pictures from many different regions.

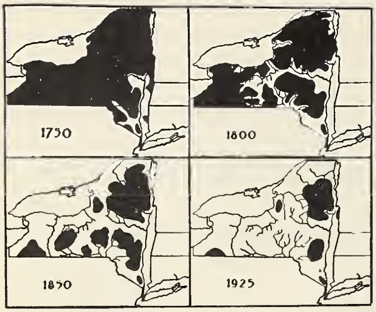
4. Collect a sample of water from a near-by river, during flood stage if possible. Let the water stand for several days and measure the amount of silt. Stir it up again and pass it through a piece of coarse filter paper. Weigh the amount you obtain. (Measure the water accurately; weigh the filter paper before and after filtering.)

5. Locate, on an outline map of United States, the major dams and water control projects of the nation.

Chapter 60

Forest and Wildlife Conservation

The inroads of civilization, the growth of large cities, and the extension of agriculture in America have resulted in critical problems of conservation other than those dealing with soil and water. The wildlife of America is in an equally critical condition. Clearing of the land meant destruction of the forests. Destruction of the forests meant disappearance of birds and other forest animals. Cities brought stream pollution and stream pollution meant doom for much of our aquatic



Disappearance of Forests. These charts show how the forests of New York State have yielded to the demands of an ever encroaching civilization. Black areas represent forests. Note that it is from the water courses and valleys that the forests first began to disappear. Why is this so?

life. All phases of conservation are closely related. One problem cannot be solved without considering others.

It is startling to learn that our timber supply is nearly gone. World War II called upon the forests to give up their last reserves for the winning of the war. Much of our remaining supply of trees was sent to the mill to furnish lumber for the extensive construction of new buildings, shipyards, and countless articles essential to the war effort.

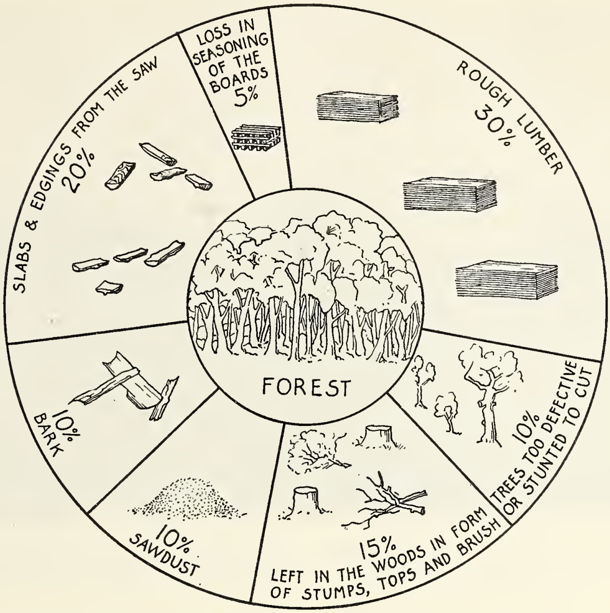
More than ever before, America looks to the conservation program for hope for the future. Can conservation restore our timber so that we may again build houses, barns, furniture, and countless other products as we did in the past? Will game birds and animals again abound in the fields and woods? Will fish again flourish in our lakes and streams? It all depends upon the success of our total conservation program.

Forest destruction. The story of the destruction of forests was told in Chapter 20, dealing with Forests and Forest Industries. It started as a movement to clear the land for agriculture.

As early as 1822, De Witt Clinton, Governor of New York State, suggested that some protective action be taken in regard to forests, but it was 1885 before the state had its first "forest preserve." The American Association for the Advancement of Science urged some form of national forest protection in 1873, but it was not until 1891, during the presidency of Harrison, that the Department of Agriculture began making national forest reserves. Gifford Pinchot of Pennsylvania was one of the leaders in urging adequate forest protection, and Theodore Roosevelt was the first of our presidents to take an active interest in conservation as a whole. He called a conference of state governors in 1908, created a Conservation Commission and began a definite national conservation policy, not only of forests, but of minerals, soils, waters, and animal life. Many states now have conservation commissions composed of selected citizens, who actively safeguard the natural resources of the state and co-operate with the federal government. It has been uphill work, because so few individuals possess vision.

Causes of Forest Destruction

Careless lumbering. Forest destruction is not based merely on our enormous use of timber. Wasteful methods by which only a fraction of the cut timber ever becomes lumber, or cutting hemlock and only using the bark for tanning, leaving the stripped timber a total loss and a fire hazard, are two of the barbarous results for which thoughtless man is responsible. Many lumbermen, to save money, leave the tops and limbs of trees strewn through the woods.



Waste of Lumber. When living trees are cut for commercial purposes less than one-third finally becomes lumber. Seventy per cent is waste.

These small branches soon dry and become veritable fire hazards.

Man has also taken out the trees as a miner takes out ore, with no thought of replacement. If we are to have wood and paper much longer, this " timber mining " must stop. Trees must be replaced as used. The annual growth of timber in the United States is estimated to be about 9,000,000,000 cubic feet, while the annual timber cut totals 14,495,308,000 cubic feet. In 1935 this country imported wood and paper (a product of wood) to an amount totaling $208,343,000. In 1934 we imported 264,000,000 board feet of lumber.

Another waste is in the making of lumber. At present over 70 per cent of the standing trees of the forest is wasted through careless lumbering, handling, or in manufacture.

Fire. Fire is one of the forests' worst foes and, except for lightning, man is to blame in all cases. Sparks from locomotives sometimes start fires, but abandoned campfires of sojourners in wilds, or lighted cigarettes or matches thrown into dry leaves or underbrush are more likely causes.

Forest fires take terrible toll both of timber and of lives. One uncontrolled fire in the Olympic National Forest burned 14,000 acres in four hours. Fires in Minnesota at Hinckley (1904) and at Cloquet (1918) killed 1,800 people. In 1921 there were 38,400 fires, but by 1931 the total had climbed to the staggering figure of 186,894 fires. Better protection in recent years reduced this number to 140,297 fires in 1935. Yet, in that year the area burned was over 30,000,000 acres, *almost exactly equivalent to the entire*

A SEVERE FOREST FIRE. The area in the foreground has already been completely burned out. The forest on the side of the mountain was being burned at the time this photograph was taken.

area of the state of New York. The tangible loss from these fires was $32,579,300, but this does not include the damage to young growth, watersheds, wildlife, and scenic and recreational values.

In addition to destroying timber, fire prevents natural reforestation not only by killing all the young trees but also by burning the humus, thus destroying the fertility of the topsoil and burning the seed in the soil.

The cost of fire protection is mounting year by year. If every individual would be as careful as if he owned the woods, never building a fire on humus but on actual soil or rocks, and never leaving a fire without drenching it with water, or where this is impossible, covering it with sand or soil, always extinguishing lighted matches or tobacco before throwing either away, millions of dollars' worth of forest property would be saved.

Insect enemies. In our study of insects, the damage some of them do to trees was mentioned. The saw fly, bark beetles, wood-boring beetles, western pine beetle, gypsy moth, brown-tail moth, tent caterpillar, and tussock moth are among the worst of the forest pests. The extent and nature of the forest make spraying impossible. Hence we have to rely almost solely on birds to cope with insect enemies, though toads, snakes, and ichneumon flies do their share.

Except in the case of imported pests, nature's balance would protect the forest well enough to preserve it. When foreign insects, however, get a foothold in our forests, without their natural enemies to restrict their spread, the results are likely to be serious. The annual loss of timber from causes other than fire, and chiefly due to insect attacks on trees and lumber, is considered by the Forestry Service to amount to 985,209,000 cubic feet.

Fungus enemies. Although the shelf fungus and many other kinds of fungi attack and ruin trees and lumber, even greater damage is done by less conspicuous forms such as rusts and blights. The chestnut blight, a fungus disease introduced from eastern Asia about 1892, has almost exterminated that valuable tree in eastern United States. The white pine blister rust, another European visitor within the past thirty years, now threatens the white pines throughout the country.

No curative means have been discovered which will save infected trees. However, since the pine rust passes part of its life history on the leaves of the wild currant and gooseberry, destruction of these plants will stop the spread of the rust. Over a million acres of these host plants have been cleared in the northeastern and lake states at a cost of only thirty-five cents per acre. This is a method of forest protection in which anyone who knows a wild currant or gooseberry bush can help.

Weather conditions. Despite their great strength, trees often fall victims to wind and snow, and in many regions great strips are blown down by tornadoes making the almost impassable "windfalls" which later, when dead and dry, furnish ideal fuel for forest fires. Sleet storms destroy many buds and even large branches, especially if followed by severe winds, and thus damage or kill many valuable forest trees.

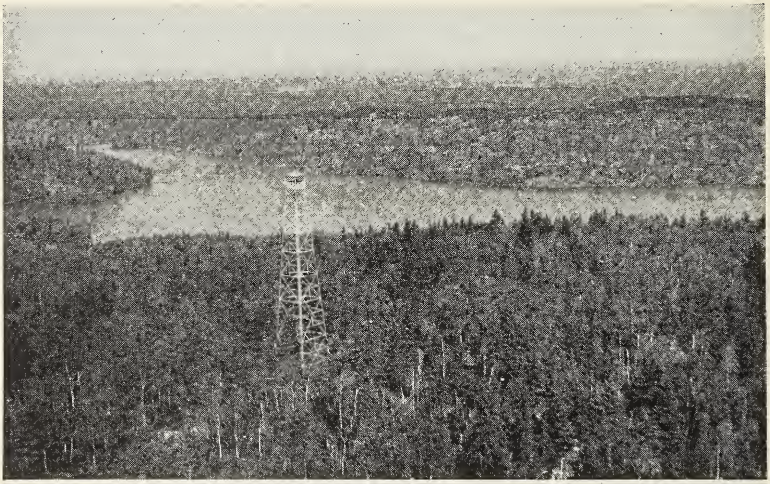
Grazing animals and others. Large herds of cattle or sheep often damage forests by trampling on the young trees and by feeding on the limbs and leaves. Mice, porcupines, and rabbits often girdle the trees by eating their bark, and some little damage is done by birds and squirrels which eat their seeds. Some of these results can be avoided through better control of the animals involved.

Forest conservation methods. Various measures have been established to conserve our remaining timber supply and to increase this supply for future generations. They require the close co-operation of all individuals who visit the forest lands as well as federal, state, and local forest agencies and private lumber companies. These measures include:

1. Fire protection
2. Reforestation and preservation of seed trees in lumbering
3. Operation of a plan of sustained yield
4. Improvement of lumbering operations
5. Reduction of lumber waste
6. Protection of forests from disease.

Fire protection. At present, about two-thirds of our useful forest area has some sort of fire protection. National, state, and private agencies are all helping. The U. S. Forest Service and state Departments of Forestry have established numerous fire towers where "lookouts" watch for fires in order to extinguish them while they are still small. In many timber sections, all areas of the forest are within sight of at least two fire towers. Fire lines are formed by cutting trees to form open areas at regular intervals through the forest. These fire lines are kept clear of underbrush and are used to head off forest fires and to prevent their spread from one area to another.

The states of Washington, California, Oregon, Idaho, and the Province of British Columbia have about 700 regular fire-protection officers and handle some 8,000 fires each year. The forest area which these men guard is as large as the whole of Great Britain and France together, so their task is not an easy one.



Fire Tower in Superior National Forest, Minnesota. This tower is in the heart of the wilderness country. Communication is by radio and supplies are brought in either by canoe and portage or by plane.

Reforestation. In regions which have been swept by fire or cleared by lumbering, reforestation is the only method by which forests may be restored. It is our most pressing forest problem today. To reforest areas which have been so devastated that the forest will never come back naturally, tree nurseries have been established by federal and state Forestry Departments. Millions of seedlings of valuable timber species are set out annually by special forest crews or are distributed at cost to private individuals for reforestation.

Before January 1, 1937, the planting of young trees by the Forest Service on national forest land had covered a total of 760,000 acres. The total numbers of acres planted by all agencies was 3,018,239 acres in the United States.

Operation of a plan of sustained yield. The most satisfactory plan of forest supervision is the sustained yield plan. According to this plan, trees are grown as crops and are harvested when mature. A trained forester surveys a stand of timber and marks certain trees for cutting. Others which may be diseased or crooked are removed to provide space for better specimens. No species unsuitable for timber is permitted to remain. The forest is a continuous crop. Young trees grow in a natural environment and make perfect timber specimens. By *selective cutting* of mature trees and *improvement cutting* of crowded and diseased trees, a stand of desirable timber is maintained continuously.

Improvement of lumbering operations. It is estimated that timber equal to a year's growth of 170 million acres of timber can be saved by improved lumbering operations. Former operations were very wasteful. Large stumps were left, trees were dropped upon other trees, and large amounts of timber were burned with the tops and large branches. Modern methods save much of this. New uses for wood will demand that nearly all parts of a tree be saved.

Reduction of lumber waste. Much waste has formerly resulted from waste of sawed lumber and constructed wooden buildings. Construction lumber has become sufficiently scarce that we are now forced to make use of scraps and preserve our homes and buildings with proper paint. Any measures which will preserve lumber already cut will lessen the demands upon our current timber supply.

Protection from insects and disease. The U. S. Forest Service, the Bureau of Entomology, state agencies, and large lumber companies are co-operating in this work. National quarantine helps prevent importation of foreign pests. The agencies mentioned above are fighting those already here and furnish information about their control. Importation of trees is banned because of the danger of bringing forest pests with them.

A letter to the U. S. Forest Service, the Bureau of Entomology, your state Department of Agriculture, or the Conservation Commission will bring interesting and helpful information as to local conditions.

National forests. The government has set aside 161 timber areas covering more than 175 million acres as national forests. The trees in these forests are closely guarded by expert forest rangers. These men are equipped to fight fires and patrol the forests regularly to guard against theft and vandalism. This work has saved millions of dollars and many lives.

National forests serve many important purposes aside from conservation of timber. Trees are cut regularly, but only under supervised lumbering methods. In this respect, they furnish a considerable portion of our annual *timber* demand. In addition, the national forests supply *homes for wildlife* and aid immeasurably in restoring many game birds and animals which have been greatly reduced in number in past years. In many western states, national forests are used as *grazing areas* during the summer months when drought strikes the great plains. Cattle and sheep may be driven into the forests in limited numbers under supervision. In addition, the national forests serve as ideal *recreational areas.* Tourists by the thousands come to the forests each season to enjoy their beauty and the sport of fishing in the many lakes and streams which they include.

Many of the states have established state forests which operate much in the manner of national forests. In addition to these, many colleges and universities have set aside tracts of timber as experimental areas used in connection with schools of forestry. These national, state, and privately owned forests are of extreme importance in maintaining a supply of timber for future generations.

Wild flowers. Wild flowers need protection. The destruction of the forests by lumbering and frequent forest fires have already reduced the areas where they can grow. Thoughtless picking by tourists has greatly increased since the automobile has widened the area over which flowers can be gathered.

It is no rare sight to see cars returning from the country loaded with drooping dogwood, azalea, or laurel, none of which will be of more than temporary beauty at home. Many flowers once common are now nearly exterminated because of this wholesale picking.

Distribution of wild flowers varies so greatly in different parts of the country that no one list can be made of plants to be protected. But everyone should heed some general rules of wild-flower conservation if we would preserve this source of beauty.

1. Pick no flower that is *rare in your vicinity;* admire them, study them, but "enjoy, not destroy."

2. When picking the more common flowers, do not pull up the roots; few wild flowers bear transplanting.

3. When picking flowering shrubs and trees, don't break large branches, or strip the bark.

Twenty-three states already have framed laws protecting certain wild flowers. They are: Alabama, Arizona, California, Colorado, Connecticut, Delaware, Florida, Illinois, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, North Carolina, Oregon, Pennsylvania, South Carolina, Vermont, Virginia, Washington, and Wisconsin.

Laws, however definite, will not give desired protection without education and publicity. If the schools of our land could enlist all the pupils in a real conservation movement, there would be developed such a regard for the beauty of nature and the rights of others, together with a new individual self-respect, that no legal measures would be necessary to safeguard wild flowering plants.

Conservation of wildlife. Fourteen species of wild birds since 1840 and many species of mammals, fish, and other animals have been exterminated either locally or completely by the advance of so-called civilization and indiscriminate slaughter.

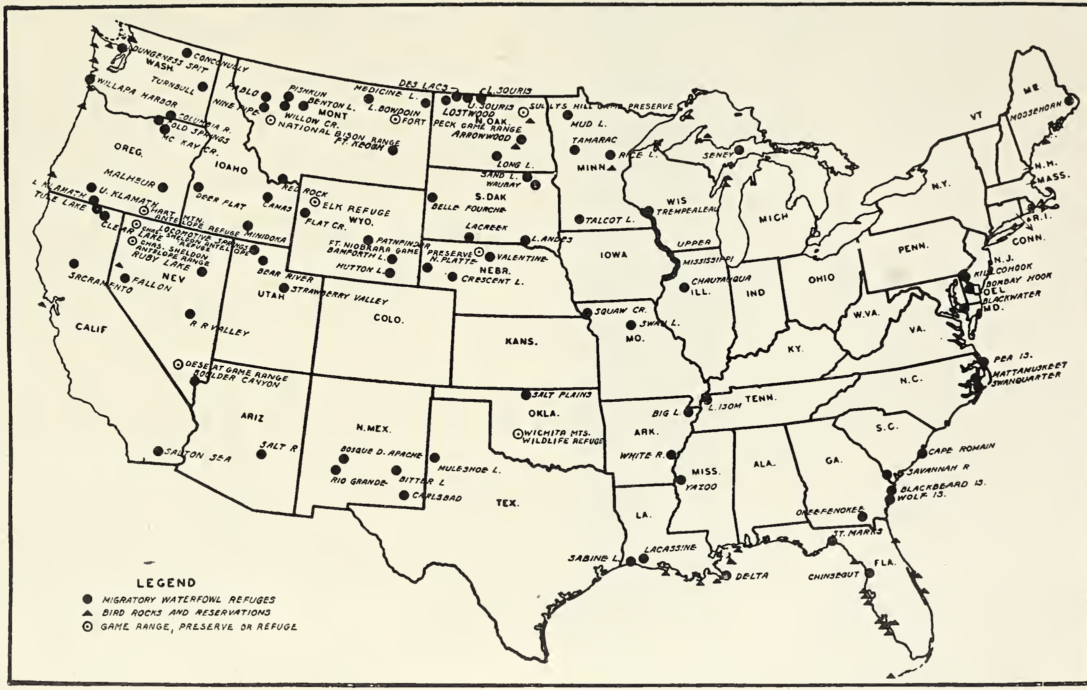
Necessarily, as the country has been developed, land has been cleared and the regions where wild animals and birds can live have been much reduced. In many places, dams now interrupt streams and factories pollute waters so that in many cases fish can no longer live in them. This would cause sufficient loss of life, but greater damage has been done by useless slaughter by man.

The destruction of birds and the means taken to preserve them are discussed in Chapter 36. Due to increased protection many species of birds are increasing in numbers. In many states there are farms where game birds are reared and released to restock regions.

According to the best authorities it is now a world-wide problem to save the wild mammals, especially those which are killed for their fur. During the years 1919–1921 over 100,000,000 skins were sold and many more were taken which were unfit for sale. Among these were 14,000,000 muskrats, 24,000,000 moles, and 13,000,000 opossums. With such a rate of destruction it is no wonder that fur bearers are getting scarce. Even in the depression period of 1930 there were shipped from Alaska 494,547 skins, valued at $2,128,148. A report from the Fish and Wildlife Service shows that in the United States alone the annual traffic in furs has shrunk from $500,000,000 in 1929 to less than $150,000,000. This country already uses more than twice as many foreign as domestic furs. The Fish and Wildlife Service says this: "We are headed straight for a general extermination of fur animals. The same neglect that caused the extermination of the passenger pigeon and the decimation of the buffalo herds and that has brought the migratory waterfowl to a crisis is bringing fur animals there just as fast."

The need is imperative for better laws and their enforcement, together with an intelligent study of the whole question of the conservation of wild fur bearers, which are a natural heritage belonging to future generations as well as to ourselves.

Several animals killed for food or sport are in danger of total destruction in many regions. The bison is gone, ex-



Wildlife Reservations, Ranges, and Refuges. These are under the supervision of the Fish and Wildlife Service, Department of the Interior.

cept for a few herds under government or private protection. Elk and deer are now scarce in places where they were once very abundant, and the Fish and Wildlife Service has endeavored to save these animals in certain places in winter by feeding them hay. State governments also have realized these bad conditions and have taken measures to correct them. Many states have excellent laws wholly forbidding the killing of certain animals and restricting the hunting season for others, so that they will not be killed during the breeding period. There is much agitation for laws providing for humane methods of trapping, so that animals are not left to die in misery in the grip of steel traps. Certain types of traps are forbidden in some states and trappers required to visit traps often. If traps are used they should be of a kind to kill the animal instantly. Many individuals have turned to the rearing of fur-bearing animals — especially the silver fox. Fox farmers in 1934 and 1935 produced 170,000 pelts valued at $7,000,000. Fur farming is conducted in more than 35 states and does not compete with any other type of farming.

Application to the Department of Agriculture in your state or the Conservation Commission will secure information as to the laws which regulate these matters. The United States Department of the Interior publishes a summary of all the state laws, revised each year.

Game sanctuaries. In time of war the land of a non-combatant country is considered "neutral territory." The war of destruction from millions of hunters would quickly have ended in extermination if neutral zones had not been established where animals are completely protected, and where they may breed and roam without molestation.

In June, 1937, the federal government had 387 such game sanctuaries where both mammals and birds are protected. Of these, 131 were national parks and monuments under the supervision of the National Park Service of the Department of the Interior, the largest being Yellowstone Park with an area of nearly 2,000,000 acres. The Wildlife Service has 231 wildlife sanctuaries under its control, with many additions constantly being made. In addition, the Forest Service controls 23 more, one of which, the Grand Canyon National Game Preserve, consists of nearly 900,000 acres. The Wildlife Service has two in Alaska; the Bureau of Lighthouses two in California and two in Louisiana; and the Navy Department six. The areas protected by these divisions of the government total somewhat over 20,000,000 acres of surveyed land, an area equivalent to the state of South Carolina. Thousands of acres are unsurveyed.

Some of the animals specifically protected are bison, elk, antelope, deer, mountain sheep, mountain goats, sea otters, seals, sea lions, bears, caribou, moose, beavers, muskrats, foxes, and raccoons. Birds include ducks, geese, swans, turkeys, grouse, prairie chickens, all shore birds, loons, gulls, and cormorants.

The Fish and Wildlife Service has general supervision of the conservation of birds and mammals. It controls the national reservations and administers laws pertaining to interstate commerce in game, including the placing of surplus animals produced on the preserves. It also investigates the relationship of animals to agriculture, surveys the range of animals and plants, and publishes reports on these and related topics.

The Department of the Interior, through its National Park Service, also

STOCKING A STREAM. These biologists are examining a stream to determine the amount of bottom organisms it contains and thus its fish-productive capacities. Such quantitative studies of fish food are of vital importance as the preliminary work to stocking the stream.

aids in mammal-conservation work. The Department of Agriculture, which among many subdivisions includes the Soil Conservation Service, the Forest Service, and the Bureau of Entomology and Plant Quarantine, publishes many reports which relate to conservation of wildlife.

An agency in wildlife conservation is the Migratory Bird Conservation Commission, which was created through the enactment of the Federal Migratory Bird Conservation Act of February 18, 1929. Since then approximately 125,000 acres of land have been purchased with funds made available for expenditure under the direction of the Migratory Bird Conservation Commission. Nine refuge areas in eight states make up the acreage mentioned.

Fish conservation. The United States produces between two and three billion pounds of fish every year. The total value is not far from a hundred million dollars, and the industry gives employment to over 200,000 persons. This enormous consumption, together with the pollution of the streams, reduction of flow, and construction of dams, has reduced the number of valuable fish.

To minimize the enormous natural mortality, as well as to promote the widest possible distribution of our fresh-water fish, the Wildlife Service, which is a division of the Department of Interior, carries on an extensive program of artificial propagation. In the United States, 472 hatcheries, 81 of them federal, the rest state-controlled, are engaged in this work. Oregon has 42 hatcheries, the largest number of any state; New York has 25 hatcheries. At these institutions, mature fish are captured and stripped of their eggs and sperms. These reproductive cells are then mixed, thus effecting fertilization, and the eggs are developed in the scientifically controlled and protected environment of the hatchery. The young fish are raised to the fry state (recently hatched), fingerling stage (about as long as a finger), or in some states until they are even larger. They are then placed in streams in places where they are most needed. Catfish, shad, whitefish, salmon, trout, lake trout, bass, pike, perch, cod, haddock, and winter flounder are the predominant species of fish propagated. In May, 1930, Congress passed a law providing for 30 new fish-culture stations.

In addition to its hatchery operations, the Wildlife Service co-operates with state governments in improving streams by enlarging spawning grounds, building up riffles and pools, clearing away needless obstructions, and eliminating pollution. In special cases, the Service supervises the construction of fish ladders (a series of pools, each slightly higher than the preceding one, leading from the bottom to the top of a dam) to permit migratory fish to get over obstructing dams.

Our most valuable fish are the marine species. Although there are a few hatcheries in operation where cod, haddock, and flounder are propagated, such means alone cannot perpetuate the supply of these widely distributed fish. Consequently, the Wildlife Service carries on an extensive program of research to show how the fisheries can be managed so as to eliminate waste and to obtain the maximum yield from the fisheries without disturbing the sustaining stock.

As a result of such management of the salmon fisheries in Alaska by the Wildlife Service, those most valuable fish are gradually returning to a state of abundance comparable with that of former years. Likewise, the halibut fishery has been managed during recent years by the International Fisheries Commission of the United States and Canada and as a consequence has shown encouraging signs of improvement.

Summary

The conservation of forest and wildlife is a problem equal in importance to any other phases of the conservation program. Forest destruction has resulted in the depletion of many plants and animals associated with the woodlands. While it has been necessary to reduce the areas of native plants and animals to make room for the expansion of civilization, most of our present problems have resulted from pure waste and carelessness.

Fire leads all other causes of forest destruction. While a few forest fires are caused by lightning, they usually result from man's carelessness. A large staff of trained rangers and fire fighters is necessary to protect our forests from this ever present danger.

In addition to fire protection, forest conservation measures include reforestation and the preservation of seed trees, operation of a sustained yield program, improvement of lumbering operations, reduction of lumber waste, and protection of the trees from disease. National forests, covering more than 175 million acres, serve as a source of timber supply, homes for wildlife, grazing areas, and recreational areas.

Wildlife conservation includes the protection of wild flowers, birds, game and fur-bearing animals, and fish. The various national and state conservation agencies are aided tremendously by numerous private organizations in the entire program of conservation of North American wildlife.

Using Your Knowledge

1. Enumerate man-made and natural causes of forest destruction.

2. Explain how selective cutting and improvement cutting are applied in the operation of a sustained yield.

3. A forest crop, grown under scientific conditions, is a better source of timber than a natural forest. Can you explain why?

4. List four valuable services rendered by national forests.

5. How can you, as an individual, co-operate with the effort to conserve native wild flowers?

6. What measures have been taken to protect native birds and other animals?

7. In what respect are game sanctuaries important in the conservation of wildlife?

8. Why is an extensive hatchery program not a sufficient means of restoring fish to our waters?

Expressing Your Knowledge

national forest	reforestation	grazing area
forest preserve	sustained yield	forest litter
ranger	selective cutting	wildlife
fire tower	improvement cutting	game refuge
fire line	seed tree	sanctuary

Applying Your Knowledge

1. Make a diagram of a forest area and locate two fire towers. Indicate the location of a fire in the forest and show how two rangers can sight the fire from different angles and locate it exactly. Secure the information from your state forestry bureau.

2. Find out where state forests and reforestation areas are located in your state (if a forest state) and indicate their location on an outline map.

3. Prepare an outline map of the United States showing the location of the principal national forests.

4. Prepare a list of suggestions for improvement of lumbering methods.

5. Make a chart of native wild flowers of your vicinity which have become rare because of destruction by man.

6. Make a list of private organizations and societies which are working in the conservation program. Find out the nature of the work of each organization.

Increasing Your Knowledge of This Unit

Arnold, Oren. *Wonders of the West.* Banks, Upshaw and Co., Dallas, Texas. 1936

Baer, M. E. *Pandora's Box.* Farrar and Rinehart, New York. 1939

Beard, Daniel. *Fading Trails.* The Macmillan Co., New York. 1942

Bennett, Hugh H. *Soil Conservation.* The McGraw-Hill Book Co., New York. 1939

Bromfield, Louis. *Pleasant Valley.* Harper and Brothers, New York. 1945

Butler, Ovid M. (Editor). *American Conservation.* Revised Edition. The American Forestry Association, Washington, D. C. 1941

Butler, Ovid M. (Editor). *Rangers of the Shield; a Collection of Stories Written by Men of the National Forests of the West.* The American Forestry Association, 919 Seventeenth St., N.W., Washington 6, D. C. 1934

Cahalane, Victor Harrison. *Meeting the Mammals.* The Macmillan Co., New York. 1943

Chase, Stuart. *Rich Land, Poor Land, a Study of Waste In the Natural Resources of America.* The McGraw-Hill Book Co., New York. 1936

Cheney, E. G. and Schwartz-Hanson, T. S. *This is Our Land.* The Webb Book

Publishing Co., 55–79 E. 10th Street, St. Paul, Minnesota. 1940

Clark, James Lippitt. *Trails of the Hunted*. Little, Brown and Co., Boston. 1928

Ditmars, Raymond L. *Thrills of a Naturalist's Quest*. The Macmillan Co., New York. 1935

Faulkner, E. L. *Plowman's Folly*. University of Oklahoma Press, Norman, Oklahoma. 1944

Gabrielson, Ira N. *Wildlife Conservation*. The Macmillan Co., New York. 1941

Gabrielson, Ira N. *Wildlife Refuges*. The Macmillan Co., New York. 1943

Glover, Katherine. *America Begins Again*. The McGraw-Hill Book Co., New York. 1939

Gustafson, F. S. *Conservation in the United States*. The Comstock Publishing Co., Ithaca, New York. 1944

James, Harlean. *Romance of the National Parks*. The Macmillan Co., New York. 1939

La Monte, F. R. and Welch, M. H. *Vanishing Wilderness*. Liveright Publishing Corporation, New York. 1934

Lord, Russell. *Behold Our Land*. Houghton-Mifflin Co., Boston. 1938

Lorentz, Pare. *The River*. Hackpole Sons, Harrisburg, Penn. 1938.

Pearson, Gilbert. *Adventures in Bird Protection*. D. Appleton-Century Co., New York. 1937

Person, H. S. *Little Waters: Their Use and Relation to the Land*. U. S. Government Printing Office, Washington, D. C.

Rouke, Constance. *Audubon*. Harcourt, Brace and Co., New York. 1936

Rush, William. *Wild Animals of the Rockies*. Harper and Brothers, New York. 1942

Sears, Paul B. *Deserts on the March*. University of Oklahoma Press, Norman, Oklahoma. 1937

Twain, Mark. *Life on the Mississippi*. Harper and Brothers, New York. 1935

Van Dersal, W. R. and Graham, E. H. *The Land Renewed*. Oxford University Press, New York. 1943

Yard, Robert Sterling. *Book of the National Parks*. Charles Scribner's Sons, New York. 1928

Yard, Robert Sterling. (Revised by Story, Isabelle F.). *Glimpses of Our National Parks*. U. S. Government Printing Office, Washington, D. C. 1941

Yearbooks, Dept. of Agriculture. *Soils and Men*, 1938. *Farmers in a Changing World*, 1940. U. S. Government Printing Office, Washington, D. C.

Biology in Our World of the Future

You have studied biology for a year. You have completed a course in which basic information in many fields of biology was presented. You should now have a much better understanding of the many phenomena of life which occur within you and all around you. The things you learned in biology represent the scientific achievement of centuries. Your present knowledge of the science surpasses the entire body of proven facts which comprised biology a few generations ago.

Biology is still growing. Its growth in recent years has been almost phenomenal. Great achievements of today will be the common knowledge of tomorrow. The discovery of penicillin and streptomycin will be recorded as great accomplishments in the science textbooks of the future, but emphasis probably will be placed upon even greater discoveries belonging to the biology of the next ten or twenty years. One needs only examine the research publications of experiment stations, field workers, research foundations, biological companies, clinics, universities, and hospital laboratories to appreciate the tremendous rate at which biology is progressing.

What is to come? What will the biologist write on tomorrow's page? Which of the many unsolved problems will be solved by the persistence and skill of some investigator? This much is certain. Within a month of the publication of this book, some scientist will make an announcement which will outdate certain statements presented in its chapters. This is the progress of science. You have been studying a progressive, dynamic subject. Perhaps you, yourself, will be the investigator to modify, improve upon, or even disprove something you learned in your high-school course in biology.

Biologists still have endless mysteries to explain. How can a salmon, hatched in fresh water, enter the ocean and live equally well in salt water? And why does it always return to fresh water to spawn? What drives the seal on a migratory trip two hundred miles through icy waters to a rocky island like its first home? What strange impulse directs the eel a thousand miles seaward to its traditional spawning ground? The migrations of birds have always stimulated men to wonder and to investigate. We do not yet understand pollination in flowers like *Yucca* and certain orchids, the production of "cold" light by fireflies and deep-sea fishes, the ability of certain organisms to exist without oxygen, and many more such problems.

Perhaps some day biologists will be able to explain more fully many phenomena of the living cell. It may be that photosynthesis will be spoken of as something more than a "marvelous process" occurring in tissues of green plants. Maybe the green plant will eventually yield its food-making secret to a searching scientist and sugar factories will be able to operate with air, water, and sunlight.

The biology of the future will certainly continue and intensify the war on insects. New weapons, even more powerful than DDT, will serve as we press the attack further against the insect world.

Some of the most startling advances will undoubtedly be made in the field of medicine. Penicillin and streptomycin mark only the beginning of a new era of chemotherapy in the treatment of disease. The Atomic Age will no doubt revolutionize much of our medical practice. Newly discovered *isotopes* will enable the biologist to learn much about growth, glandular secretions, and other important aspects of physiology. It is quite possible that the flying *neutrons* and deadly rays which have awed the world in recent years will, in the end, serve mankind in the control of that dread disease, cancer.

The biology of the future will, likewise, include important advances in the field of genetics. Strikingly different varieties of flowers will bloom in our gardens and new and better crop plants and farm animals will render their service as a result of man's hastening improvement of life through the application of new facts concerning inheritance. We may expect that much more light will be thrown upon human inheritance which may lead society to take steps toward a general improvement of the human race.

In at least one respect, the biology of the future will lead us back into the past. Great forests will flourish under the skilled control of conservation experts. We may expect native fish to return to their former haunts, freed of the pollution which destroyed their predecessors. Native birds and animals may find that they have again been given a place in a nation which has paid dearly for their near extermination.

Man is learning to control nature. He has learned, through bitter experience, to live with nature. Perhaps in some future generation, he may learn to live with his fellow man. This is our hope for our world of the future.

Appendix

TABLE OF 100-CALORIE PORTIONS

Foods of Plant Origin

	Approximate Measure	Distribution of Calories		
		Protein	Fat	Carbo-hydrates
Vegetables				
Asparagus	20 large stalks	32	8	60
Beans (baked)	3 heaping tablespoons	21	18	61
Beans (string)	2 heaping tablespoons	22	7	71
Beets	4 (medium size)	15	2	83
Cabbage	5 cups, chopped	20	9	71
Carrots	4–5 (small size)	10	5	85
Cauliflower	$1\frac{1}{2}$ cups	23	15	62
Celery	8 stalks	24	5	71
Corn (canned)	$\frac{1}{3}$ cup	11	11	78
Lettuce	2 large heads	25	14	61
Mushrooms (fresh)	$\frac{1}{2}$ pound	30	8	62
Onions (raw)	3–4 (medium size)	13	6	81
Parsnips (cooked)	2 (medium size)	10	7	83
Peas (green, fresh)	$\frac{3}{4}$ cup	29	4	67
Potatoes (sweet, baked)	1 (small size)	6	5	89
Potatoes (white, baked)	1 (medium size)	11	1	88
Radishes	3 doz. (small size)	18	3	79
Spinach (cooked and chopped)	$2\frac{1}{2}$ cups	12	8	80
Tomatoes (fresh)	2–3 (medium size)	16	16	68
Tomatoes (canned)	$1\frac{3}{4}$ cups	21	8	71
Fruits and Nuts				
Apple	1 (large)	3	5	92
Banana	1 (large)	5	6	89
Brazil nuts	2	10	86	4
Cherries (unstoned)	$1\frac{1}{3}$ cups	5	10	85
Currants	$1\frac{1}{2}$ cups	12	...	88
Dates (unstoned)	3–4	2	7	91
Figs (dried)	$1\frac{1}{2}$ (large)	6	1	93
Grapes	1 large bunch	5	16	8
Lemon juice	1 cup	..	...	100
Lemons	3	10	15	75
Olive oil	1 tablespoon	..	100	...
Orange juice	1 cup	..	...	100
Oranges	1 (large)	7	2	91
Peaches	3	6	3	91
Peanuts	20	20	63	17
Pears	1 (large)	4	6	90
Pineapple	2 slices, 1 inch thick	4	6	90
Prunes (stewed)	2 prunes and thin juice	2	...	98
Raisins	$\frac{1}{4}$ cup	3	8	89
Strawberries	$1\frac{1}{3}$ cups	10	15	75

	Approximate Measure	Distribution of Calories		
		Protein	Fat	Carbo-hydrates
Bread and Pastry				
Bread, Boston brown	¾ in. slice, 3 in. in diameter	10	10	80
Bread, graham	3 small slices	15	6	79
Bread, white	3 medium slices	14	6	80
Cookies	2	6	33	61
Crackers, graham	2	10	20	70
Crackers, soda	4	10	20	70
Doughnuts	½	6	45	49
Griddle cakes	1	15	25	60
Macaroons	2	10	14	76
Rolls	1	12	8	80
Candy				
Chocolate fudge	piece 1½ × ¾ × 1 inches	2	21	77
Chocolate (sweet milk)	piece 2¼ × 1 × ⅛ inches	7	58	35
Honey	1 tablespoon	1	..	99
Sugar (white)	2 level tablespoons	..	..	100
Cereals				
Cornflakes	1½ cups	6	4	90
Cornmeal	1 serving	10	5	85
Oatmeal	1 liberal serving	17	17	66
Rice (strained)	¾ cup	9	1	90
Wheat (shredded)	1	14	5	81

Foods of Animal Origin

	Approximate Measure	Distribution of Calories		
		Protein	Fat	Carbo-hydrates
Meats				
Beef (sirloin)	small steak	30	70	...
Chicken	1 large serving	55	45	...
Eggs	1 (large)	34	66	...
Lamb (chops)	1 chop	40	60	...
Lamb (roast)	1 large serving	41	59	...
Mackerel (broiled)	½ small fish	56	44	...
Oysters	1 dozen	49	22	29
Pork (loin)	1 small serving	20	80	...
Salmon (canned)	½ cup	46	54	...
Veal (leg)	1 large serving	72	28	...
Dairy Products				
Butter	1 small portion	1	99	...
Cheese (American)	1½ cu. inches	25	72	3
Cream (heavy)	1 overflowing tablespoon	2	96	2
Milk	¾ cup	18	52	30

Comparative Nutritional Chart

Name of Food	Vitamins				Minerals		Reaction	
	A	B	C	D	Phos.	Calc.	Acid	Alkaline
Vegetables								
Asparagus	+ +	+ + +	......	......	+	+ +	......	+
Beans, Kidney (canned)	+	+ + +	......	......	+ + +	+ +	......	+ +
Beans, Navy (cooked)	+	+ + +	......	......	+ + +	+	......	+ + +
Beans, (Lima)	+	+ + +	+	......	+ + +	+ +	......	+ + +
Beans, String (cooked)	+ +	+ +	......	......	+ +	+ +	......	+ +
Beans, Soy (cooked)	+	+ + +	......	......	+ + +	+ + +	......	+ +
Beets (root)	+	+	+	......	+	+	......	+ + +
Brussels Sprouts	+ +	+ + +	+	......	+ +	+	......	+
Cabbage (raw)	+ +	+ + +	+ + +	......	+	+ +	......	+ +
Cabbage (cooked)	+	+ +	+	......	+	+ +	......	+ +
Carrots (fresh raw)	+ + +	+ +	+ +	......	+ +	+ +	......	+ + +
Carrots (cooked)	+ +	+ +	+	......	+ +	+ +	......	+ + +
Cauliflower	+	+ +	+	......	+ +	+ + +	......	+ +
Celery	+	+ +	......	......	+	+ +	......	+ +
Chard	+ +	+	......	......	+	+ + +	......	+ +
Corn (fresh — yellow)	+ +	+ +	+	......	+ +	......	+	......
Cucumber	+	+	+ +	......	+	+	......	+ +
Dandelion Greens (cooked)	+ +	+ +	+	......	+ +	+ + +	......	+ +
Lettuce	+ +	+ +	+ + +	......	+	+ +	......	+ +
Onions (raw)	+	+ +	+ +	......	+	+	......	+
Parsnips	+	+ +	......	......	+ +	+ +	......	+ + +
Peas (cooked)	+ +	+ +	+ +	......	+ + +	+	......	+
Potatoes, Sweet (cooked)	+ +	+ +	+	......	+	+	......	+ + +
Potatoes, White (baked)	+	+ +	+	......	+ +	+	......	+ + +
Radishes	......	+ +	+ +	......	tr	......	......	+
Rhubarb (cooked)	......	......	+	......	+	+ +	......	+ +
Spinach (cooked)	+ + +	+ + +	+	......	+ +	+ + +	......	+ + +
Squash (cooked)	+ +	......	......	......	+	+	......	+
Turnip (cooked)	+	+ +	......	......	+	+ +	......	+
Turnip Greens (cooked)	+ + +	+ +	+	......	+ +	+ + +	......	+ +
Meats — Fish								
Fish (average)	+	+	......	tr	+ + +	+	+ + +	......
Kidney (beef)	+ +	+ +	+	......	+ + +	......	+ +	......
Liver (beef-pig)	+ +	+ +	+ +	......	+ + +	+	+	......
Meat (average)	+	+ +	+	......	+ + +	......	+ + +	......
Oysters (raw)	+ +	+ +	+	tr	+ + +	+ +	+ + +	......
Sweetbreads	+	+	......	......	+ + +	......	+ +	......
Nuts — Fruits								
Almonds	+	+ +	......	......	+ + +	+ + +	......	+ + +
Apples (raw)	+	+	+	......	+	......	......	+ +
Bananas (raw)	+ +	+	+ +	......	+ +	......	......	+ + +
Cantaloupe	+ +	+ +	......	......	+	+	......	+ + +
Cranberries (cooked 3 min. unstirred)	......	......	+ + +	......	+	+	+	......
Grapefruit	+	+ +	+ + +	......	+	+	......	+ +
Grapes	+	+ +	+	......	+	+	......	+ +
Lemon Juice (fresh)	+	+ +	+ + +	......	+	+	......	+ +
Orange Juice (fresh)	+ +	+ +	+ + +	......	+	+ +	......	+ + +
Pears	+	+	+	......	+	+	......	+
Pineapple (fresh or canned)	+ +	+ +	+ +	......	+	+	......	+ + +
Prunes (dried)	+ + +	+ +	......	......	+ +	+ +	+	......
Raisins	......	+	......	......	+ +	+ +	......	+ + +
Raspberries (fresh)	......	......	+ +	......	+ +	+ +	......	+
Tomatoes	+ +	+ + +	+ + +	......	+	+	......	+ +
Dairy Products								
Butter	+ + +	......	......	+ V	......	......	......	......
Buttermilk	+	+ +	+	......	+ + +	+ + +	......	+ +
Cheese	+ +	+	......	......	+ + +	+ + +	+ +	......
Eggs (yolk)	+ + +	+ +	......	+ + V	+ + +	+ +	+ + +	......
Milk (whole)	+ + +	+ +	+	+ V	+ + +	+ + +	......	+ +
Grain Products								
Barley (pearled)	+	+ +	......	......	+ +	......	+	......
Oatmeal (cooked)	+	+ +	......	......	+ +	+ +	+ +	......
Rice, Whole (cooked)	......	+ +	......	......	+	......	+	......
White Bread	+	+	......	......	+	......	+	......
Rye Bread	+	+ +	......	......	+ +	+	+	......
Wheat, Whole	+	+ + +	......	......	+ + +	+	+ +	......
Fats and Oils								
Lard or Olive Oil	+	......	......	......	......	......	......	......
Margarine, Oleo	+	......	......	......	......	......	......	......
Cod-Liver Oil, and other fish oils	+ + +	......	......	+ + +	......	......	......	......

Courtesy of General Baking Co.

Key: + + + excellent source. + + fair source. + weak source. *tr* trace. V 500% variation in the vitamin-D content.

FIRST AID TREATMENT FOR EMERGENCIES

Bruises. Symptoms: swelling; black and blue spot; pain.

Treatment: Very cold applications of water at once; alcohol or witch hazel; raise injured part.

Sprain. Symptoms: swelling at joint; severe pain, increased by movement.

Treatment: Cold packs for several hours; absolute rest. Call doctor for severe sprain, especially of ankle.

Dislocation. Symptoms: deformity of joint; limited movement; intense pain and swelling.

Treatment: Send for doctor. Do not try to reduce a dislocation except of jaw or finger. Get patient in easy position; treat joint with hot or cold compresses.

Fracture (broken bone). Symptoms: pain and tenderness; deformity; loss of rigidity; grating of broken ends.

Treatment: Do not move broken parts; send for doctor; prevent movement by support on pillow or folded coat.

If patient *must* be moved, the injured limb should be well padded and "splints" bound alongside which will entirely prevent motion. Flat pieces of wood, canes, umbrellas, wire netting, heavy cardboard, rolled blankets, or clothing may be used for splints. Belts, scarfs, or handkerchiefs will hold them in place.

Ordinary wounds. If a wound does not bleed, aid bleeding by pinching. Do not handle cut surface, nor wash with water. Treat at once with 2% tincture of iodine. Cover with sterile dressing if possible. Adhesive plaster should not be used except to hold the dressing in place.

Strong antiseptics, like bichloride of mercury or carbolic acid, destroy white corpuscles and should not be used.

Wounds with hemorrhage (bleeding). Symptoms: blood flow from arteries comes in spurts, and the blood is bright red; blood from veins comes in steady flow and is a little darker color.

Treatment: Send for doctor. Unless wound is on the head, keep head low and wound high; keep patient quiet. Try to check bleeding at once. For arterial bleeding apply pressure between wound and heart. For venous bleeding apply pressure on the wound itself.

Arterial bleeding from scalp wound may be checked by bandage around head just above the ears or by pressure on the temporal artery which can be felt in front of the ear, above the joint of the jaw.

Other head wounds may be controlled by pressure on carotid arteries which are found by pressing backward, deeply, into the neck along the muscle that extends behind the jaw to the base of the ear.

The subclavian artery which supplies the arm may be reached by pressing the thumb strongly into the hollow, behind and above the collar bone. The brachial artery of the upper arm can be compressed just behind the inner edge of the large arm muscle. For the hand, use pressure on the " pulse " and on the opposite side of the wrist.

The femoral artery supplying the leg can be compressed on the inside of the upper leg near the body. For the lower leg or lower arm, make a hard pad as large as an egg and bend the knee or elbow sharply over it.

A tourniquet, used to stop bleeding, consists of a pad and strap. The pad may be a smooth stone or other hard substance wrapped in the strap; the strap may be a towel, handkerchief, or tie. The pad is placed exactly over the artery, the strap loosely wound twice around the limb and pressure applied by twisting the outer loop with a stick.

Tourniquets can only be used to advantage on the brachial artery of the upper arm and on the femoral artery of the upper leg. Do not use one unless necessary and never leave it in place continuously for over two hours; release as soon as bleeding stops.

Important. Practice locating these arteries until you can find them quickly. Do not wait till the emergency comes. It is not easy even when you are not excited. If you really want to use this information, practice it in advance. Better still, get your family doctor to help you or take the First Aid work in courses offered by the Boy Scouts, Campfire Girls, or the Red Cross.

Nose bleed. Harmless except when prolonged and severe.

Treatment: Loosen neck clothing; hang head over back of chair; apply cold water to back of neck. Pressure on upper lip at base of nose; plug nostril with cotton.

Burns. The best way to treat a burn is not to have one. Most fires and many burns result from carelessness, and could be avoided.

Clothing on fire can be smothered by wrapping from head downwards in rug or blanket. Do not run. A wet cloth over the nose and crawling close to floor will help breathing in smoke-filled rooms.

Treatment: Exclude air with paste of water and flour or starch. Vaseline or olive oil is good. Picric acid gauze or solution of Epsom salts is an excellent dressing. Never dress a burn with absorbent cotton.

Deep burns or even blisters, if extensive, should have a doctor's care.

Acids and alkalies cause burns similar to those caused by heat.

Treatment: Wash with water; neutralize alkalies with vinegar or lemon juice; neutralize acids with limewater; use *dilute solutions* of limewater or vinegar respectively. For either acid or alkali in eyes *wash out* with much water.

Poisons. 1. Corrosive poisons: strong acids like sulphuric, nitric, or hydrochloric; strong alkalies like lye, caustic soda, and lime.

Treatment: (*a*) Neutralize acid with magnesia, baking soda, soap, or wall plaster. Neutralize alkalies with vinegar, lemon, or orange juice.

(*b*) Dilute and soothe with large doses of olive oil, salad oil, water, milk, flour and water, or raw eggs.

(*c*) Stimulate by drinking tea or coffee, and by using smelling salts.

2. Irritant poisons: Paris green; bichloride of mercury (antiseptic tablets); arsenic or phosphorous poisons for rats, etc.; plant poisons.

Treatment: (*a*) Produce vomiting *at once* by some means. Run finger down the throat; give much warm water and mustard or salt and water. Syrup of ipecac is good.

(*b*) Dilute and soothe as for corrosives only use *no oils where phosphorus is concerned.*

(*c*) Stimulate as for corrosives.

3. Nerve poisons producing sleep: opium, morphine, laudanum, paregoric, soothing syrup.

Treatment: (*a*) Emetic.

(*b*) Keep awake with strong coffee, and walking.

(*c*) Artificial respiration if unconscious.

Nerve poisons producing convulsions: strychnine, belladonna.

Treatment: (*a*) Emetic instantly.

(*b*) Artificial respiration if breathing stops.

Artificial respiration. The following directions for the Schaefer Method of resuscitation are taken from "Red Cross Life Saving Methods" by permission of the American National Red Cross, Washington, D. C., from whom much other valuable information may be had. This method may be used for stoppage of respiration from drowning, smoke or gas, electric shock, or certain poisons.

In application of artificial respiration, SAVE THE SECONDS AND YOU HAVE A BETTER CHANCE OF SAVING THE LIFE. Don't waste time carrying victim to a quiet spot. Waste no time trying to get harmless water out of the stomach. Turn subject face down and GO TO WORK *INSTANTLY.*

CAUTION. Often inexperienced or excited persons attempt to administer artificial respiration when there is no need for such treatment. It is required only when the victim is unable to breathe. If the victim is unconscious, but breathing, he requires treatment for fainting or shock; that is, raising the feet, leaving the head low; applying stimulants such as aromatic spirits near nose; rubbing limbs and body toward the heart to stimulate circulation.

Procedure. Lay the victim face downward on a flat surface or with his head slightly downhill. Turn his head to one side, extend both arms up beyond head and place one hand under the face to protect his open mouth and nose from dirt. Kneel (straddling one or both knees) facing subject's head.

Place hands over lower ribs, one on each side of backbone and about four inches apart, thumbs and fingers together. If hands are in correct position, the little finger of each hand is over and following the line of lowest rib.

Move the weight of your body slowly downward and forward for about three seconds — don't slide. Keep arms straight. The shoulders should be behind the hands, so that pressure exerted is forward. Then withdraw the hands quickly, allowing the ribs to expand, filling lungs with air. Swing body slowly backward to upright position, thus relaxing muscles of back.

At the end of two seconds again place hands in position and apply pressure. This timing (three seconds pressure and two seconds release) allows five seconds for one complete respiration, assuring twelve respirations per minute. This is fast enough and will make it possible for the operator to continue for some time without exhaustion.

To assist in properly timing these movements, repeat either silently or aloud during the period of pressure *"out goes the bad air."* Then *snap* off the hands and repeat during the period of release, *"in comes the good."*

Supplemental treatment. As soon as helpers arrive, put them to work. Send for a doctor, for warm bottles or bricks, and for tea or coffee for stimulation. When you need rest from the administration of artificial respiration, let one of your helpers take your place. One may clean the patient's mouth, stimulating reflexes by moving the tongue back and forth. Patient's clothing may be loosened, and his body and limbs rubbed toward the heart to stimulate circulation. Coverings and heated articles may be applied. (Be careful not to burn the patient.)

Aromatic spirits of ammonia may be placed near the patient's nose at frequent intervals. All of this treatment is helpful, but must not be allowed to interfere with, or interrupt for one second, the process of artificial respiration.

Don't give up! Persons who have been under water as long as thirty minutes have been resuscitated by this simple method. Even if no results are seen, the subject should not be abandoned until at least two hours' effort has been made to revive him.

When the subject begins to breathe and can swallow, give a teaspoonful of aromatic spirits of ammonia (NOT household ammonia) in half glass of water. Hot water, tea, or coffee may be used as a stimulant if ammonia is not available.

Don't allow patient to walk or exert himself. After such an experience, a person requires medical attention and should be put to bed.

CONTROL OF HARMFUL PLANTS

To kill poison ivy and poison oak plants. Dissolve 1 pound of potassium chlorate and 1 pound of calcium chloride in about 2½ gallons of water. Spray this mixture on the plants while the sun is shining. In a few days the leaves will begin to turn yellow and die. Sometimes two doses may be needed to kill the plant.

Preventive and remedy for poison ivy and poison oak. Mix equal parts of ferrous chloride and ferric chloride in the proportion of 1 part of the combined chlorides to about 100 parts of water. Wet the hands and those parts likely to be exposed to poison ivy and allow the mixture to dry on the skin. This mixture may be used as a remedy for poison-ivy blisters. Ferric chloride alone (the standard solution) may also be used, somewhat diluted. Use cotton to wet the skin with the solution and let it dry on the skin. Then cover with flexible collodion solution.

Antimildew mixture. Thoroughly dissolve ½ pound of sugar of lead and ½ pound of alum in a pail of warm water. This will take some time, and there will be a sediment. Pour off the clear liquid into a tub or barrel. Soak the cloth or tent in this clear liquid for 24 hours. Hang up, but do not wring out. If the tent is new, wash before treating, in order to remove starchy sizing. Make up more solution in the proportions given. One antimildew treatment will be effective for several years.

CLASSIFICATION OF ORGANISMS

PLANTS

PHYLUM I

THALLOPHYTA (75,000 species)

These are the simplest plants, without roots, stems, or leaves. Most are many-celled, some one-celled. Some possess chlorophyll; others do not. Reproduction is mostly by asexual methods.

Subphylum A — *Algae,* aquatic plants with chlorophyll (18,000 species)

Class 1. **Cyanophyceae:** Blue-green algae (Nostoc; Oscillatoria)

Class 2. **Chlorophyceae:** Green algae (Spirogyra; Protococcus; diatom; desmid)

Class 3. **Phaeophyceae:** Brown algae (Fucus; kelp; sargassum)

Class 4. **Rhodophyceae:** Red algae (seaweed)

Subphylum B — *Fungi,* non-green saprophytic or parasitic thallophytes (90,000 species)

Class 5. **Schizomycetes:** Bacteria (bacillus; coccus; spirillum)

Class 6. **Myxomycetes:** Amorphous, slimy growths (slime mold)

Class 7. **Phycomycetes:** Algae-like fungi (black mold; blight; mildew; bread mold)

Class 8. **Ascomycetes:** Sac fungi (yeast; lichen)

Class 9. **Basidiomycetes:** Club fungi (puffball; mushroom; smut; rust)

PHYLUM II

BRYOPHYTA (23,000 species)

These are multicellular green plants living on land. They have alternation of generations, in which the gametophyte generation is the part commonly seen. They are without vascular systems and reproduce by spores.

Class 1. **Hepaticae:** Liverworts (Riccia; Marchantia)
Class 2. **Musci:** Mosses (pigeon-wheat moss; Sphagnum)

PHYLUM III

PTERIDOPHYTA (9,800 species)

These are plants with alternation of generations in which both generations are green. The sporophyte is the conspicuous, leafy organism. They are mostly terrestrial plants, with true roots, stems and leaves with vascular systems; reproduction by spores.

Class 1. **Filicineae:** Ferns (wood fern)
Class 2. **Equisetineae:** Horsetails (Equisetum)
Class 3. **Lycopodiaceae:** Club mosses (Selaginella, Lycopodium)

PHYLUM IV

SPERMATOPHYTA (195,630 species)

These are seed plants with alternation of generations in which the gametophyte is parasitic upon the conspicuous sporophyte. Sexual reproduction is by means of true seeds. They are provided with vascular systems.

Subphylum A — *Gymnospermae* (630 species); Plants whose flowers have reduced parts and whose seeds are not covered

Class 1. **Cycadales:** Fernlike gymnosperms (Cycas)
Class 2. **Ginkoales:** (Ginko)
Class 3. **Coniferae:** Evergreens (pine; spruce; cedar; hemlock; Sequoia; etc.)

Subphylum B — *Angiospermae* (195,000 species); The typical flowering plants of the world, bearing true seeds with an ovary

Class 4. **Monocotyledones** (40,000 species): Embryo with one cotyledon; vascular bundles scattered through the stem structure; flower parts in threes or sixes; leaves parallel-veined (grass; lily; sedge; rush; etc.)
Class 5. **Dicotyledones** (155,000 species): Embryo with two cotyledons; vascular bundles forming a cylinder around the pith in the stem; netted-veined leaves (buttercup; rose; apple; elm; etc.)

ANIMALS

PHYLUM I

PROTOZOA (15,000 species)

This includes all unicellular animals. Reproduction is by means of fission or spores.

Class 1. **Rhizopoda:** Protozoa which form pseudopodia (Amoeba; fossil eozoon)
Class 2. **Mastigophora:** Protozoa with one or more whiplike threads, each called a flagellum (Euglena; Volvox)
Class 3. **Ciliata:** Protozoa with many cilia and usually two nuclei (Paramecium; Vorticella; Stentor; Prorodon)
Class 4. **Sporozoa:** Parasitic Protozoa with reduced organs; reproduce by means of spores (Plasmodium malariae)

PHYLUM II

PORIFERA (2,500 species)

This includes both marine and fresh-water sponges. They are many-celled animals (metazoans) with body of two layers, penetrated by many pores. Body structure includes cells and a " skeleton " of silicious or calcareous spicules or of horny spongin.

Class 1. **Calcarea:** Small marine sponges with calcareous spicules (Grantia; fossil sponge)

Class 2. **Hexactinellida:** Deep-sea sponges with a " skeleton " of silicious spicules (Venus's-flower-basket)

Class 3. **Demospongiae:** Sponges with a " skeleton " of spongin or a combination of spongin and silicious spicules, fresh-water and marine sponges, including all commercial sponges (bath sponges)

PHYLUM III

COELENTERATA (5,000 species)

This includes attached or free-swimming two-layered metazoans with a baglike body cavity and a single opening to the outside. They live as solitary individuals or in colonies. All possess stinging cells and most of them have tentacles.

Class 1. **Hydrozoa:** Without mesenteries or walls inside the body: in the solitary type (Hydra), reproduction asexually by means of buds and also sexually by means of eggs and sperms; in the colonial type (hydroid), alternation of generations with reproduction sexually (medusa) and asexually (polyps; fossil cup corals)

Class 2. **Scyphozoa:** Exclusively marine forms, mostly with mesenteries, some having alternation of generations (large jellyfish; Portuguese man-of-war)

Class 3. **Anthozoa:** Marine forms, solitary or colonial, without alternation of generations; body cavity with mesenteries; many tentacles (sea anemone; coral; sea fan)

PHYLUM IV

PLATYHELMINTHES (6,500 species)

These are flatworms with a ribbonlike body, not truly segmented, and with no body cavity.

Class 1. **Turbellaria:** Free-living forms, aquatic or terrestrial (Planaria)

Class 2. **Trematoda:** Parasitic forms with mouth at anterior end (liver fluke)

Class 3. **Cestoda:** Parasitic forms, adapted by a hooked scolex to hang in the intestine of host; body a series of detachable proglottids (tapeworm)

PHYLUM V

NEMATHELMINTHES (3,500 species)

Elongated, unsegmented, round worms with body cavity.

Class 1. **Nematoda:** Some forms parasitic (vinegar eels; trichina; threadworm; hookworm)

PHYLUM VI

ECHINODERMATA (5,000 species)

These are marine forms, radially symmetrical when adult and possessing a spiny exoskeleton composed, in some types, of calcareous plates. Most forms have tube feet for locomotion.

Class 1. **Asteroidea:** Body usually with five rays and double rows of tube feet in each ray; eyespot (starfish)

Class 2. **Ophiuroidea:** Slender arms (brittle stars)

Class 3. **Echinoidea:** Body spherical or disc-shaped; no rays (sea urchin; sand dollar)

Class 4. **Holothurioidea:** Elongated, thickened body with tentacles around the mouth (sea cucumber)

Class 5. **Crinoidea:** Flowerlike, with calcareous plates (sea lilies; sea feathers; fossil crinoid)

Phylum VII

Rotifera (1,500 species)

These are small aquatic organisms with rows of cilia near the mouth (rotifer)

Phylum VIII

Annelida (5,000 species)

These are segmented worms with the body cavity separated from the digestive tube and unjointed appendages.

Class 1. **Chaetopoda:** Fresh-water, marine, and terrestrial forms with bristles on the sides of the body (Nereis; earthworm)

Class 2. **Hirudinea:** No bristles; suckers at both ends (leech)

Phylum IX

Mollusca (80,000 species)

This includes unsegmented and soft-bodied forms with a mantle which usually secretes a univalve or bivalve calcareous shell. Most forms have a muscular foot. There are terrestrial, fresh-water, and marine forms.

Class 1. **Gastropoda:** Flat-footed, with or without coiled shells (slug; snail; fossils)

Class 2. **Pelecypoda:** Ax-footed, with bi-valve shell (mussel; oyster; clam, scallop; shipworm)

Class 3. **Cephalopoda:** Head-footed, with long tentacles around mouth (squid; octopus; chambered nautilus; cuttlefish; fossils)

Phylum X

Arthropoda (674,500 species)

These have segmented bodies and appendages and chitinous exoskeletons. There are terrestrial, aerial, and aquatic forms.

Class 1. **Crustacea** (20,000 species): Head and thorax fused; breathe by means of gills; two pairs of antennae; exoskeletons of larger forms hardened by calcareous deposits (crayfish; lobster; barnacle; crab; cyclops and Daphnia)

Class 2. **Myriapoda** (2,000 species): Elongated bodies with many segments, each bearing one pair of legs (centipede) or two pairs of legs (millepede); breathe by means of tracheae

Class 3. **Arachnida** (27,500 species): Head and thorax fused; no antennae; four pairs of legs; breathe by means of lung books or tracheae (spider; scorpion; daddy longlegs; mite; tick)

Class 4. **Insecta:** (625,000 species): Head, thorax, and abdomen; six legs; one pair of antennae; breathe by means of tracheae or gills; usually two pairs of wings

Order 1. *Odonata:* Biting mouth parts; strong, membranous wings; incomplete metamorphosis (dragonfly and damsel fly)

Order 2. *Orthoptera:* Biting mouth parts; two pairs of wings, outer pair much thickened; incomplete metamorphosis (grasshopper; roach; cricket; walking stick; mantis; katydid)

Order 3. *Hemiptera:* Piercing and sucking mouth parts; wingless or with front pair of wings folded over hind wings; incomplete metamorphosis (true bugs: squash bug; chinch bug; bedbug; water strider; water bug; back swimmer)

Order 4. *Homoptera:* Piercing and sucking mouth parts; wingless or with four wings; incomplete metamorphosis (aphid; leaf hopper; tree hopper; cicada and scale insect

Order 5. *Lepidoptera:* Sucking

mouth parts in adult, biting in larva; four wings covered with colored scales; complete metamorphosis (butterfly; moth; skipper)

Order 6. *Diptera:* Piercing and sucking mouth parts; two wings; complete metamorphosis (fly; mosquito)

Order 7. *Coleoptera:* Biting mouth parts; four wings, the front pair much hardened; complete metamorphosis (true beetles; ground beetle; potato beetle; weevil; ladybird beedle; Japanese beetle; firefly; Calosoma beetle; boll weevil)

Order 8. *Hymenoptera:* Biting and sucking mouth parts; four wings; complete metamorphosis (bee; ant; wasp; ichneumon fly; hornet; gall fly; etc.)

Phylum XI

Chordata (40,000 species)

These possess a notochord, usually temporary; gill slits, temporary or permanent; and a dorsal nerve cord. They never have more than four legs.

Subphylum A — *Entropneusta,* a group of primitive chordates whose bodies are composed of three distinct regions; a proboscis, a collar, and a trunk. (Glossobalanus; Rhadopleura)

Subphylum B — *Tunicata* or *Urochorda,* marine animals with saclike body in adult, but better developed in the larva with a temporary notochord in the tail (sea squirts)

Subphylum C — *Cephalochordata,* marine, fishlike animals with a permanent notochord (Amphioxus or lancet)

Subphylum D — *Vertebrata,* animals in most of which the notochord has been replaced by a segmented column of vertebrae which protects the dorsal nerve cord

Class 1. **Cyclostomata:** Fresh-water or marine eel-like forms without true jaws, scales, or fins, and with a skeleton of cartilage (lamprey; eel; hagfish)

Class 2. **Elasmobranchii:** Fishlike forms with true jaws and fins; gills present but not free and opening through slits; no air bladder, cartilaginous skeleton (shark; ray; skate)

Class 3. **Pisces:** True fish: fresh-water and marine forms with gills free and attached to gill arches, one gill opening on each side; true jaws and fins; bony skeleton; two-chambered heart; cold-blooded; numerous eggs

Subclass 1. *Ganoidei:* Mostly extinct forms with armored body, heterocercal tail, and air bladder with duct (sturgeon; garpike; amia; fossil armored fish)

Subclass 2. *Teleostei:* Common bony fish; tail rarely heterocercal; air bladder (with or without duct) present or absent; numerous eggs (perch; trout; salmon; eel; bass; catfish; sucker; shiner; pickerel; flounder; cod; haddock; etc.

Subclass 3. *Dipnoi:* Air bladder connected with throat and used as a rudimentary lung (Ceratodus of Australia; Protopterus of Africa; Lepidosiren of South America)

Class 4. **Amphibia:** Fresh-water or terrestrial forms, all having gills at some stage; naked skin; three-chambered heart; cold-blooded; numerous eggs, usually laid in water; metamorphosis

Order 1. *Apoda:* Worm-like Amphibia with tail short or lacking; without limbs or limb-girdles; small scales embedded in the skin (caecilians)

Order 2. *Caudata:* Body long with distinct tail throughout life (salamander; newt; Necturus; Siren, etc.)

Order 3. *Salientia:* Body short and tailless; all four limbs present; hind legs adapted for leaping; young called tadpoles; breathe by means of gills in larva, by means of lungs in adult (frog; toad; tree frog)

Class 5. **Reptilia:** Terrestrial or semi-aquatic forms; breathe by lungs at all stages; scaled; cold-blooded; legs vestigial in one order; eggs relatively few, large, and leathery; oviparous or ovoviviparous

Order 1. *Lacertilia:* Eyelids movable; mouth not dilatable; limbs four, rarely vestigial; tail long and brittle or fleshy (iguana; Gila monster; fence lizard; chameleon; horned toad; etc.)

Order 2. *Serpentes:* Body elongated; vestigial limbs; scales molted with outer skin at intervals; mouth dilatable; forked tongue; no movable eyelids or external ears (hognose snake; copperhead)

Order 3. *Chelonia:* Body enclosed between two bony shields or shells, usually covered with large scales or plates; toothless (painted terrapin; Galapagos tortoise; green turtle; hawksbill turtle, etc.)

Order 4. *Crocodilia:* Large, heavily scaled body with muscular tail; heart approaching four-chambered condition (alligator; crocodile)

Class 6. **Aves.** The only animals possessing feathers; warm-blooded with complete double circulation from a four-chambered heart; breathe by means of lungs throughout life; front limbs modified as wings; hollow bones

Order 1. *Strigiformes:* Nocturnal birds of prey (owl)

Order 2. *Falconiformes:* Large birds of prey (hawk; eagle; vulture; condor)

Order 3. *Anseriformes:* Short-legged waterfowl (duck; goose; swan)

Order 4. *Galliformes:* Fowl-like birds (hen; turkey; quail; heath hen; grouse; prairie chicken; etc.)

Order 5. *Charadriiformes:* Shore birds (snipe; curlew; plover; gull; tern; etc.)

Order 6. *Columbiformes:* Pigeons and doves (mourning dove; passenger pigeon)

Order 7. *Ciconiiformes:* Long-legged waders (heron; bittern)

Order 8. *Coraciiformes:* Fishing birds (kingfisher)

Order 9. *Gruiformes:* White egret

Order 10. *Piciformes:* Wood-boring birds (woodpecker)

Order 11. *Passeriformes:* Perching birds (flycatcher; lark; swallow; crow; wren; thrush; bluebird; starling; blackbird; sparrow)

Class 7. **Mammalia:** Covered with more or less hair; warm-blooded; four-chambered heart; mammary glands and diaphragm; brain case relatively large; viviparous except in one order

Order 1. *Monotremata:* Egg-laying forms (duckbill; spiny anteater)

Order 2. *Marsupialia:* Young born immature and carried in a pouch (kangaroo; opossum)

Order 3. *Edentata:* Forms toothless, or nearly so (sloth; hairy anteater; armadillo)

Order 4. *Cetacea:* Marine forms, with flippers instead of legs (whale; porpoise; dolphin)

Order 5. *Sirenia:* Aquatic; fore limbs fin-like, hind limbs absent; tail with horizontal fin; body whale-like but with a definite neck (sea cows)

Order 6. *Insectivora:* Insect-eaters (mole; shrew; hedgehog)

Order 7. *Chiroptera:* Adapted for flight (bat)

Order 8. *Rodentia:* Equipped with incisor teeth adapted for gnawing (beaver; rat; mouse; porcupine; squirrel; rabbit; muskrat)

Order 9. *Ungulata:* Hoofed forms; vegetarians with grinding teeth (horse; cow; sheep; camel; deer; pig; elephant; rhinoceros)

Order 10. *Proboscidea:* Upper lip and nose lengthened to form a long, prehensile trunk or proboscis; incisor teeth forming long tusks; molars very broad (elephant; tapir)

Order 11. *Carnivora:* Sharp teeth with cusps for eating flesh; claws (cat; dog; wolf; lion; bear; tiger; fossil saber-toothed tiger; seal; walrus)

Order 12. *Primates:* More or less erect forms with hands (monkey; gorilla; chimpanzee; orangutan; gibbon; man)

Index and Guide to Terms

Unless otherwise indicated, the first page reference for each word or term includes a definition or meaning of that word or term.

Italics indicate illustration. In many cases the topic, too, is to be found within text on that page.

CANADIAN SUPPLEMENT

MOON, MANN, OTTO

MODERN BIOLOGY

by Paul B. Mann

CONTENTS

SUPPLEMENT

Additional Information on Mushrooms

(*To follow the first paragraph, first column on page 230*)

Mushrooms, puffballs, shelf fungi, and earth stars are all types of saprophytic fungi, varying enormously in character but agreeing in that they all are *sporophores* bearing fabulous numbers of spores. A germinating spore soon develops hyphae in soil that is favorable because of the presence of decayed leaves or manure. Hyphae continue to grow until they make a rootlike structure called the *mycelium.* The mycelium absorbs and stores up food. Then the sporophore is developed.

The life history of a typical gill-bearing mushroom is as follows: A small "button" appears in the mycelium just below the surface of the ground. This sporophore soon elongates and, after it comes through the soil, reveals its true umbrella shape. It consists of a cap (*pileus*) supported by a stalk (*stipe*). From the under surface of the cap thin gills (*lamellae*) extend from the stalk to the rim of the cap. On the stalk usually may be found a ring of remnants of the outer skin that covered the young "button." The rest of this original skin usually remains as a cup (*volva*) at the base of the stalk in the ground.

The outer surface of each gill bears two kinds of microscopic cellular growths. The fruiting type is the *basidium,* or *hymenium,* which develops four *basidiospores.* Mingled with the basidia are sterile growths each of which is called a *paraphysis.* One common mushroom is considered to produce about 1,800,000,000 spores, which are light enough to be carried away by the wind. There are five groups of the gill fungi, according to the color of the spores. A spore print is easily made. Cut off the cap and place it gill side down on paper selected, if possible, to contrast with it in color. Cover the cap with a large dish and leave for several hours. Within a day or less spores will have dropped on the paper leaving a colored spore print.

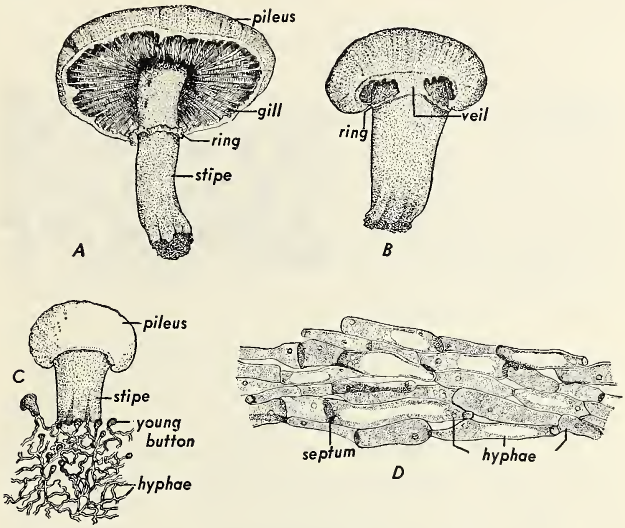


FIG. 1. — Development of the mushroom.

Besides the gill fungi, there are two other types somewhat similar in shape, namely, the tooth fungi, in which gills are replaced by spiny extensions on the underside of the cap, and the pore fungi in which a fleshy mass of pores replaces the gills. The pore fungi also grow on the sides of trees as brackets, and in this case are called shelf fungi. Some of these forms are only saprophytes living on dead wood, but many are parasites, destroying the tissues of the tree host.

The puffballs may be small buttonlike growths on the surface of the ground, or they may attain the size of a foot or two in diameter and weigh many pounds. They lack gills and produce spores within their outer coat, which splits only when the spores are ripe. One large puffball contained 7,000,000,000 spores! Spores from a puffball will not cause blindness as some superstitious persons believe.

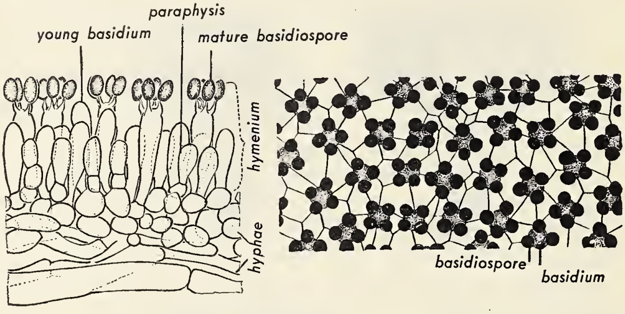


Fig. 2. — Small section of the spore-bearing layer (hymenium) of a mushroom.

There are other kinds of fleshy fungi, such as coral mushrooms, which resemble their animal namesakes; oyster mushrooms, which are white and grow on trees; shaggy-mane mushrooms with apparently broken fragments of skin on the cap; earth stars, whose thick, outer coat splits and spreads out like a star, then rolls tightly around the inner puffball when dry, and many more.

Additional Information on the White Pine Blister Rust

(*To follow the second paragraph, second column on page 234*)

The white pine blister rust is a fungus which, since its appearance in the United States about 1906, has steadily spread over large areas of that country and Canada, attacking and killing our valuable white pine trees.

Like the wheat rust, this fungus requires an intermediate host, which it finds in wild or cultivated currants and gooseberries. These plants, when infected, have little spots on their leaves. Each spot is a fruiting area which produces spores similar to the red and the black spores of the wheat rust. These spores infect healthy tissue of these plants, which, in turn, produce still another kind of spores, called *basidiospores*. If there are any white pine trees within 900 feet of these infected plants, the wind may carry some of these microscopic basidiospores to the pine trees. Basidiospores that reach the pine soon germinate on the needles, sending their hyphae down into needles, twigs, and bark.

For three years following this initial infection of the white pine, there is nothing to show that the tree has become infected. But all this time spores of a new type have been developing, unseen, underneath the bark. At the end of this incubation period, small diseased spots appear in areas on the bark. These growths look innocent enough, but from each eruption enormous numbers of microscopic orange-colored *aeciospores* constantly escape into the air. A favorable wind easily blows them back to the currant and gooseberry plants, thus starting the cycle over again.

Infected white pine trees are doomed, and should be cut down and burned to prevent more infection. However, since the aeciospores never infect other white pine trees, directly, the only sure method of controlling the white pine blister rust and saving healthy white pines is to wipe out all currant and gooseberry plants within 900 feet of these trees. It is difficult for uneducated inhabitants of the rural districts of Canada and the United States to accept the facts about the life history of this fungus parasite, as mysterious as is the development of all such organisms requiring alternate hosts. Therefore, in order to secure the coöperation of the persons most concerned, correct information regarding the white pine blister rust must reach the most remote regions. The most valuable timber in Canada is the white pine. With proper control the menace of the white pine blister rust can be eradicated.

Apple Scab

(*To follow the first paragraph, first column on page 235*)

Apple scab is one of the most serious diseases affecting apples in Canada. It causes the loss of many thousands of dollars' worth of fruit annually. Yet, fortunately, it can rather easily

Fig. 3. — Apple scab on fruit showing fruiting bodies which make scab on the surface.

be controlled by timely and intelligent spraying. The fungus was discovered in America first in 1834. Since then it has spread widely wherever apples are grown.

Apple scab is due to a fungus which attacks the blossoms, leaves, and fruit, producing conspicuous brown and black scab spots, frequently cracking the fruit and always making it unsightly and liable to shrivel or rot. Young fruits that become scabby are usually deformed and do not fully mature. Scabby apples are more likely to develop pink rot and be spoiled by blue mold and other fungi. On blossoms, the disease usually begins in the ends of the calyx, then the spores travel to the base of the calyx and the little apple becomes infected. On the leaves, the scab kills so many of the chlorophyll cells that there is a marked drop in the quality and quantity of food manufactured for the tree. Thus severe injury to the apple leaves impairs the normal growth of leaf and fruit buds and is bound to reduce the apple crop in subsequent years unless checked.

The following varieties of apples are *very* susceptible to scab: McIntosh, Melba, St. Lawrence, Early Harvest, Stark, Snow, Gravenstein, and Baxter. Those that are moderately susceptible to scab are Ben Davis, King, Baldwin, Spy, Rhode Island Greening. The following are only slightly susceptible to scab: Blenheim, Yellow Transparent, Golden Russet, Tolman, and Duchess. More thorough measures have to be taken with those varieties that are more easily infected.

The apple scab starts in the spring from any single spore that escapes from infected leaves usually lying on the ground during the winter under the apple trees. The spores escape from the fruiting body of the fungus (consisting of microscopic spots on the leaves) only if there is considerable moisture. Under wet conditions, such as those during spring rains, each sac-like *ascus* in a fruiting body shoots out its eight *ascospores.*

These spores are very light and are carried by air currents to young leaf buds and flower buds. The spores quickly germinate on the moist surface and hyphae easily grow down into the epidermis of these tissues. Brownish spots soon appear on both sides of the leaf where the cells have been killed by the parasite. As the fungus spreads, it sends up microscopic stalks, the terminal cells of which, called *conidia,* break off, and, during moist spells, cause secondary infections of other leaves and fruits. In the autumn and winter, the fungus lives in infected leaves and develops new fruiting bodies from which ascospores are released the next spring.

One method of control is to gather up and burn *all* dead apple leaves found under the trees in the fall. However, not all the infected material can be found, therefore this is not so important a procedure as is correct spraying. A good fungicide, such as lime-sulphur or Bordeaux mixture, should be used several times early in the season. It is not enough to have fixed seasonal

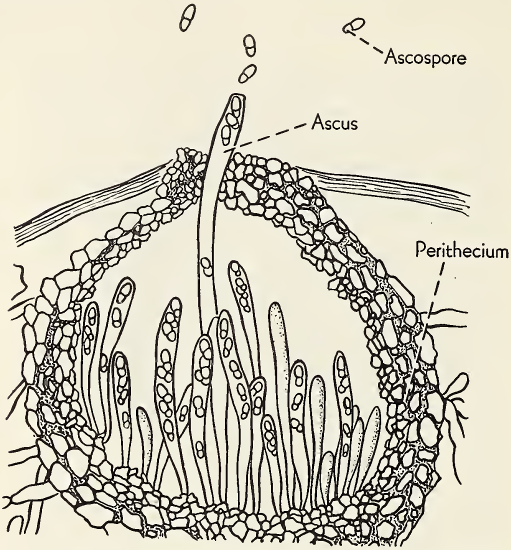


FIG. 4. — Greatly enlarged view of a single fruiting body or perithecium of apple scab.

times for spraying; one must remember that the spores are scattered and germinate on the apple tree *only when there is wet weather*. The Ontario Department of Agriculture states in its bulletin No. 403, "One or two sprayings with either lime-sulfur or Bordeaux mixture are not sufficient as the rain gradually washes the spray off, and as the leaves and fruit, by growing larger, develop more surface to cover. In order to be sure of preventing disease one must spray from four to six times during

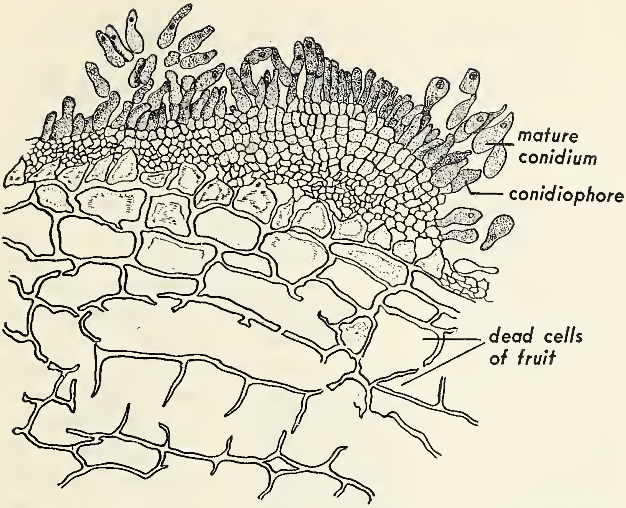


FIG. 5. — Greatly enlarged section through an infected fruit showing the formation of conidia of apple scab.

the season, the number of sprayings depending upon whether the weather is wet or dry." The Ontario Department of Agriculture advocates spraying as follows:

1. *First spray,* when the leaf buds begin to open.
2. *Pre-pink spray,* when flower bud clusters begin to show.
3. *Pink spray,* when the blossoms are showing pink.
4. *Calyx spray,* when the petals have dropped. This should be very thorough. It also assists in the control of the codling moth.
5. *First cover spray,* about 12 days after the calyx spray.
6. *Second cover spray,* about four weeks after the blossoms fall, probably about the last week in June or the first week in July.

Additional Information on Lichens

(To follow the second paragraph, second column on page 236)

General Characteristics. The lichens are among the most widely distributed plants of the earth. There are said to be more than 4,000 species of lichens, most of which resemble each other in having an exposed structure, more or less flattened and leaflike, called the *thallus.* Lichens are found growing on stones, fences, walls, tree trunks, and on the ground. Among the lichens most commonly found are the following. Parmelia is the gray or greenish rosette, sometimes many inches in size, seen on the bark of trees and on rocks. Old Man's Beard is a curious gray lichen which is long and threadlike. It hangs from trees like Florida moss (actually a flowering plant). Rock tripe consists of blackish discs attached by their centers to rocks. When wet it is greenish and rather rubbery. The Indians used to grind it up and mix it with acorns for food. Reindeer moss may flourish extensively on dry or barren soil. It sends up little gray stalks, called *podetia.* Scarlet-crested cladonia, found in the same regions, are beautiful little lichens whose gray podetia are adorned with bright red knobs.

Body Structure of a Lichen. A lichen is a curious and complex plant; actually it consists of two plant organisms living together in a mutually helpful relationship. One layer consists of single-celled algae which are surrounded and supported by a mass of hyphae, the threadlike cells of a sac fungus. The algae cells are green or blue-green, and their chlorophyll makes food by photosynthesis for the partnership. The fungus absorbs water and mineral matter from the soil or other base to which it is attached and is able to store this moisture for long periods. Thus together these two plants can survive conditions that would destroy either one if alone.

Reproduction. Reproduction of a lichen occurs in two different ways. (*1*) At certain seasons minute cuplike structures are produced on the surface of the thallus. The upper margin of each of these tiny cups is composed of elongated fungus hyphae, or threads, each made up of many narrow fungus cells. Each of these upright hyphae is called a *paraphysis*. Little pockets, each called an *ascus*, occur among these paraphyses. Inside each ascus are produced special reproductive spores called *ascospores*. When the ascospores are ripe, the top of the ascus

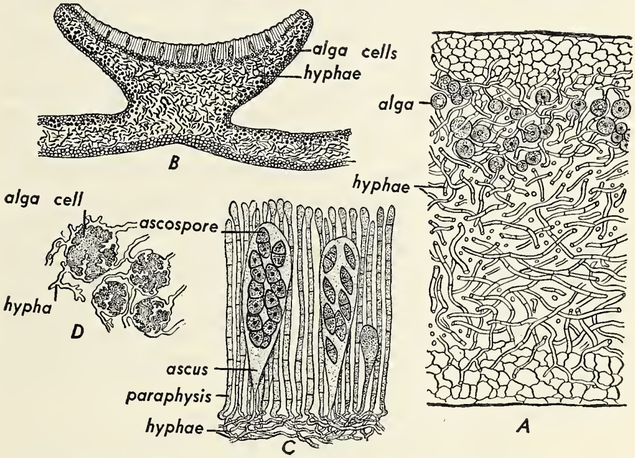


Fig. 6. — Microscopic details of the structure of a lichen. A. Section through the thallus, showing alga cells surrounded by fungus hyphae. B. Structure of a fruiting cup of the lichen, bearing ten asci. C. Cellular details of two asci and their ascospores. D. Four soredia with hyphae.

breaks open and the ascospores escape. If now they come in contact anywhere with alga cells that are free-living, they begin to grow hyphae around these alga cells and thus start a new lichen. Unless the ascospores find such alga cells they rarely survive.

(*2*) There is another method of reproduction, which resembles the asexual reproduction of a geranium plant by slips, of a potato plant by cuttings of buds, or of a rhubarb plant by portions of the root. At certain times ball-like fragments form near the surface of the thallus. Each fragment consists of one or more alga cells surrounded by fungus hyphae. Such bits of the lichen are called *soredia.* They are scattered easily by wind or water, and possibly by insects. Reaching a favorable base they flourish and expand into the usual lichen colony.

Economic Importance. Lichens are able slowly to break down the surface of rocks to which they are attached, thus making a thin layer of humus which eventually adds considerably to the available soil. Carbon dioxide is excreted from the fungus. Dissolved in moisture, this forms carbonic acid, which, though weak, slowly dissolves rock. The drying of the lichen after each wetting exerts enough mechanical pull to break off tiny rock particles. Thus in several ways, lichens help to make soil. In addition to forming soil, lichens serve as food. A lichen called reindeer moss, widely distributed throughout Canada, is a valuable food eaten by reindeer and musk ox in the northern regions. Iceland moss is another lichen. It is used as a food by the inhabitants of Iceland and Norway. Lichens are also responsible for certain dyes, and for the litmus paper of the chemistry laboratory, the latter being manufactured chiefly in Holland.

Life History of the Moss

(*To follow the second paragraph, second column on page 94*)

The mosses and liverworts form a very large group of plants which is widely distributed. We shall consider the life cycle of a typical moss plant in which an asexual generation alternates with a sexual generation.

A moss spore germinates on the moist earth, producing a branching, filamentous body called the *protonema.* This protonema spreads over the ground forming a dense carpet and here and there produces buds which develop into short, erect, leafy shoots. The leaves are small, thin, and spirally-arranged. At the base of the stem are several absorbing organs called *rhizoids.* These are not highly differentiated like roots, but resemble root hairs except for the fact that there are several cells placed end to end. The vertical shoot, or stem, has little or no conductive and supporting tissue.

At the tip of the leafy shoots are found the specialized sex organs called the *antheridia* and *archegonia*, respectively. The antheridium is somewhat elongated and embedded in a good deal of sterile tissue. At the time of fertilization the tip of the antheridium breaks open and releases a large number of single-celled male cells, or *sperms*. Each sperm has two cilia which lash about in the water which must be present to convey the sperm to the region of the archegonium, or female sex organ. The archegonium is shaped somewhat like a Florence flask and is situated at the tip of a leafy shoot, generally a different one from that containing the antheridium. At the time of fertilization, the middle cells or *neck canal cells*, of the archegonium disintegrate and leave a passageway to the female or *egg cell* which is situated at the base of the archegonium. When the cells in the neck disintegrate, they emit a mucilaginous material into the water. This has some attraction for the sperms which swim towards the archegonium. Several sperms may enter the mouth of the archegonium but only one fertilizes the egg cell. It should be pointed out that the plant which bears the sex cells (*gametes*) is known as the *gametophyte plant*. It has the *haploid* or single number of chromosomes. The fertilized egg or zygote, has the double number of chromosomes, or *diploid phase*.

From the zygotes the *sporophyte plant* develops. It consists of a *foot*, by means of which it derives its nourishment, a long stalk, and an enlargement at the tip called the *capsule*. The capsule contains cells, which by reduction division form *spores*. These spores, now containing the haploid number of chromosomes, are discharged and this process ends the sporophyte stage and completes the life cycle.

SUMMARY OF BRYOPHYTES

1. They are primitive types of land plants and show tendencies towards absorptive and photosynthetic structures. As they have little or no vascular tissue, and as they are unable to conserve water effectively, they are usually confined to moist habitats.

2. Alternation of generations occurs in all Bryophytes. The

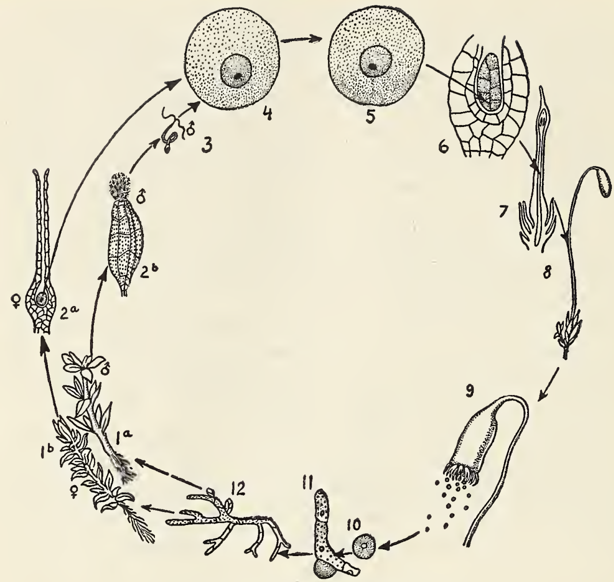


Fig. 7. — Life cycle of a moss plant.

There are two kinds of leafy moss plants. One (1^a) bears male organs, antheridia, at the top. The other (1^b) bears female organs, archegonia, at the top. A single archegonium (2^a) contains an egg cell, ♀. A single antheridium (2^b) contains many sperm cells, some of which, ♂, are escaping.

A sperm cell (3) lashing about when the moss is wet penetrates the tube of an archegonium and then unites with the egg cell (4), thus producing an oöspore (5). The oöspore soon germinates and grows (6) into an extended structure (7) which finally produces a spore-bearing capsule on a long stem (8). In this capsule (9) spores are produced which escape from the capsule when the spines open (magnified). On moist ground a spore (10) germinates, producing a protonema (11). Soon buds appear on the protonema (12), from which the common leafy moss plants develop.

dominant food-making generation is the gametophyte. The sporophyte is insignificant, simple in structure, and dependent on the gametophyte for its existence. Because of the limited ability of the gametophyte to absorb water and to make food, it necessarily follows that the sporophyte must be small.

3. The sex organs of the Bryophytes are multicellular and specialized for reproduction.

4. Water is essential for the sperm to reach the egg cell.

Life History of the Fern

(*To follow the second paragraph, first column on page 97*)

The spores of ferns, like mosses, are haploid and begin the gametophyte generation. If conditions are favorable the spore germinates and by cell division forms a green, flat, heart-shaped structure called the *prothallus.* This prothallus is only a few millimetres in width and produces *rhizoids* on its underside. Since it has absorbing organs and photosynthetic tissue it is an independent organism. As one might expect, this gametophyte plant produces the gametes or sex cells. They are on the underside, the archegonia near the notch and the antheridia among the rhizoids. The archegonia and the antheridia are fundamentally the same as in the Bryophytes. The sperms have many cilia instead of two, but they depend on water to reach the egg cell. In most fern gametophytes dew is quite an adequate liquid medium for this process to occur, because the sperms are microscopic, and because the distance they have to travel from the antheridium to the archegonium is so short.

The zygote, or fertilized egg cell, is diploid and starts off the sporophyte generation. For a short time the young sporophyte is dependent on the gametophyte for its food but it soon establishes its own root and becomes independent. This is very important as the sporophyte can now grow into a large, highly complex plant.

Most mature fern plants have underground stems with true roots arising from the underside. The leaves of most ferns carry on vegetative and reproductive functions. As a rule the leaves are large and well fitted for photosynthesis. The spores are produced in spore cases, or *sporangia,* on the backs of the leaves. Clusters of sporangia appear as "dots" called *sori.* Some have a membranaceous covering, or *indusium,* over each sorus. When the spores are ripe the outer wall of the sporangium splits open, draws back, and with a snap returns to its original position forcibly, ejecting the spores. In the formation of the fern spores, as in mosses, there is a reduction division which results in the haploid chromosome number.

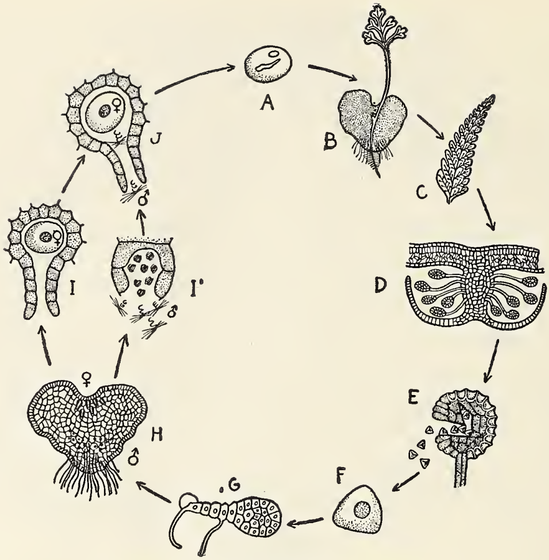


Fig. 8. — The life cycle of a fern plant.

An oöspore, A, grows into the leafy fern plant, B. On the underside of each frond, C, appear raised dots called sori. One sorus, sectioned, D, shows ten spore cases or sporangia. From a single enlarged sporangium, E, spores escape. A spore, F, germinates in moist soil, growing into a new organism, G, which soon develops into a tiny heart-shaped prothallium, H. Near the notched end of the prothallium are the archegonia or female organs, ♀. Near the pointed end are the antheridia or male organs, ♂. An archegonium, sectioned, I, contains an egg cell, ♀. An antheridium, sectioned, I′, has produced twelve sperm cells, ♂. Two of them have lashed their way into the tube of an archegonium, J, the egg cell of which, ♀, will be fertilized by one sperm.

SUMMARY OF PTERIDOPHYTES

1. The sporophyte is the large, conspicuous generation and has achieved complete dominance. The gametophyte plant is much reduced but still independent.

2. Pteridophytes are well adapted to a life on the land. The root with its many root hairs is well fitted for absorption. The stem in tree ferns has good vascular and supporting tissue. The leaves are large, well provided with chlorophyll and consequently food-making tissue.

3. In the matter of fertilization, however, there is no advance over the Bryophytes. Water is still necessary as a medium for the swimming sperm to reach the egg cell.

Introduction to the Spermatophytes

(*To precede the second column on page 97*)

The seed plants, or Spermatophytes, are the dominant plants of today. They have made two advances over the Pteridophytes: (1) the *pollen tube*, and (2) the *seed*. The pollen tube is a new structure which brings the sperm directly to the egg cell and thus obviates the need for water. The male gametophyte and female gametophyte are much reduced, and are confined to the pollen grain and ovule, respectively. Neither of these structures have green tissue and consequently are parasitic on the sporophyte. After fertilization, the young sporophyte, or seed, develops in contact with, and at the expense of, the parent sporophyte. It is finally released, dormant, well supplied with food, and protected by heavy coats. Thus, the Spermatophytes do not require water for fertilization and consequently are not as limited in their habitat. The seed, a new structure, is well fitted to carry the plant over unfavorable conditions.

Life History of the Pine

(*To follow second paragraph, second column on page 97*)

There are four great groups of plants: the Bryophytes or mosses, the Pteridophytes or ferns, the Thallophytes, which comprise all the other flowerless plants and which have no leaves, stems, or roots (the lowest plants), and the Spermatophytes, consisting of our most common and familiar plants.

This last group is divided into Gymnosperms, the cone-bearing plants such as the pine, and the Angiosperms, those plants that produce flowers such as grasses, roses, and most trees. Spermatophytes alone produce seeds and form pollen tubes. The word *gymnosperm* means "naked seed," that is, the seed is not formed within fruit, while *angiosperm* means "enclosed seed." There are nearly 200,000 species of Spermatophytes.

As you know, a seed is a very complex structure, consisting of a tiny embryo plant, usually surrounded by stored food and protected by seed coats. The story of how seeds came into existence can be suggested by the life history of the pine tree, a typical Gymnosperm.

It will be noted that in the first three great groups of plants, lower and probably much older in type than the Spermatophytes, moisture was necessary for the motile sperm to reach the egg cell. In the progressive changes among plants on the earth a new type of plants evidently came into existence which produced sperm cells in the form of pollen grains, and which sprouted tubes and thus carried the sperm nuclei to the egg cells without the need of water. We do not know what sort of organisms these first pollen-bearing plants were, but fossils lead us to think that they were fernlike in character. Undoubtedly many of these plants were transformed into the coal which we dig today from the depths of the earth. The conifers or evergreen trees seem to be the nearest to these ancient forms of any living plants, and the pine, then, will be typical of the group.

The Cone. The pine tree is a *sporophyte* which bears two kinds of spores which are grouped on short stems and form two kinds of cones. The male cones develop quite early in the spring on the ends of twigs. Each male cone is less than an inch long, and though yellowish in color is inconspicuous. The female cones are the woody, scaled "pine cones" with which we are all familiar. These cones, which are of considerable size, are borne throughout the same pine tree.

The Male Spores. Each of the scales of the male cone is called a *sporophyll* because it bears spore cases. In fact each scale bears two or three of these spore cases or *sporangia*. It is obvious that these scales, together with their sporangia and the rest of the pine tree, comprise the *sporophyte generation.* Early in the season each of these sporangia forms four male spores. Each spore matures into a yellow *pollen grain.* Each pollen grain contains two small *vegetative* or *male prothallial cells* which do not function in reproduction. The ripe pollen grain also contains two other cells, the *generative cell* and the *tube cell.* By means of two wings or air sacs, one on each side

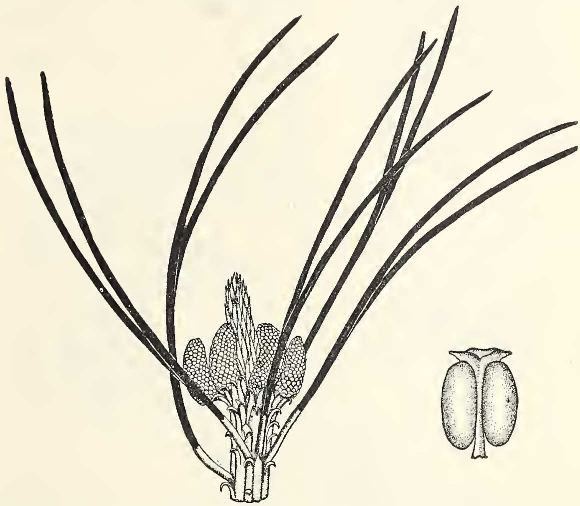


FIG. 9. — Pitch pine showing needles and four male or staminate cones, also single sporophyll (cone scale) and two sporangia (pollen sacs).

of the pollen grain, the pollen is carried away by gusts of wind. Late in May the showers of pollen from a pine tree sometimes look like clouds of sulphur.

The Female Spores. The young female cone is a compact, green, spindle-shaped growth, made up of closely joined scales, or sporophylls. Each female cone scale now bears two minute *ovules.* Each ovule is a female sporangium protected by a layer called the integument, which covers the ovules except directly in front. The ends of the integument around this

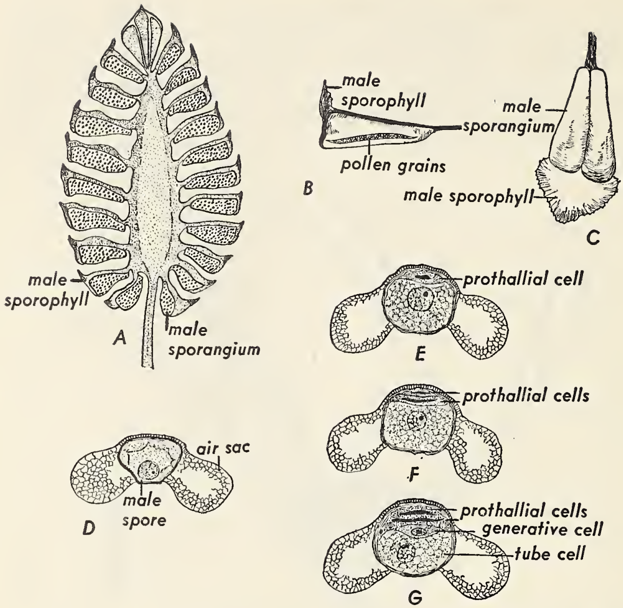


FIG. 10. — The male or staminate cone, with details of the sporangia and the spores. A. Longitudinal section through a staminate cone showing the location of the sporophyll and the sporangia. B. Sporophyll and its two sporangia seen from the side. C. Sporophyll and its two sporangia seen from below. D. Male spore before germination. E and F. Stages in the development of germination of a male spore. G. Mature pollen grain showing microscopic structure.

opening are called the micropyle. After the ovule is fertilized and becomes the seed, the integument becomes the seed coat, as in the seeds of flowering plants. Each sporangium produces one female spore *mother cell.* This mother cell, by cell division, produces four female spores, three of which soon disintegrate. The remaining spore increases in size, and by a process called *free nuclear division,* its nucleus divides into an enormous number of nuclei. At first these nuclei are without cell walls.

Later, walls and other cells are formed, and the spore and other cells make a structure which constitutes the *female prothallus* or *endosperm*. From two to five egg cells, each in a short *archegonium*, are formed in the end of the prothallus nearest the micropyle. The female prothallus is an interesting case of

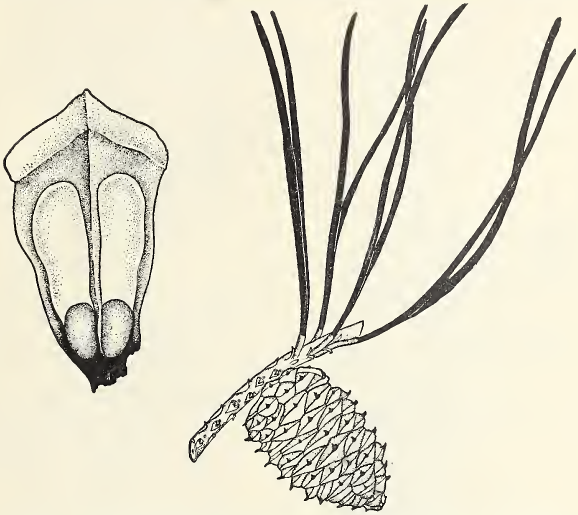


Fig. 11. — Pitch pine with needles and one female cone, with a greatly enlarged diagram of a single cone scale and two seeds.

a parasitic growth depending for nourishment upon the surrounding tissue of the sporangium. It should also be noted that the female prothallus, together with the useless male prothallial cells, corresponds to the prothallium of the fern.

Pollination and Fertilization. Pollen becomes fully ripe in late spring or early summer. At that time the female cones point upward and their scales are slightly separated. Pollen grains drift everywhere with the moving air and some grains are bound to lodge next to the micropyle. The passage of pollen from the male cone to the base of the female cone is *pollination.* Some time after this, the scales close, and the cone now hangs from its branch. Resin seals the openings between the scales and thus prevents the entrance of water. Pollen grains caught on the micropyle start to germinate, each

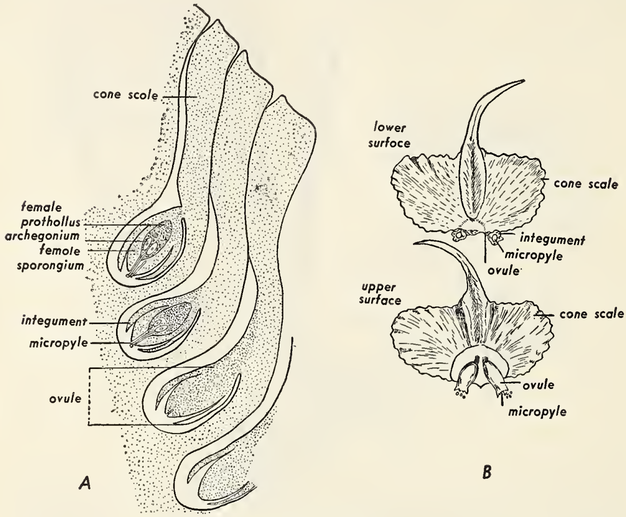


FIG. 12. — Female sporangia and sporophylls. A. Ovules of pine, showing position and attachment to cone scales. B. Cone scales and ovules of fir, as seen from below and above.

producing a *pollen tube* which begins to penetrate the tissue of the female sporangium, taking a year in the process. The pollen generative cell divides, and one of its daughter cells forms two sperm cells, which are true *gametes.* One of the pollen tubes grows down into one of the archegonia, and one of its two sperm nuclei or gametes fuses with the egg nucleus. This is *fertilization.* The second sperm nucleus and any other cells arriving with the pollen tube now disintegrate. It is well

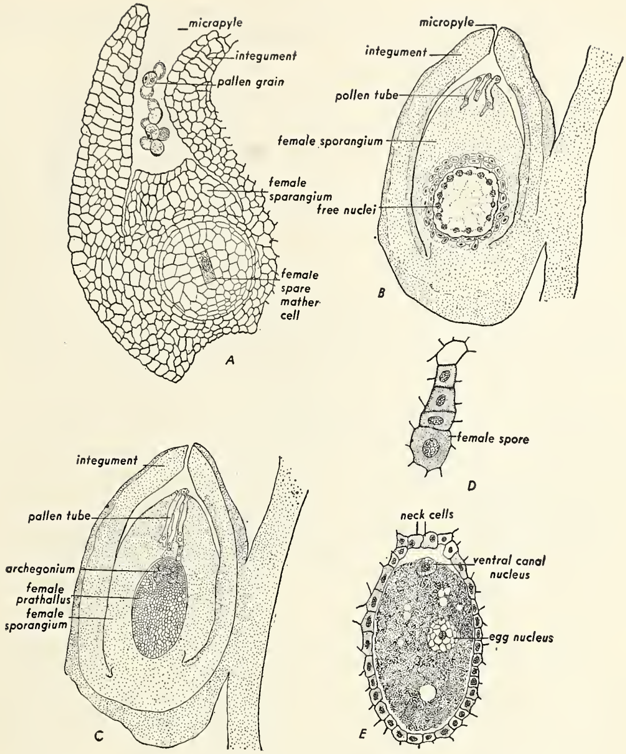


Fig. 13. — Microscopic details showing the cellular structure of an ovule at the time of pollination and the growth of pollen tubes. A. Pollen grains about to lodge on the sporangium. B. Pollen tubes forming, and free nuclei developing in the female spore. C. Pollen tubes having reached the female prothallus. D. Divisions of the spore mother cell. E. Single archegonium, much enlarged.

to note that pollination occurs in the late spring or early summer of the first year, but that fertilization occurs a year later in the spring of the second year.

The Seed. After fertilization, the egg cell grows by cell division until it has formed distinct organs. It is now an embryo, consisting of from two to five seed leaves or cotyledons, the number varying with the species of pine, and the plumule, hypocotyl, and radicle, not as specialized as these parts are in the seed of a typical flowering plant. The size of pine seeds varies with the species, but they are usually from one half to two thirds of an inch in length. The endosperm has so much stored food in it, that certain pine seeds are used extensively as food. While the seeds are developing, the female cone has become much enlarged. The seeds do not become fully matured until the end of the second season. The pine seed has attached to it a sort of membranous wing, which consists of a part of the cone scale and the integument. This wing acts as a sail in the air and helps to scatter the pine seeds when the wind blows. The cone scales open wider when the seeds are ready for dispersal. The seeds of certain pines, such as the white and red pine, are shed as soon as they mature. In some other species the cones bearing seeds may remain unopened on the tree for a year or more.

Germination. When the pine seed finds suitable conditions of moisture, soil, and temperature, it swells, and the radicle emerges, grows downward, and soon develops into the root. The hypocotyl also elongates; it becomes erect, and bears the cotyledons aloft. Gradually the cotyledons become free from the seed coats and turn green. The plumule now develops a true stem and new leaves above the cotyledons, and the little plant is on its way to becoming a pine tree.

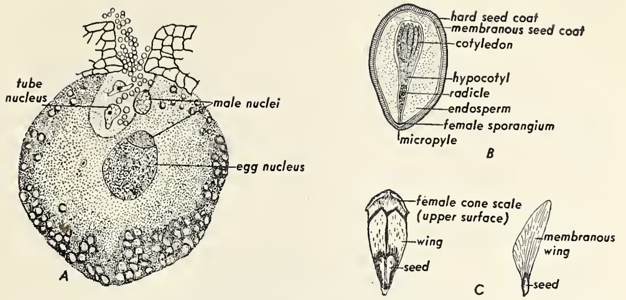


FIG. 14. — Fertilization and seed structure in the white pine. A. Microscopic details of fertilization. B. Longitudinal section through a pine seed. C. Two seeds still attached to cone scale (left), and single seed showing wing.

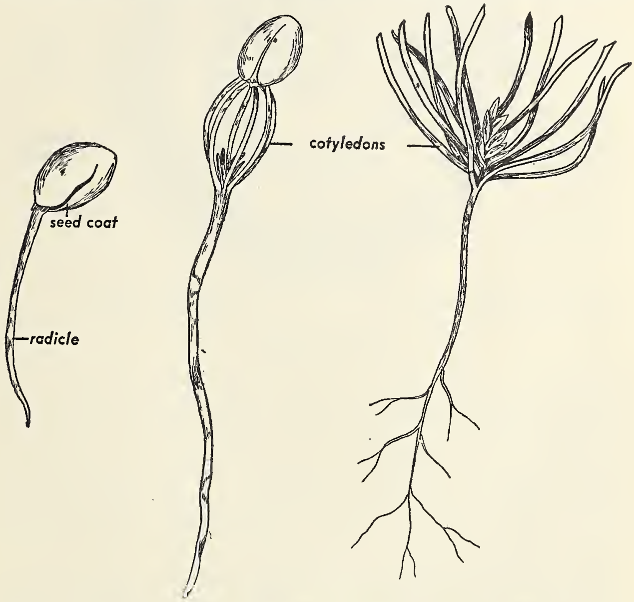


FIG. 15. — Stages in the germination of a piñon pine seed.

Additional Information on the Earthworm

(To follow second paragraph, second column on page 271)

External Structure. Earthworms are distributed over almost the entire world. They vary in size from a few inches long in some species to a length of several feet in certain tropical forms.

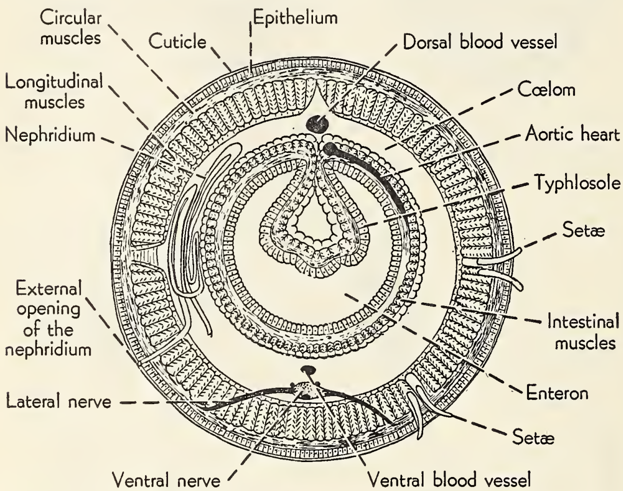


Fig. 16. — Cross section through earthworm, showing typical structures in one segment.

The body is of the same general color, but the dorsal region is darker than the ventral, and the anterior is darker than the posterior. This can be explained by the influence of the light in developing *chromoplasts.* The body consists of continuous and similar segments called *metameres.* In the longest specimens there may be as many as 180 metameres, but in the common species there are about 130.

About one third of the body length from the anterior end is a somewhat thickened portion of the body. This comprises six or seven metameres and is called the *clitellum.* It is concerned with reproduction.

Locomotion. The body wall of the earthworm is made up of all the primary animal tissues with the exception of bone, but muscles predominate. Just under the skin are the relatively thin layers of circular muscles. Below these muscles are the thick bands of longitudinal muscles. When the earthworm starts to crawl forward the setae are pointed backward. This prevents any slipping of the body. By shortening the longitudinal muscles the posterior part of the body is pulled forward; the bristles, meanwhile, prevent any backward movement of the front end of the worm. Now the circular muscles contract and this elongates the body. Again, the bristles hold the body from moving backward, and the only possible effect is a wavelike forward motion. By the alternate use of the two sets of muscles, the earthworm moves about, usually exceedingly slowly. By reversing the direction of the setae, the same muscular contractions will force the earthworm posterior end first. Animal locomotion in almost all cases depends upon having a certain amount of environmental resistance, which is overcome by various structural adaptations. Locomotion would be impossible for the earthworm on a very smooth, frictionless surface.

Eating. Not only does the earthworm eat its way through the soil, but it consumes much organic food, particularly leaves, decayed wood, bits of meat, and other things. Leaves are first moistened by a secretion that softens them.

Excretion. The so-called kidneys or nephridia are little coiled tubes. Each begins in one segment as a ciliated funnel-like opening, and then passes through the body partition between metameres, to end in the next segment to the rear as a tiny pore on the surface. Nitrogenous wastes pass off through these nephridia.

Reproduction. Earthworms are *hermaphroditic,* that is, each worm contains testes and ovaries. However, the eggs of one earthworm have to be fertilized by the sperms from another,

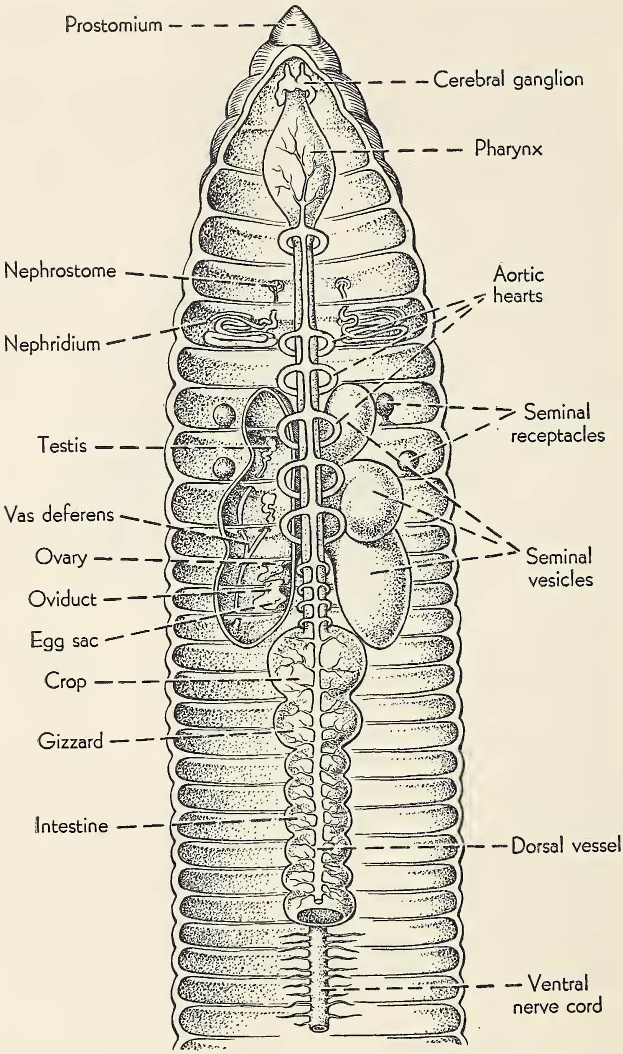


FIG. 17. — Dissected earthworm, seen from the dorsal aspect as pinned in dissecting pan.

since the worm is not self-fertilizing. Two mature earthworms come close enough to make this necessary exchange of sperms, the eggs in the clitellum region of each thus receiving sperms from another worm. The fertilized eggs are then enclosed in a sort of thickened skin formed by a secretion from the clitellum. This egg case is called the *cocoon,* though it does not in any structural way resemble the true cocoons of moths. The egg case finally slips off from the body, in late spring or early summer, and the tiny worms hatch in the ground, in regions most frequented by the adults.

Activity. Earthworms come to the surface of the earth and move about in the grass, chiefly at night. To this degree they may be called nocturnal animals. Earthworms may appear to be sluggish, but the speed with which an adult can retreat to its burrow at night is amazing. Their appearance after a rain is due to the fact that their burrows are flooded, and they are not adapted to absorb oxygen from water.

Additional Information on Spiders

(*To follow material on spiders, page 286*)

Spiders resemble insects, but even a casual glance shows that they have eight legs instead of six as have the insects. Also, the head and thorax are usually grown together, forming a cephalothorax, as in the crayfish and lobster. Like insects, spiders are air-breathers, having tracheae; but, unlike insects, spiders have a respiratory organ known as a lungbook, located on the underside of the abdomen. Spiders differ from insects in having only one spiracle, also on the lower side of the abdomen, just in front of the spinnerets. The abdomen is unsegmented and it is joined to the cephalothorax by a narrow stalk. Near the posterior extremity of the abdomen, on the ventral side, are the six spinnerets. Each spinneret bears many tiny spinning tubes from which a liquid issues. Upon reaching the air this hardens into a strand of silk. There may be as many as

100 spinning tubes on a single spinneret. A spider thread, thin and slender as it is, is thus made up of several hundred threads, each more delicate than any of man's products.

Spiders lack antennae. They also lack true jaws; therefore, they cannot crush and eat their victims. The first pair of appendages on the cephalothorax is known as the *chelicerae*, each of which consists of a basal segment and a sharp terminal claw at the tip of which a poison gland opens. Spiders kill their prey by injecting poison from the chelicerae, then suck out the body juices. Between the chelicerae and the first pair of true legs is another pair of slender appendages known as *pedipalps*. Most spiders have four pairs of eyes, but the number of pairs varies and certain cave spiders are said to be blind.

Life History of the Monarch Butterfly

(*To follow the photograph on page 299*)

The monarch or milkweed butterfly is widely distributed throughout Canada, as indeed it is throughout the world. This conspicuous butterfly has large tawny brown wings, with the veins and borders black, and a double row of white spots near the margins. The male has narrower bands of black, and on each of the hind wings there is a small black pouch containing scent scales, which seem to make it distasteful to birds.

The monarch appears first in June or July. Since this butterfly is known to migrate like the birds, it is probable that these early arrivals are pioneers from the "sunny south." Entomologists think that in the autumn, in most of the northern regions, this insect dies, though in some areas they collect in great swarms and fly south. The naturalist Medsger reports seeing these butterflies halfway across Lake Ontario.

The pale eggs are laid singly on the underside of milkweed leaves. In a few days the larva hatches, a grayish-white worm banded with yellow and black lines, giving it a zebra-like appearance. It becomes yellower as it gets older. Each larva grows by feeding on the leaves of the milkweed plant where it hatched. When full-grown it bears a pair of long fleshy filaments on the second thoracic segment and the seventh abdominal segment. The larva eats and grows for several weeks, the length of this period depending somewhat on the weather. Then it transforms into the pupa stage, the details of this process being given in the legend under Fig. 140. The chrysalis is about one inch long.

After about two weeks or less the amazing change into the adult has been perfected and the butterfly emerges by splitting the thin chrysalis skin, expands the wings and then flies off. During a favorable season it may have two or three broods.

Life History of the Ichneumon Fly

(*To follow the second paragraph, first column on page 305*)

The true ichneumon flies are members only of the family Ichneumonidae, a name derived from the Egyptian "ichneumon" or "Pharaoh's rat," which eats the eggs and the young of the crocodile. However, there are many other parasitic members of the Hymenoptera that are popularly called ichneumon flies. These insects vary in size from the large *lunator* whose threadlike ovipositor is sometimes six inches long, and the somewhat smaller *ophion*, down to tiny *brachonids*, such as the members of the genus *Aphidius* which infest and kill plant lice. There are countless others, as there are said to be more than 25,000 species of Ichneumonidae alone.

Practically all of the ichneumon flies are active during the summer season, pursuing their insect prey on which, or in which, they seek to lay their eggs. The female lunator has the strange instinct to hunt down the wood-boring larva of another Hymenoptera, the *Tremex*. She finds a spot on a tree underneath which there is a tunnel of the Tremex larva. How she is aware of this invisible tunnel is a mystery. Arching her long abdomen she works her slender ovipositor, really a delicate saw, until she has penetrated through solid wood to the tunnel. Then she passes an egg down through the saw-ovipositor into the tunnel. In due time this egg will hatch into a larva which will wriggle its way to the tremex larva whose blood, fat, and lymph it will begin to suck. The lunator larva finally changes into a pupa while still within the tunnel of its host, and when changed to an adult, it either finds the original hole made by the parent tremex when she laid her egg, or it bites its way out.

The female Aphidius stands near a selected plant louse, then with a lightning-like dart of the ovipositor, she thrusts an egg into the soft body of the victim. The larva which hatches develops within the body of its unwilling host, consuming the body tissue but respecting vital organs until the last. When mature, it cuts a neat disc in the dorsal wall of the abdomen of the dead or dying plant louse, and escapes to continue the warfare on other plant lice. Would that there were more of these parasites.

A female braconid seeks common caterpillars, into whose bodies her eggs are deposited by thrusts of her ovipositor. These eggs hatch and the developing larvae finally emerge and spin little cocoons on the outside of the body of the caterpillar, which is usually quite weakened by this time. When the braconid becomes adult it cuts a hole in the top of the cocoon and escapes to seek caterpillars as its parents did.

The so-called ichneumon flies are among the most beneficial insects known to man.

Life History of the Dragonfly

(*To follow the paragraph entitled Odonata, on page 305*)

The true dragonflies have four powerful membranous wings and are very rapid fliers. Their mouth parts are equally strong, being adapted for biting and chewing. They do not, like their cousins, the damsel flies, fold their wings when at rest. They have large heads principally because of their huge compound eyes, which give them keen vision. Thus, they are well adapted to catch their food of midges, mosquitoes, flies, and the like on the wing.

After mating, the female dragonfly lays several hundred eggs, placing them on a submerged stem, in wet mud, or even in clear water into which she dips while flying. In two to three weeks the eggs hatch out into an aquatic form called a nymph, but which from its habits might better be called a *water ogre.* It possesses strong legs and powerful jaws; in fact the lower lip can be extended far in front and is provided with large hooks by means of which it captures and kills its prey of other water insects, tadpoles, and even little fish. Unlike most aquatic animals, it breathes by drawing water into its alimentary canal, the posterior end of which is enlarged and is lined with tracheae. After a moment the water is expelled, minus its oxygen, and a fresh amount taken in. The expulsion of this water may be used to assist the nymph in swimming.

There is only one brood a year and the nymphs usually spend the winter in the mud and trash at the bottoms of ponds and streams. The nymphs of some dragonflies take a full year for complete development.

In late spring, the mature nymphs begin to emerge from the water, usually crawling up the stems of water plants. Here, the exoskeleton splits down the back and the adult dragonfly emerges, soft-bodied and weak until its wings and other structures have become hardened. The adults live until late summer or autumn, then die.

Life History of the May Beetle

(*To follow the paragraph entitled Coleoptera on page 305*)

The May beetles or "June bugs" are familiar examples of the order Coleoptera. They are brown insects with heavy wing covers, and thin yellowish wings by means of which they fly clumsily about, especially during the evenings of early summer. Because of their strong biting mouth parts they may prove very injurious to the leaves of young fruit trees.

Early in the season the female May beetle lays her eggs (50–100) in little pockets just below the surface of the earth. After a period of from ten days to several weeks, the eggs hatch into larvae known as "white grubs." They have strong jaws which they use in eating the roots of plants, thus causing much damage. Sometimes large strawberry beds, and lawns and other grass crops are ruined by them. They are very difficult to control or eradicate, though they are sometimes effectively attacked by bacteria, and certain birds like crows and flickers eat some of them. They are most destructive during the second season. They remain as larvae until the end of their second or even their third season. Their underground existence terminates with two months spent as white pupae in a sort of earthen cocoon. From these they emerge as adults, though they may remain in the ground for the next winter.

The Life History of the Squash Bug

(*To follow the paragraph entitled Hemiptera on page 305*)

The squash bug is a true bug and its typical sucking mouth parts cause extensive damage to many of man's crops. This little yellowish-brown insect winters in dead vegetation. Early in the spring the female, after mating, lays her large golden-brown eggs on the first sprouts of squash, pumpkin, and cucumber vines, or on any other foliage if these are not available. The numerous eggs hatch quickly into active little bugs, which grow rapidly, molting five times before reaching maturity. They feed constantly on the juices of the vines or other foliage, and if not controlled will entirely destroy them.

Young plants likely to be attacked by squash bugs should be covered with netting, and insecticides should be used later. One or two decoy plants can be left to attract the bugs, which can then be killed by kerosene. Handpicking the adult insects is an excellent procedure. It is equally important, at the end of the season, to burn all vines that have harbored squash bugs in order to kill any adults that would otherwise hibernate there and start the cycle again in the spring.

THE FROG

(*To precede the Summary on page 359*)

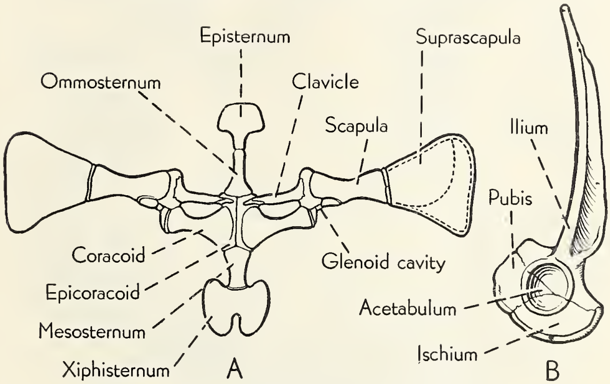


FIG. 18. — Pelvic girdle and pectoral girdle of frog.

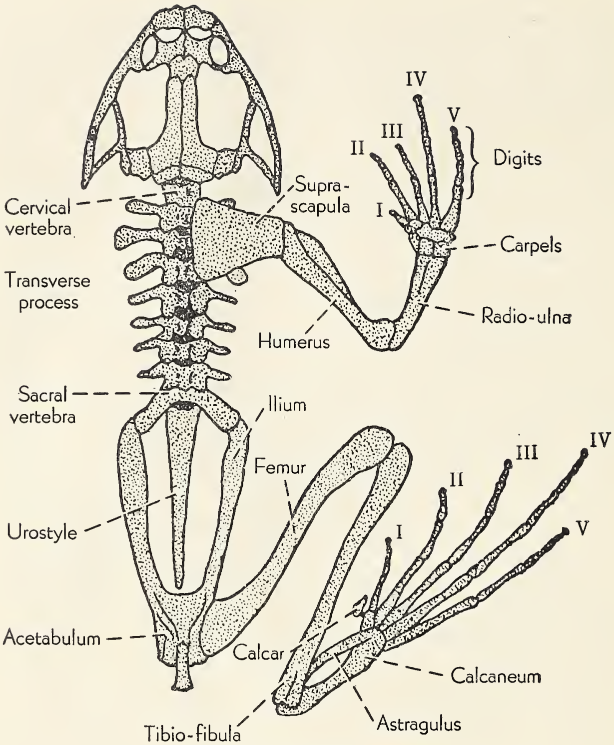


Fig. 19. — Skeleton of frog.

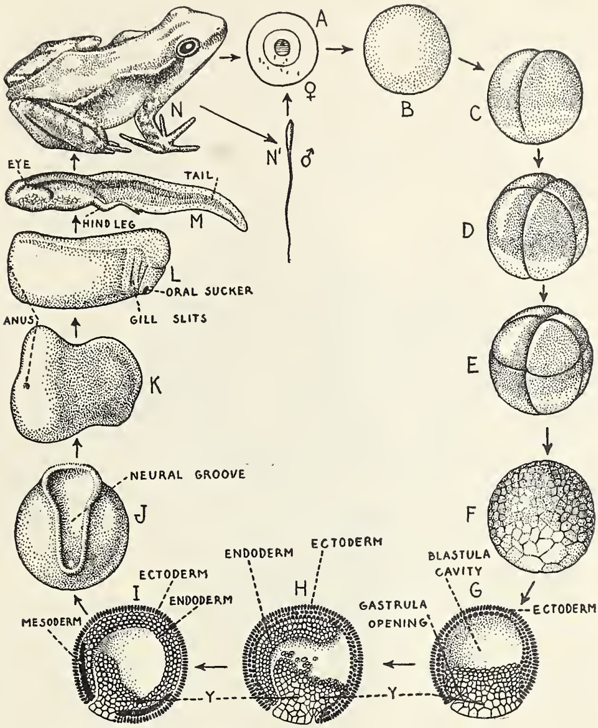


FIG. 20. — Embryological development of the frog. A, egg (note tiny sperms penetrating the double coverings of jelly); B, fertilized egg; C, beginning of cleavage to form two cells; D, four-celled stage; E, eight-celled stage; F, blastula or many-celled stage; G, section through blastula to show ectoderm cells, yolk cells, and beginning of gastrula opening; H, section through later stage showing formation of endoderm cells (gastrula opening has joined blastula cavity); I, section through gastrula stage showing formation of mesoderm and diminishing yolk cells; J, groove marking the beginning of the vertebral column, brain, and spinal cord; K, embryo with anus developed from gastrula opening; L, later embryo with gill slits and oral sucker; M, tadpole; N, adult frog; N′, sperm cell greatly enlarged.

Cleavage and Early Embryology. Each frog's egg is partly black and partly white. The white portion is the yolk or stored food material which is to be used during the complicated stages which the egg must go through before hatching. The black portion represents the living protoplasm of the egg with dark pigment to protect it. The yolk is heavier than the living part of the cell, so that the position of the egg is always dark-side-up.

The frog's egg has very little yolk, however, compared with that of the fish egg. The tiny fish hatches with yolk still attached to it. The tadpole hatches with none.

Soon after fertilization, the egg begins to divide vertically into two cells. A second division, horizontally, results in four cells. A longitudinal division follows, making eight cells. Divisions follow one another many times until a many-celled ball is formed. It is hollow in the center and is known as the *blastula.* These divisions are often called *segmentation* or *cleavage.* In this ball the cells on the lower side are more heavily laden with yolk than the rest and divide more slowly than those containing more of the protoplasm, so that the symmetry of the ball is soon lost. Next, a narrow opening appears on the lower side. This widens, and yolk cells fill the space.

Since some cells divide more rapidly than others, they fold over them on the inside, forming a two-layered embryo shaped like a cup, hollow and open at one end. Here is the first real promise of an advanced future, for the hollow will become the digestive tract, and the opening will become its posterior end or anus. The inner layer, which first appears only on one side, is the *endoderm* ("inside skin"). The outer layer of cells is the *ectoderm* ("outside skin"). Soon, between the ectoderm and endoderm, another layer of cells, the *mesoderm* ("middle skin"), begins to grow. All the organs develop from one of these embryonic or germ layers. This process is called *differentiation.*

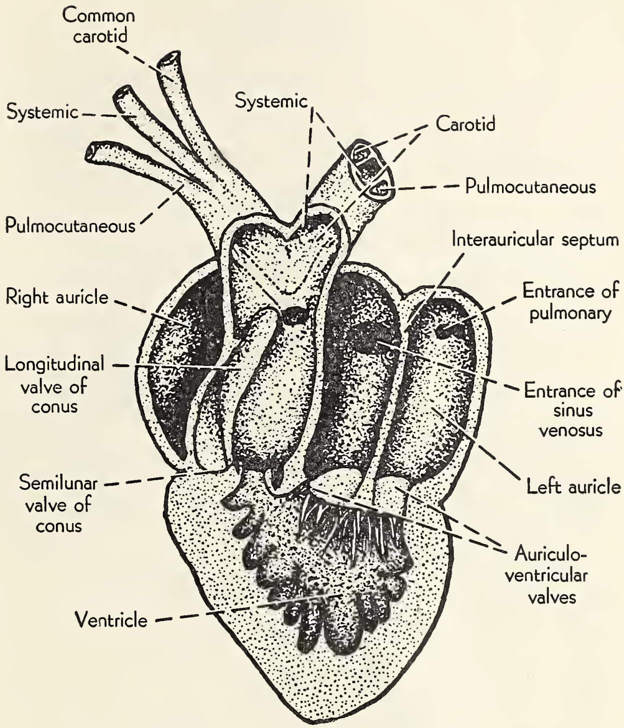


FIG. 21. — Cross section of heart of frog.

The Bird

(*To follow page 376*)

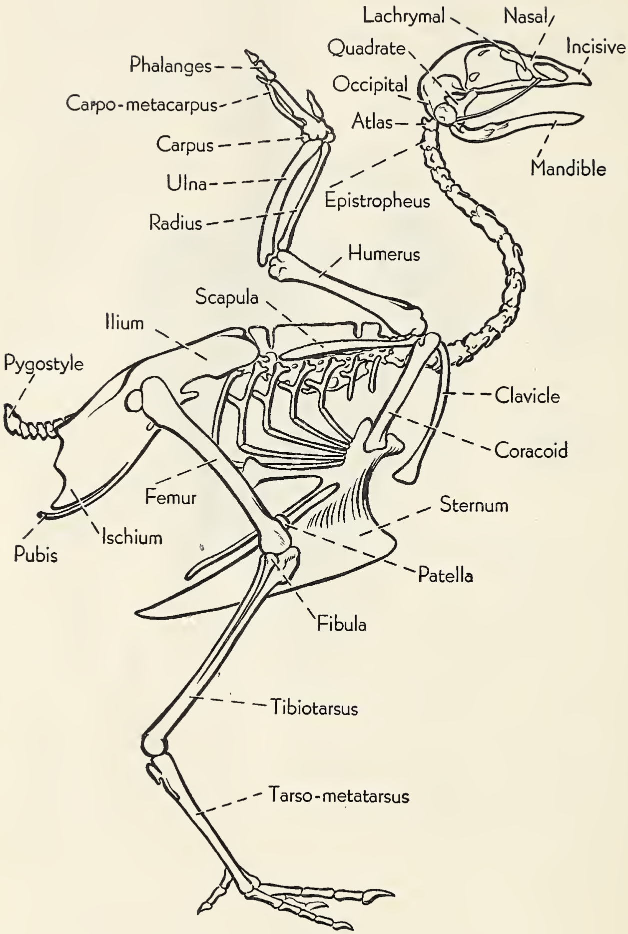


Fig. 22. — Skeleton of bird.

The Cat

(To follow the second paragraph, first column on page 411)

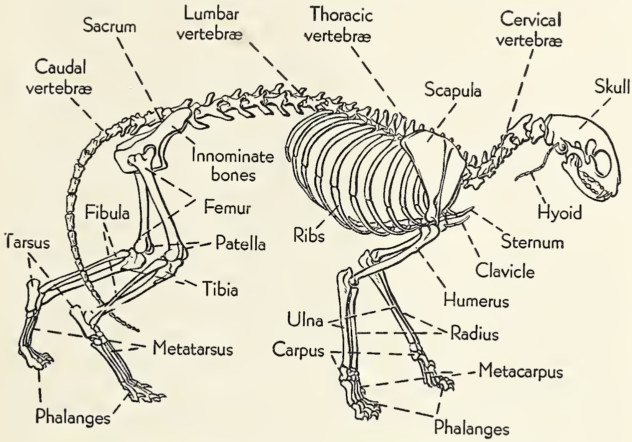


Fig. 23. — Skeleton of cat. (From Reighard and Jennings)

Ecology

(To follow Chapter 5, page 63)

Although plants, in comparison with animals, seem almost lifeless, actually they are such sensitive organisms that they are influenced profoundly by all sorts of external conditions or factors, all of which taken together constitute the environment. These influences may be classified as *climatic:* factors that affect plants through the atmosphere, comprising temperature, moisture and light; *edaphic:* factors that affect plants through the soil, comprising available water in the soil, air in the soil, temperature, character of the soil and drainage, and character of soil solutes; and *biotic:* factors that affect plants through other plant and animal organisms, comprising competition, parasitism, symbiosis, decomposition and synthesis by bacteria, pollination, effects from animals, and the influence of man.

The science that seeks to determine to what extent plants have been and are now influenced by these environmental factors, is called *ecology.* The study of botanical ecology is exceedingly complex, since it requires the most painstaking field work based on a profound knowledge of all divisions of botany, especially taxonomy and plant physiology, also basic chemistry, physics, meteorology, geology, geography, and statistical mathematics. It is obvious that only a brief treatise can be given here. Biologists are convinced that a full knowledge of ecology can explain many of the internal changes altering physiological activities and growth in plants, external alterations of structures, and the development of many kinds of adaptations. The distribution of plants on the earth has resulted from their reactions to environmental factors. Ecology is valuable for its contributions to soil restoration, reforestation, flood control, control of sand and soil movements, propagation of wild life, and the like.

A. Climatic Factors. *1. Temperature.* Plants vary greatly in their ability to endure low temperatures. Grass, roses, and strawberries resist freezing temperatures which would kill squash, tomatoes, begonias, canna, etc. Temperatures lower than 34° and higher than 110° cause physiological changes that kill most plants. Freezing kills plants because of the rapid withdrawal of water from the cells rather than from mechanical injury due to the development of ice crystals. So, plants and seeds which have little water or considerable sugar in the cells usually escape injuries from low temperatures. Low temperatures play an important part in stunting tree growth and in delaying or preventing the formation of flowers and seeds. Thus, temperature is the important factor that determines to a large degree the kind of plants to be found in a given altitude or latitude. Plant growth is most luxuriant in the tropics, and most scanty in the polar regions. For instance, cotton will not grow profitably unless it has at least 77° summer temperature. Apples will not grow south of the line of 79° average summer temperature. This means that in Canada cotton growing should not be attempted, but that apples can be a profitable crop.

2. Moisture. All plants need more or less water, in fact the amount of water available to plants is of primary importance in determining their world distribution. In general, whether the plants in a given region constitute a lush jungle, meadow land or a desert, will depend upon the rainfall. The relative humidity of the atmosphere affects the rate of transpiration and the general growth of plants.

3. Light. Light is a primary factor for the making of food by photosynthesis. It also affects plant distribution, which is based on light tolerance. Most woodland, flowering plants grow best in shaded places; sunflowers, corn, legumes, many grasses, and the like, all require strong sunlight for their best growth. The intense light in the northern parts of Canada may be a powerful factor in stunting the growth of certain Alpine plants in those regions. Oaks and Douglas firs require strong light; beeches and hemlocks, on the other hand, thrive in reduced light. Light affects the production of flowers. Laboratory experiments show that more illumination than normal, produced through artificial means, forces the plant to bloom, days, weeks, or even months earlier than it would normally bloom. Reducing the amount of light will extend the period of flowering. Thus there are several kinds of nut trees such as English walnuts, pecans, filberts, etc., that might grow in Canada, yet would not have enough hours of sunlight and warmth in the relatively short summer to flower and fruit. Light or its absence also affects transpiration, soil temperature, rate of digestion and enzyme action in plants. It is natural that plant structures are affected by the amount of light. Stands of forest evergreen trees are planted only a few feet apart (about six feet in the case of spruce) so that as they grow up, the lower side branches will die off from lack of light, and the trees will grow taller, seeking the light above them. One authority states that in general the leaves of plants that grow well in the sunlight are thicker, have small intercellular spaces, have cutinized epidermis, have frequently a smooth and shiny surface, and have stomata confined to or more abundant on the lower surface. Plants that grow best in the shade generally have thinner leaves, with large intercellular spaces, only slightly cutinized epidermis, generally dull surfaces, and stomata on both sides.

B. Edaphic Factors. Soil factors are very important. Plant growth and distribution are so dependent upon available water in the soil that plants have been classified into four great groups on the basis of their water requirements, as follows:

1. Xerophytes. Plants structurally and functionally adapted to live in dry places and to resist drought. Examples: cactus, Russian thistle, millet, sorghum, sagebrush, Yucca, some species of grass.

2. Hydrophytes. Plants that live in water or in wet places. Examples: cattail, waterlily, lotus, pickerel weed, Elodea, duck weed.

3. Mesophytes. Plants that grow best with a moderate amount of water. Examples: our common plants, both wild and cultivated.

4. Halophytes. Plants that grow in salt marshes or in alkali flats where there is such a high concentration of chemicals in the water that absorption of water by the plant cells is difficult. Examples: saltbush, greasewood, salt meadow grass, glasswort.

(*a*) *Water in the soil.* The available water in the soil is determined by several factors, the principal one of which is the amount of annual rainfall together with its distribution through the year. The degree of humidity of the atmosphere affects the rate of transpiration of water from plants and the rate of evaporation of water from the soil. Precipitation and evaporation indirectly may determine the distance of the level of water-saturated soil from the surface, i.e., the position of the *water* *table.* Heavy, clay soils do not allow water easily to penetrate the ground, while light, humous soils receive water freely and tend to hold it. The amount of water in soil may be greatly lessened by excessive transpiration from weeds, and other plant organisms.

(*b*) *Air in the soil.* Since oxygen is necessary for the life of all cells, soil should be light enough by composition or by mechanical stirring, so that there is air throughout the ground. In soil that is water-soaked there is no air except that dissolved in the water. Plant roots are not adapted, as are aquatic creatures by gills, to absorb oxygen from water. Hence most plants, except Hydrophytes, are smothered to death if the soil about their roots is continuously soaked. Even water plants such as cypress trees send aërial branches of their roots upward above the water in which they grow, in order to get air. Germinating seeds especially require plenty of oxygen in the soil for their more rapid respiration.

(*c*) *Soil temperature.* Plant growth is greatly influenced by the temperature of the surrounding soil. Low temperatures slow down the rate of absorption of water by the roots. Soil temperature is affected by the intensity, angle, and duration of sunlight falling on it, the air temperature above the soil, the amount of moisture in the soil (moist earth is cooler than dry earth), and whether or not there is a covering, since humus, for instance, would tend to retain heat but to retard the absorption of heat by the soil.

(*d*) *Reaction of the soil.* It has been found that many plants, such as saltbush, many ferns, beech trees, etc., seem to require soils that are slightly or heavily alkaline, while other plants, such as rhododendron, heather, sour dock, cranberry, blueberry, etc., grow well only in soils that are somewhat acid. Most plants do not seem to need special soils.

(*e*) *Soil solutes.* Osmosis, i.e., water absorption, can take place only if the concentration of the cell sap of the root hairs is greater than that of the soil solution. Most plants would be killed by the conditions in which halophytes live, because the quantity of solutes (dissolved substances; here, salts in the soil water) may make a concentration equal to or higher than the fluids of the root cells. Some soils may lack certain of the essential mineral elements. Plants growing in such soils have their growth rate reduced or they may be dwarfed.

C. Biotic Factors. Individual plants may seem to live alone. However, there is no wild organism that is not influenced by the other organisms of its environment. Competition, parasitism, symbiosis, pollination by insects, destruction by animals, and man's actions are all biotic factors that have profound effects.

1. Competition. Every plant is subject to the most remorseless competition from near-by plants for space, light, moisture, and mineral matter from the soil. Weeds grow faster than cultivated plants, robbing legitimate plants of needed moisture and minerals. Plants with longer root systems, more efficient water absorption, immunity to low temperatures and to plant diseases, better ability to manufacture food, etc., will live where other plants succumb and die.

2. Parasitism. Parasitism is a kind of competition. It occurs where plant forms such as bacteria and fungi infect the host plant and consume or poison its tissues. The chestnut blight, a kind of fungus, has killed off practically all the grand old chestnut trees in eastern North America. Similarly, the Dutch elm disease fungus has seriously depleted the elms in North America. The white pine blister rust menaces most valuable pines of the United States and Canada wherever there are adjacent currant or gooseberry plants. Many other examples of the effects of destructive parasitism will come to mind.

3. Symbiosis. Such symbiotic relationships as are seen in the case of algae and fungi forming lichens, and the nitrogen-fixing bacteria in the roots of legumes, reveal an association as intimate as parasitism, but unlike parasitism, of mutual benefit to both organisms concerned. Such cases of symbiosis are beneficial even beyond the two organisms concerned. Lichens help other plants by making soil; nitrogen-fixing bacteria make the soil richer for plants other than legumes.

4. Decomposition and synthesis by bacteria. The dead structures of plants or animals and animal wastes are broken down by bacteria in the process of decay. The end products of such decomposition are water, carbon dioxide, hydrogen, nitrogen, ammonia, and many other chemical compounds. Green plants consume the water and carbon dioxide in making carbohydrates by photosynthesis. The free nitrogen and the ammonia are converted into nitrates by nitrogen-fixing bacteria. Hydrogen and some of the chemical compounds are oxidized by other bacteria. Iron, calcium, magnesium, sulphur, phosphorus, and many other elements are released in the soil as compounds in the form of salts. These mineral compounds are necessary to green plants for the making of proteins, fats, enzymes, and other products.

5. Pollination. The distribution of flowering plants throughout the world is influenced to a very large extent by the presence (or absence) of insect pollinators, since fertilization and seed-making are largely dependent upon insect-pollination.

6. Animals. Injurious insects are perhaps the worst enemies of plants. It is only with man's aid that cultivated plants, as well as many wild forms, have survived the incessant attacks from hundreds of species of insect marauders. Also, grazing animals, such as deer, sheep, and cattle, crop away leaves and twigs. Most plants cannot endure the loss of their green parts which make food for the plant. Some kinds of grass and hardy plants like weeds may be able to survive. Thus, the types of plants left in a given region may be greatly altered. The distribution of plants may also be determined by birds, which eat seeds and pass them from their alimentary canal undigested. Hosts of spiny or barbed fruits and seeds are distributed to new territory by being entangled in the hair of fur-bearing animals. Upsetting the balance of nature among animals may have important effects upon plants in a given region. For example, the killing of hawks brings about an increase in field mice which then cause much destruction of wheat. Similarly, rabbits introduced in Australia became a great pest since they fed upon desirable plants.

7. *Man.* Uneducated man is a most destructive agent. Without farsighted individuals and conservation laws our forests would long ago have disappeared, together with all the wild animals. On the other hand, constructive measures have given civilized countries organizations and institutions such as departments of agriculture, experimental schools and colleges, and laboratories, all engaged in progressive work. Thus new plants, discovered in remote places, have been brought back to be cultivated in many other parts of the world. Horticultural experimentation has given us many plants such as smut-resistant corn, Kanred wheat (rust-resistant), Marquis wheat (drought-resistant), and the like. Plants have been developed that can endure lower temperatures, are disease-resistant, and have a greater yield of larger seeds. This means a wider distribution of such plants with corresponding value to mankind. Hybridization, grafting, treatment with chemicals such as colchicine, and other methods, are giving the world new types of plants which bid fair to revolutionize plant cultivation on the earth.