The Biology of Man and Other Organisms

Henry R. Linville

THE BIOLOGY OF MAN

AND

OTHER ORGANISMS

BY

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PREFACE

First of all, this textbook probably covers any formal syllabus in biology now in use. But if the book did only that, its existence would be inexcusable. At most, the average syllabus is a crystallization, a static thing. A syllabus in biology is almost a contradiction in terms, because the essence of biology is dynamic and fluid life. For this reason, a good textbook must transcend the syllabus, and break new paths for the minds of the young. The inspiring portion of any textbook in biology will continue as something over and above the things that are likely to be named in any formal outline of topics, subtopics and suggested material.

There are two groups of critics which teachers of biology, and the writers on that subject must encounter. One of these groups is composed of young students who have to be attracted to undertake serious intellectual work of any kind. They may say frankly that they don't care for biology. The other group is composed of grown-ups who regard the subject of biology as of slight importance in the intellectual life of modern times. Curious and often interesting, they say, but more a museum than an interpretation of real life for intelligent, red-blooded men and women.

It would be a valuable experience to teachers of biology if they should listen to these groups of critics, or to any others, and seek thereby to ascertain the bases of the objections. Probably there is no objection to biology itself, but, in the case of the adolescents, rather to the forbidding or disciplinary aspects of the methods pursued in its presentation.

The intellectuals are not concerned so much with matters of presentation. Their objection is directed against the biologists themselves. To these critics the biologists do not seem to be interested in establishing the fundamental connections between biology and the great social problems in human life. To them there seems to be in the minds of biologists too much of "bugs and flowers," and too little of mankind. In other words, the very devotion of biologists to their subject-matter seems to cause them to narrow their vision, and to fail to see, and hence to point out, the ramifications of the principles and the processes of biology in the living, and in the activities, of all human beings.

This tendency to narrowness on the part of our professional biologists results in putting off the day of the possible supremacy of biology as a great educational and social science. We must get into the stream of human life itself with our equipment of biological lore. We must learn the special forces manifesting themselves in that stream. We must also be ready to assist in directing these forces along clearly discernable biological lines, to the end that the greatest possible power in the race may be developed.

The "over and above" part of this book comprises an attempt to meet the sound objections of critics of the two groups mentioned, and possibly of other groups as well. This is done by making biology set its best foot forward. "Human interest" is a good pedagogical lead. It is not sensationalism. Young persons, and older ones, too, like stories that bring out the charm of existence, their own existence, or of some existence in obvious or suggested relation to theirs. With this approach well laid, the mind has no hesitation in setting to work to comprehend the intricacies of life itself. If this approach can be made better than it is done in this book, that is still the thing to do.

For the rest, the working out of the biological principles and processes in their relation to the manifold activities in which man engages, and to his origin, his background, his environment, and his destiny, serves as the basis upon which biology may fittingly lay claim to the intelligent consideration of the human mind. If this working out is well done, biology will no longer mean "bugs and flowers." It will mean life, and at the center, comprehending it all, and in large measure controlling and directing it, will stand man himself.

THE AUTHOR.

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CHAPTER I

INTRODUCTION

As little children all of us have annoyed our parents greatly by the incessant asking of questions. Alas, too many of us have been trained out of that racial habit. But happily some have retained it to the great pleasure of themselves, and to the good of mankind. For, asking questions is the expression of an inner curiosity. And curiosity has always been a very important stimulus to the making of the great discoveries for which our civilization is famous.

Among the many discoveries that have resulted from the habit of expressing our curiosity is the one that shows Nature as the original and authentic source of knowledge. Nowadays, we may think such a statement is like an axiom, a fact that is self-evident, but the history of natural science shows that for hundreds of years in the early part of the Christian era men preferred to ask what the great Greek philosopher, Aristotle, had thought about a subject. It seems never to have occurred to the wisest men there were in those days that Aristotle himself, or others before him, must have gone to Nature for their information.

Although we must necessarily obtain our facts from Nature, we should understand that we use the expression "going to Nature" only in a figurative sense. Nature is not a person, and cannot tell us anything. Nature is a marvelously complex system of facts, manifested as living and non-living things and as processes. Without the mind of man to see, to investigate, and to understand, we might almost say Nature does not exist.

Thus, there is infinite use for our inborn disposition to inquire. The use a particular person may make of the trait may seem trifling to the young student, doubtful of his powers to see and understand, but we have discovered that the desire to know, and a confidence in one's ability to comprehend, come with practice. There are many elder persons who interfere with the natural education of a child by doing things for him. Much of the doubt of our own abilities comes from being told as children that we "cannot do it right." What a pity it is to do everything for a child of three or four, instead of giving it the chance to find out for itself. Fortunate is the little one who has the spunk to say, "Let me do it!"

If you of older years who read this book think there is no fun in science, ask your teachers to "let us do it." We who are teachers are making our important discoveries, too; and slowly we are coming to see through our experience that constant "telling" is not teaching.

So, the natural inclination of the human mind is to want to be allowed to have its way, profiting wisely by the experience of the race in general, and by the practice of the scientists in particular; for, it would be short-sighted to neglect to use the ideas and the skill that men before our day have developed. We have no time to waste going over and over everything again, as if the field of knowledge were altogether new.

The purpose of this book is to set before you some ideas about animals and plants as they have interested, and still interest, mankind. These ideas are stated very definitely, and are related to one another in such fashion as to demonstrate the degree of organization to which the science of Biology has attained. Formerly, the books on biology made no mention of man at all, but now we are beginning to emphasize the relation that has always existed between man and other organisms. In fact, it is the very complex, and the very dependent, relations that man bears to the living things of the world, plants as well as animals, that makes the study of Biology naturally interesting and important.

We have always lived surrounded by other creatures and by plants. In the time of our primitive ancestors long ages ago, man ranged the forests, taking his chances with the more ferocious animals, making use of others for food, for clothing, and for domestic purposes. The plants and their natural products he used for food and for shelter. To-day, our very civilization is characterized by the great number of uses we make of animals and of plants, as well as by the control we have gained over their multitudinous forms, and their productiveness.

This control extends not only over the field of products which we use as food, medicine, clothing, and shelter, but also to the very existence of forms of life, and even to the creation of new varieties of plants and animals. Who has not heard of Burbank's wonderful results in the creation of new kinds of plants out of older kinds? And who does not know of the vast experimenting that is going on in the breeding of animals for all possible uses?

A great deal of the control over life and living things has come through the expression of the inborn curiosity of men who wanted to see what would happen in a given experiment thought out by them. But the mastery of life has always been in the hands of those men who have been trained, or have trained themselves, to think and work scientifically, with thorough knowledge of some basic facts and underlying principles, and with definite understanding of how to go about it to learn more facts and more underlying principles.

The road to becoming a "master of life" is not so long and difficult as you may think, for it does not necessarily mean becoming a scientific experimenter or investigator. The most immediate, and in fact the best, thing it can mean is for each one of us to become master of his own life.

However, we cannot obtain control of our own living self, understanding it and our bodily processes, without a more or less extensive knowledge of other life. The reason is that man is the most highly developed of all living things, representing in himself structures and processes which exist in more simple ways, and are studied more easily, in lower forms of life. But if this were the sole reason for learning about the less well known animals and plants, the study of life might prove dry and uninviting. As a matter of fact, life among the lowly of the air, the land, and the sea is extremely interesting in itself to read about as well as to study first hand. Persons do not have to be stimulated to take an interest in things that are capable of holding the attention naturally. It would be unfortunate, indeed, if a young person should miss the opportunity to start from his natural interest in living things, and with his increasing knowledge of life in general, develop real love for nature in all its phases.

One of the aims of this book is to present the facts and principles of the subject of animal and plant life in such manner that you will *want* to go to the forests, the fields, and to the sea, where the other creatures live; and while doing so, will become better acquainted with your own bodily and spiritual self, and better satisfied with its possibilities, besides probably finding in it a well of happiness the existence of which you may never have suspected.

Moreover, the author feels that he is justified in having another important aim in writing this book, and that is to encourage in you the desire to go on and find out things for yourself during the time you are studying this book and afterward. The time you spend on the book is comparatively short, while a lifetime of possible experiences stretches out before you. If you learn the method of inquiring, and especially if you regain the *desire* to inquire, and consequently to think, you will surely be in a position to lead a happier life, for you will understand your environment, and be able to master it, instead of permitting it to master you.

CHAPTER II

THE SLIPPER ANIMALCULE AND ITS NEAR KIN

If you are accustomed to thinking of animals as creatures that have exactly four legs and bodies large enough to command your immediate attention and respect, you may be surprised to learn that probably the very first animals to exist and the most common to-day have no legs at all, and are not large enough to be seen unless you have a high-power microscope.

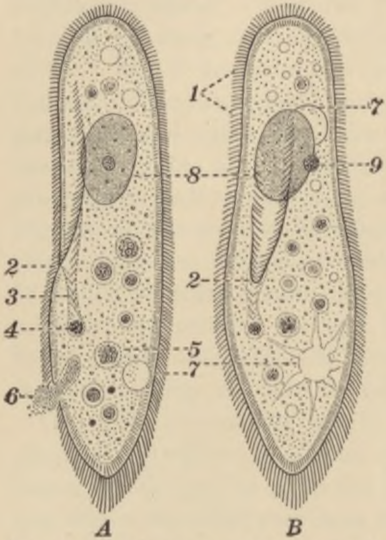


Fig. 1. Paramœcium. Much enlarged.

A, left side; *B*, under surface; 1, cilia ("oars"); 2, mouth; 3, gullet; 4, food vacuole forming; 5, food vacuole in cytoplasm; 6, anus; 7, contractile vacuole; 8, macronucleus; 9, micronucleus. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

Among the commonest is the Slipper Animalcule or the Paramœcium. As the drawing indicates, it has the general form of a slipper. If you are lucky enough to have the use of a compound microscope, you may find Paramœcia in abundance in jars of rotting hay that have been standing for at least three weeks. A small drop of water placed on a glass slide and adjusted on the stage of the microscope will contain many hundreds of tiny "slippers" shooting spirally hither and thither through the water. With a very highly magnifying lens in the microscope you may see the minute "oars" with which they swim. These are fine hair-like and very flexible short organs covering the entire body. With them the animals can swim either forward or backward. Forward means with the blunt end in front, although you will not find a head, or eyes, or any of the organs you might expect to find.

At the inner end of a short gullet droplets of food and water form and periodically float away through the soft, jelly-like interior substance of the Parmœcium which is called *protoplasm.* You may see that digestion of the food is taking place, for the droplets get smaller and smaller. Waste particles are sent out from the body by means of two tiny organs called vacuoles that contract periodically, one after the other. A contracting vacuole makes one think of a toy balloon that is losing its gas.

When a Paramœcium grows to its full size it begins to form a groove around the middle of its body. The groove deepens until the original animal has cut itself into two. But while the separating is going on each half forms a new mouth with all other organs necessary to its existence. This process is called *reproduction.* Through it the race of Paramœcia continues to exist.

All the processes of this little animal are carried on by the living protoplasm of the body. The more fluid portion of the protoplasm, called *cytoplasm,* as already described, controls the nutritive or food-disposing work of the cell. The denser, more central portion of the protoplasm, called the nucleus, with an adjacent smaller body called the nucleolus, controls the reproductive process.

Amœba.——A relative and in some respects a friend of the slipper animalcule is the Amœba. The two little creatures are constructed on the same general plan, thus being relatives, and they live more or less together, existing on the same kind of food. There is plenty to eat for both, and so there is no occasion for their being enemies.

Your expectations may now be adjusted to rapidly moving objects, and to things still more striking than the Paramœcium. If they are, you must shift your effort to seeing a very small object that scarcely moves at all and to distinguishing a thing that looks not unlike scores of other apparently lifeless and formless clear specks. For the Amœba even under the microscope moves almost as slowly as the hands of the clock, which you cannot see moving at all, and it is so much without form as to suggest the term formless. But it moves and it has not a form, but forms, and the forms are the direct result of its movement. And this is the way of it.

FIG. 2. AMOEBA. Much enlarged. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

The outer layer of protoplasm of which the body is composed has the power of extending outward little knobs or points, of jelly-like material in one or another direction. Into this knob the thin and granular protoplasm flows slowly, leaving other knobs that may previously have been formed on another part of the animal. The entire outline of the Amœba is continually changing during its active moments. These little points and knobs are called "false feet" indicating their temporary character, for they may no sooner be formed than they are withdrawn into the uniform substance of the animal.

Amœba is like most other animals in having to move to get something to eat. When it strikes against a Bacterium two adjacent false feet encircle the food, and very shortly the germ is taken into the animal and digested there.

Reproduction takes place by a simple division into two parts, each part then growing to the size of the original animal. As in the case of Paramœcium, there is a nucleus which controls the process of reproduction.

Foramenifera.——The heading of this section is a long word, but there is no common term for the creatures that are included in the group which they comprise. In structure they are nearer like the Amœba than like any other animal, but their bodies are covered with a minute shell. This shell has a large opening out of which the body extends. The name comes from the fact that the shell bears (Lat. *fere*) an opening (Lat. *foramen*).

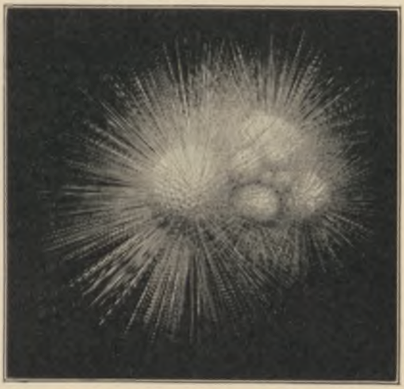


Fig. 3. Foramenifera. Much enlarged. (Photograph. Courtesy of American Museum of Natural History.)

There are at present and there have been probably since the beginning of life upon the earth billions upon billions of these minute animals floating at the surface of the ocean. When they die their shells sink slowly to the bottom. In places the oozy bottom of the ocean contains countless numbers of the shells.

At various periods in the history of the world the floor of the ocean has been elevated, dried and hardened into stone. This means that much of the land upon which we live now was at one time under the water of the ocean. In the limestone especially, we can discover the shells of these

Foramenifera. The limestone of Virginia and the chalk cliffs of the shore of England are masses of the shells of these microscopic creatures.

The Malarial Parasite.——Not many years ago people generally, and even physicians, thought that the disease malaria was due to poisonous vapors given off from low ground. Within the past twenty years scientists have proved beyond doubt that vapors have nothing to do with causing the disease. They have proved that a minute one-cell

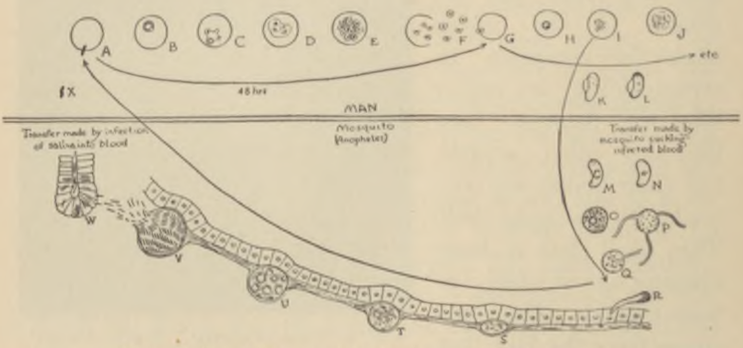


Fig. 4. The Malarial Parasite. Much enlarged.

Diagram to show the life-history of the parasite in the body of man, as well as in the mosquito. *A* to *L*, red blood corpuscles, showing the development of parasite inside; *M* to *W* shows changes in form and position of the malarial parasite in the mosquito. (Redrawn from Chandler: *Animal Parasites and Human Diseases;* John Wiley and Sons.)

animal is the sole cause of it. This discovery has made it possible for us to begin intelligently a campaign to exterminate the very disease itself.

The malarial parasite is an unwelcome guest in the bodies of two hosts, ourselves and the *Anopheles* mosquito (see Chap. VII). This mosquito is not the common one, but one that happily for us lives in places where most people seldom go, in swamps and low ground and in forest ponds. The parasite enters our blood when we are bitten by this mosquito. It increases in number very rapidly, and the young enter the red corpuscles of our blood, completely destroying all the corpuscles they enter. The stages of development through which the malarial parasite passes are extremely complicated. This made it very difficult for scientists to discover the life-history of the animal.

Since the discovery of the malarial parasite communities have been able to reduce materially the number of cases of malaria. Evidently the parasite cannot exist if there are no Anopheles mosquitoes. Since mosquitoes of any species are nuisances, many towns, counties, and states are draining swamps, clearing out stagnant ponds, and putting in fishes that will eat the mosquito "wrigglers." Sometimes undrainable swamps are covered with crude oil which smothers the wrigglers when they come to the surface to breathe.

The Yellow Fever Parasite.——About the time of our Spanish War the cause of the yellow fever was in doubt. Many observations had been made, and a certain mosquito, this time the genus *Stegomya* was suspected of being connected with the transmission of the disease from person to person. In order to test the matter finally, a commission of three American physicians established an experimental camp in Cuba. In the course of the experiments two of the physicians became ill with yellow fever by permitting themselves to be bitten by a mosquito that had under observations previously bitten a man who had yellow fever. One of the three, Dr. Jesse W. Lazear, died. They had all risked their lives so that the science of medicine might have the evidence it needed.

With the evidence thus obtained, the United States Government, the Cuban Government, and other representatives of organized society have begun intelligent campaigns to eliminate this terrible disease.

You may remember reading that when France tried to build the Panama Canal hundreds of workers died from this fever and from malaria. Later, our government by draining the mosquito swamps and by screening the houses in the Canal Zone was able to build the canal with practically no loss of life from these now preventable diseases.

For a long time the yellow fever parasite could not be found. However, all the phenomena connected with the life history of the disease proved conclusively that a parasite similar to the malarial parasite exists. Although these facts were known, it was more than thirty years after the close of the Spanish War before Noguchi, the Japanese biologist, discovered the parasite. It is very small.

Early in your study of science, one of the important and very interesting facts you will constantly be coming upon is that the truth about nature is easy enough to understand when your attention is drawn to it in a book, or when some one who knows tells you about it. Many facts, however, are within the power of anyone to see and understand, if only he uses his eyes, and more necessary still, his brain. But the great secrets, the riddles one might call them, many of which have defied the wisest men to discover, are made known only through the operation of the highest qualities of intelligence mankind possesses.

Necessarily, our greatest discoverers have always had a large stock of that wondering curiosity we all have as children. They have never ceased to want to know. Possibly, too, many scientists begin an investigation with the spirit in which we begin games. Only in their cases the game is a magnificent one, one that no person ever played through before, one that calls for every bit of mental power they possess, one in which the end brings fame, possibly, but preferably the knowledge that the mind—our human mind—has conquered this hitherto unconquerable difficulty.

Summary of the Protozoa.——The first of the great Branches of the animal kingdoms is called Protozoa. The word means *simplest animals.* The bodies of all are composed of but one *cell.* The material of this cell is the semi-fluid, living substance known as *protoplasm.* At or near the center of the cell is the *nucleus.* This also is protoplasm, but it is denser protoplasm. The nucleus is considered the most important organ of the cell, because without it the cell dies, while the remainder of the cell may be lost and the cell still live. Protozoa is the only Branch of animals that have bodies of single cells. All other Branches have bodies of many cells, sometimes billions of cells.

CHAPTER III

SPONGES

Who has not stood before a drugstore window and gazed at a display of sponges? How many allow their imagination to picture all the things that have happened to the sponges since they left their native ocean bed? But possibly a full account of their vicissitudes since death would not be nearly so entertaining as the story of their daily lives at home.

For the sponge is a living thing, or rather it is many living things. There are sponges of very small size that are usually single animals, but those that we are most familiar with are made up of several individuals so united together as to be indistinguishable. In a large display of sponges you will notice that many of the sponges show several conspicuous "chimneys" opening upward. These indicate roughly the number of animals that are merged together to form the sponge "colony," although it would be impossible to say just where the line of separation passes between them.

The chimneys themselves and all the network of tough fibers make up what is called the skeleton of the colony. In life the skeleton is covered with living protoplasm, and through all the irregular spaces which connect directly and indirectly with one another there is a continuous sheet of this protoplasm. Down at the bottom where you see the even surface, a sharp knife severed the colony from its attachment to the rock upon which it grew.

In your study of the Paramœcium you learned about cilia, those minute hair-like organs that wave back and forth, pushing the animal through the water. Sponges have somewhat similar organs, but they are located in the irregular passages. Their work is waving vigorously inward, maintaining streams of water, food and air which are absorbed directly into the tissue of the colony along the passages.

If you open a sponge colony you will find that all the incurrent passages connect with large interior spaces that lead finally to the chimneys. In life the chimney acts its part and carries off waste. This waste consists of excess

FIG. 5. COLONY OF DEEP-SEA SPONGES.

Skeletons of sponges mounted as a specimen. (Photograph. Courtesy of American Museum of Natural History.)

water and air, and of used-up material given off by the cells. Periodically, cells that take part in the reproduction of the colony are formed along the passages. The same colony may at one time form eggs, and at another, form male reproductive cells, the *spermatozoa*. The spermatozoa from one colony are drawn with the water into the canals of another, and there unite with the eggs, forming thus the *embryos*, young sponges, which later go out into the watery world and settle somewhere on a rock to take up the slow existence of their elders.

CHAPTER IV

JELLYFISHES AND CORAL POLYPS

Medusæ and Hydroids.——You must have read the story of Medusa in your Greek mythology, and you may remember why the hair of her head writhed and seemed like a mass of things alive. Biology is full of terms borrowed from Greek mythology, but often the reason for their use in the new connection is a fanciful one, as it is in the case of the medusæ of jellyfishes.

By the stretch of an imagination much less sedate and dignified than a scientific imagination you can see that the picture (Fig. 7) looks like the top of a person's head, and that the row of pendant organs resemble snakes that are fastened by their tails. If you cannot imagine the resemblance, you should see the medusæ alive! For all of its oddity, the medusæ is a real animal, living an independent existence, at least in the stage represented in the picture.

Medusæ are jellyfishes, and there are very many kinds of them. They all live at the surface of the sea. They are very small, many being microscopic. Some are beautifully colored, and all are capable of moving more or less gracefully through the water. This is done by the contraction of a circular band of muscle fibers that run around the base of their dome-shaped bodies. During contraction of the body, water is forced outward through the opening shown in the picture, and the body goes forward, with the tentacles streaming out behind.

Helpless as these tentacles appear to be, they are the little animal's stinging battery for offense and defense. All over the surface of the tentacles are groups of minute cells, which on being touched, release fine, awl-like points that pierce the skin of microscopic neighbors, and instill into their blood a paralyzing poison. So after all, there is something about these organs that suggests a dangerous animal, but they are not dangerous to persons.

When a victim has been overcome, it is swallowed through the mouth and passes up, as it happens, into the primitive

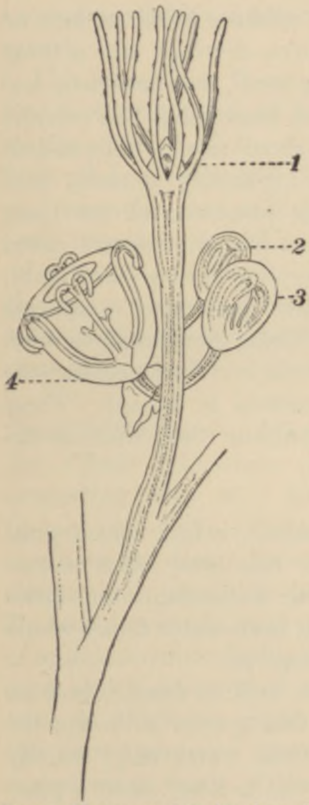


FIG. 6. HYDROID. Much enlarged (After Allman). 1, tentacles; 2, 3, 4, stages in the formation of medusa. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

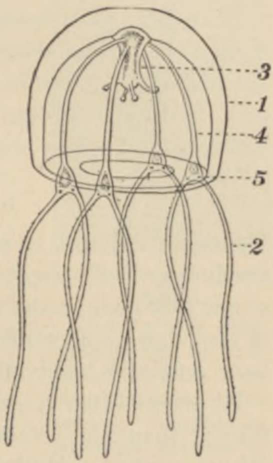


FIG. 7. MEDUSA. Much enlarged (After Allman). 1, bell; 2, tentacle; 3, manubrium; 4, radial tubes; 5, sense-organs. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

stomach located near the top of the dome. In four little pouches located on the radial canals, the eggs are formed, in the females, and spermatozoa in the males. These cells pass into the water through the mouth opening, and the embryos are formed outside in the water.

The subsequent history of the medusæ leads us into an apparently new field, for the embryo develops into a thing that looks like a plant with roots, stem, and branches, and has a fixed position. In fact, when these plant-like colonies were first discovered they were given names independent of the medusæ with which their life-history is really connected, the relationship not being suspected at the time. All the many species of these plant-like animals are called *hydroids*, because of their resemblance to Hydra (see Fig. 8).

Each head of a branch is the main portion of a separate animal, the connection with others being established through the branches. Once in a while a little bud forms on the side of a hydroid, and gradually a medusa is formed. These separate and swim away, and continue their lives as described before.

Hydra.——Hydra is another monster, a fact which your mythology will verify. If water fleas and other microscopic folk could hand down to their descendants the stories of their trials and misfortunes, this fresh-water terror would have received unenviable fame long ago.

Hydra is often a quarter of an inch in length, and no thicker than fine cotton thread. One species is brown, the other is green. Hydra lives in fresh water only, usually fastened temporarily by the basal end to a leaf or to a piece of submerged stick. The other end bears the mouth and a circle of six or more writhing tentacles. It is possible for Hydra to move from its place of attachment by slipping slowly on its basal end, and also by letting go its hold at the basal end, and crawling by its tentacles. Ordinarily, it waits until some swimming creature of suitable size strikes against its body, then it turns its tentacles about, envelops it, stings it, and draws it inexorably toward its engulfing mouth. The victim drops into the digestive cavity, where it is gradually absorbed into the cells of the body wall. All unused particles are afterward forced outward through the mouth.

This animal has two methods of reproducing the species. One method consists of forming buds on the surface of the body. These buds produce at the free end the mouth and tentacles, and subsequently separate themselves from the parent. The other method is sexual; it consists of the union of eggs and spermatozoa, both kinds of cells coming from the same animal.

FIG. 8. HYDRA. Much enlarged.

Three young specimens forming by process of budding from older specimen. (Photograph. Courtesy of American Museum of Natural History.)

Giant Jellyfishes.——Many years ago, the *Youths Companion* published an interesting story of a New England farmer, who one morning after a heavy storm on the ocean discovered on the shore great quantities of jellyfishes. He had previously used various forms of animal fertilizer for his impoverished land, and it occurred to him that this mass of jellyfishes might be used for the same purpose. Accordingly, he carted many loads of the dead creatures, and spread them over a field. The next day he discovered that his field was obscured by a thin veil of dried jellyfishes. Their previously plump bodies had disappeared as sea water into the soil. The farmer was not aware of the fact that jellyfishes are over ninety-nine per cent water.

The jellyfishes mentioned here are the large kind with which practically everyone who has been at the sea shore is familiar. They are similar in general plan of structure to those described in a previous section, but they are different in life-history, and vastly larger in size. Moreover, they are the animals to which the name "jellyfish" was first given.

Fig. 9. Model of Jellyfish. (Middle of Picture.) Reduced.
(Photograph. Courtesy of American Museum of Natural History.)

Some of the species attain the size of eight feet in diameter, which after all represents comparatively little solid tissue.

These animals have the circle of tentacles which in some species stretch out to many feet in length. The stinging cells are powerful enough to paralyze small fishes of three or four inches in length. The victims are drawn to the mouth at the center of the under part of the body, and then swallowed whole. The four large circular organs appearing in the body are the sacs which contain eggs or spermatozoa.

The little embryos are formed in the water, and sink to the bottom and there form little cylindrical stalks which later divide up into parts that resemble saucers lying in a stack. The saucer-like young separate and grow to the size of adults in one season.

Coral Polyps.——Coral polyps naturally suggest coral islands, and coral islands suggest that vast, mysterious

FIG. 10. MODEL OF CORAL POLYP. Reduced.

Showing contracted and extended specimens. (Photograph. Courtesy of American Museum of Natural History.)

stretch of ocean, the South Pacific, made famous by Robert Louis Stevenson and other writers of charming tales.

Perhaps you think there is something queer about the word "polyp," and that coral "insect" would be better and more accurate. But insect is a name used by many people when they do not know the right name for a small animal.

A polyp is the general name given to any of the fixed, soft-bodied animals described in this chapter. Thus the individuals in a hydroid colony are polyps, and Hydra is a polyp.

The coral polyp is a soft-bodied but tough, cylindrical creature varying in diameter from a fraction of an inch to a foot or more. You have seen masses of coral stone, and have noticed the crowded circular plates, with their radial ridges running from the center of each little circle. These mark the location of the polyps. In fact, the circles themselves and the ridges, and the entire mass of the coral stone are formed by the polyps. This is done by the polyps secreting or forming limestone at their bases and between pairs of thin sheets of radial partitions in their bodies.

A mass of coral with the polyps actually alive and working upon it is said to be a beautiful sight, especially when the tide covers them, and their tentacles are streaming out. Their colors mingle with the sea weeds and the brilliantly colored fishes that swim in and out between the heads of coral and other living creatures.

Summary of the Cœlentera.——The Branch of the animal kingdom to which the creatures just described belong is called the *Cœlentera.* The form of all of them is more or less cylindrical, and their substance is soft. The single opening into the cavity of the body, the mouth, is surrounded by a circle of tentacles. Upon these tentacles are microscopic cells, which have the power of stinging the small victims which they prey upon, rendering them helpless.

CHAPTER V

STARFISHES AND SEA URCHINS

The Starfish.——When you saw the display of sponges in the drugstore window, you probably also saw one or two large star-shaped shells, beside something that naturally belongs in the last chapter, some sea-fans and some sea-pens. All of these things are frequently found together in the waters of the Bahama Islands, and in many other tropical seas.

The large starfish is a giant of its kind. Most starfishes are small bodied, and have finger-shaped arms, usually five in number, stretching outward over an area of four to five inches in diameter. They are not fishes at all, any more than jellyfishes are fishes, but the name though given inaccurately still holds.

In life these animals are reddish brown, or frequently reddish blue in color. The upper part of the shell is made up of somewhat flexible plates, mounted with many short, rigid spines. Under each arm there is a shallow groove extending from the center of the body to the tip. Through minute openings in this groove, four rows of long, very flexible and delicate, muscular tubes extend to the outside. When the starfish moves, it stretches these *tube-feet* forward and fastens them in turn to the rock, contracts the muscular fibers in them, and creeps along almost imperceptibly.

Looking into a little pool left by the receding tide, one often may see several of the starfishes partially concealed between small stones, or humped curiously over something that appears to occupy their attention. Frequently investigation has shown that in this position they are engaged in

FIG. 11. MODEL OF TIDEPOOL.

Starfishes and sea-urchins at bottom of pool. (Photograph. Courtesy of American Museum of Natural History.)

opening the shell of an oyster or a mussel. This they do by a slow and continuous pull in opposite directions, drawing on the outside by sucking their tube-feet to the surface of the shell of the victim. At length the oyster or mussel gives up the fight, the muscles of the victim relax, and the valves of its shell separate. The starfish then performs the strange feat of turning its stomach inside out through the mouth opening, and enveloping the soft flesh of its exhausted prey. Before this habit of starfishes was discovered, serious inroads were made upon beds of oysters, and even now starfishes are enemies that the oyster "farmer" has to reckon with.

Although starfishes have no head, they have eyes, and these occur singly at the ends of the arms. They are probably not of much service to the owners, but keen senses of smell and of touch take the place of eyes.

There are male and female starfishes. The eggs and the spermatozoa are sent out into the water, where they unite, forming embryos that swim about in the water for some time before changing to the crawling form of the adult.

The Sea-Urchin.——Not far away from the starfishes in kinship, and often in locality, one may find something that looks at first like a flattened rubber ball, covered all over with sharp spines, sometimes very long ones. This is the sea-urchin (see Fig. 11). The spines are movable, and in one Pacific Ocean species they are used for boring holes in rocks for concealment.

In among the spines, arranged radially as in the starfishes are rows of long slender tube-feet. These tube-feet often emerge high on the sides, as well as beneath the dome of the body. By means of them, the sea-urchins move at very much the same rate of speed that is characteristic of the starfish.

The mouth is at the center of the under surface, and is surrounded by five bony teeth, pointed toward one another from the sides. Having no movable arms, they cannot open oyster shells. They feed altogether on seaweeds, and thus are not a menace to our own food supply.

The eyes of the sea-urchin are located in a circular row about the center of the top. Here they really occupy positions similar to the positions of the eyes of the starfish, for they are at the tips of the regions of the tubefeet. This is one of the interesting proofs found in the structure that the sea-urchins are relatives of the starfishes.

There are other animals that show many of the same points of resemblance. They are all classed together under the name Echinoderma, because of the possession of spiny skins.

Summary of the Echinoderma.——The two animals described in this chapter belong to the Branch called *Echinoderma*, which means "spiny skinned." The two forms mentioned, as well as many others allied to them, are constructed on a radial plan, in which usually five divisions of the body extend from a common center. The body is covered with short spines set on a more or less hard, limy shell. The organs of locomotion are muscular "tube-feet," which extend to the exterior, fasten to the rocks, contract, and cause the body to move forward slowly.

CHAPTER VI

THE EARTHWORM AND ITS KINDRED

The Earthworm.——Nobody respects earthworms, but nearly everyone is benefited by their existence. The boy who digs up a canful of them out behind the barn finds pleasure in the chase for the worms, and still keener pleasure in thinking of what he will do with them. The fishes that steal them from the hook get considerable satisfaction out of the miserable little impaled bodies. Robins breakfast on them upon the lawn, and the farmers and all the rest of us have a better breakfast because of what the earthworms are doing and have been doing since earthworms began to exist.

Indeed, earthworms were among the first of farmers, for the effect of their activities is to turn the soil over and over again. Except in winter, they are constantly burrowing through the earth, swallowing some of it for the food it contains, and dissolving particles that would otherwise remain undissolved. The natural and easy way for them to get rid of an intestine full of earth is to allow it to go through the body at the surface of the ground. Doubtless you have seen many of these coiled little masses of earth where the grass is short or thin, but you may not have understood their meaning.

Charles Darwin, the great English naturalist, took the trouble to carry on observations extending through many years, in order to get some notion of exactly how much work earthworms do along this line. He covered a field with cinders and stones of small size, and found that these afterward disappeared. He found that the earthworms brought up soil in their bodies, and spread it out on top at the rate of one-fifth of an inch a year. The practical meaning of this for us is that sticks, leaves and other bits of dead things are covered up, and their decay and return to the minerals of the soil and the gases of the air is hastened. Furthermore, the holes made by the earthworms convey water and air to greater depths than would be possible without the holes. Plowing is much less in extent than is the overturning of the soil by earthworms. The plowing done by the farmers

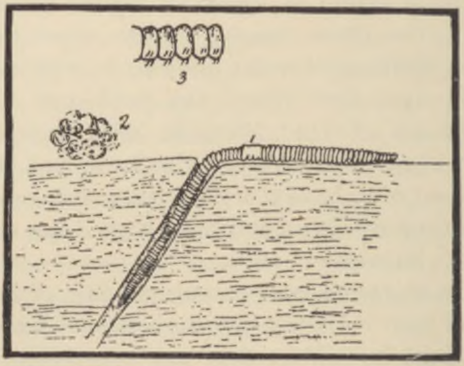


FIG. 12. EARTHWORM IN BURROW. Reduced.

1, The "saddle" of animal; 2, earthworm casts from intestine; 3, bristles on the segments. (Pen drawing.)

has the effect of being an imitation of the work done by the earthworms. But while the farmers know what they are doing, and usually why they are doing it, the earthworms do not know and cannot know the effect of their activities as they bear upon the welfare of mankind.

You can generally distinguish the head of the earthworm by the direction of its movement, although it can move backward when necessary. The only visible organ of the head is the pointed lip with which it grasps bits of leaves and draws them into its burrows. There are no eyes or other visible sense organs. However, it can feel a physical shock, as you may learn by walking near one lying at the opening of its burrow in the early morning.

Everyone has seen earthworms crawling, and knows that their bodies extend and contract. But when they operate these muscles, they use their tiny bristles on the under surface for levers. If you don't mind allowing one to crawl through your fingers you may feel the bristles, and may even see some of the largest of them.

Internally the earthworm has a very complicated set of organs. The digestive canal consisting of gullet, crop, gizzard, and intestine, extends through the body. A circulatory blood system takes up the digested food and carries it where it is used by the tissues of the body. Air that is needed comes in through the soft, slimy skin, and liquid waste is passed out through a pair of complex tubes in each ring or segment of the body. Earthworms have a microscopic brain just behind the lip in the head, and from the brain a pair of nerves pass downward and along beneath the intestine. Certain organs in the body called ovaries and spermaries give rise to the eggs and spermatozoa. The eggs of one animal and the spermatozoa of another unite, and grow into embryos in a tough little sac that is deposited in the ground.

The peculiar way in which earthworms breathe is responsible for their presence in large numbers on the ground after a rainstorm. Water running into the burrows forces out the air contained in them. Water itself contains a little air usually, but not enough for earthworms in the confined space of the burrow. So the animals are forced out into the cold world. After the rain, you may see them struggling to get back to soft earth where they can make another burrow, for there is no reason to believe that they can find their old ones, or would care to do so. A rainstorm especially in cities and towns brings disaster to earthworms, many losing their lives in the hazards of paved streets and cemented sidewalks.

The Sandworm.——One of the main reasons for mentioning the sandworm here is to show that two animals may be closely related, and still differ widely.

The sandworm lives in the mud in bays of the ocean. It has burrows, too, but these burrows are often deserted

FIG. 13. SANDWORMS IN MUD (Model). Reduced.

(Photograph. Courtesy of American Museum of Natural History.)

by their owners. Sandworms can swim vigorously and very beautifully with their numerous paddles. Where the sandworms have paddles the earthworms have only the bristles which in the sandworms give stiffness to the paddles.

Being an active animal and often going far, the sandworm has feelers with which it feels its way in narrow places. On top of the head there are four eyes. Both of these animals are quite well adapted to their surroundings or environment, but it is evident that the earthworm represents a type that is less complete than the sandworm, although both are well adapted to their place and method of living.

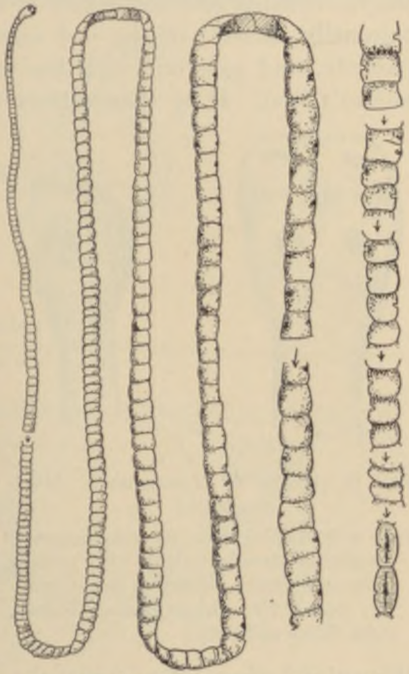


FIG. 14. THE TAPEWORM. Reduced.

The youngest segments are near the head; the oldest, containing mature eggs, at end of body. (Redrawn from Chandler: *Animal Parasites in Human Disease*, John Wiley and Sons.)

The Tapeworm.——The tapeworm (Fig 14) is still less complete than the earthworm. It is a real degenerate among animals. The explanation of this fact is that it lives in a special environment where it has to make no effort whatever to get its food. Living in the intestine of other animals upon which it is a parasite, the tapeworm has no eyes, or other sense organs. It has no mouth, no stomach, or intestine, and no blood system. But it has muscles and a nervous system, and also a simple system of tubes by which the animal rids itself of its own liquid waste. It also has organs for reproduction.

Tapeworms are found in the bodies of cattle, horses, sheep, pigs, dogs, cats, and in many other quadrupeds (four-footed animals), and also in human beings. The head of the parasite fastens itself by suckers or hooks to the lining of the intestine, and the rest of the body, sometimes many feet in length, extends into the cavity of the host's intestine. Occasionally, several of the end segments separate from the parasite, and pass out with the undigested portion of the victim's food. If by chance these segments come into food or water that is consumed by some quadruped, the embryos which the segments contain will pass down to the intestine of a new victim.

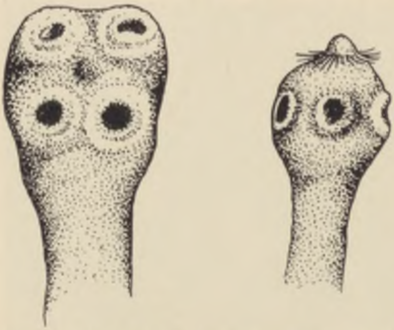


Fig. 15. Heads of Tapeworms. Much enlarged.

Left, with sucking disks for attachment to interior of intestine; right, with sucking disks and hooks. (Redrawn from Chandler: *Animal Parasites in Human Disease*, John Wiley and Sons.)

The embryos have the power of boring their way through the wall of the intestine into the muscles. There the embryos come to rest and remain until the possible death of the host by some other agency. The flesh of this animal when eaten carries the inclosed embryo into the stomach of a new victim. Thereupon, the membrane surrounding the embryo dissolves, the embryo makes its escape, and at once attaches itself to the lining of the intestine of the new victim. In this place, it begins to grow long, and to steal from its host as did its ancestor before it.

Government inspection of meats has exterminated to a large extent this parasite and others of similar kind from human beings. Of course, cooked meats cannot carry the parasite in injurious condition.

The Hookworm.——Another parasitic and degenerate type of animal is the now well-known hookworm. It lives in the intestine of human beings. A few years ago it was discovered that the existence of these terrible parasites ex-

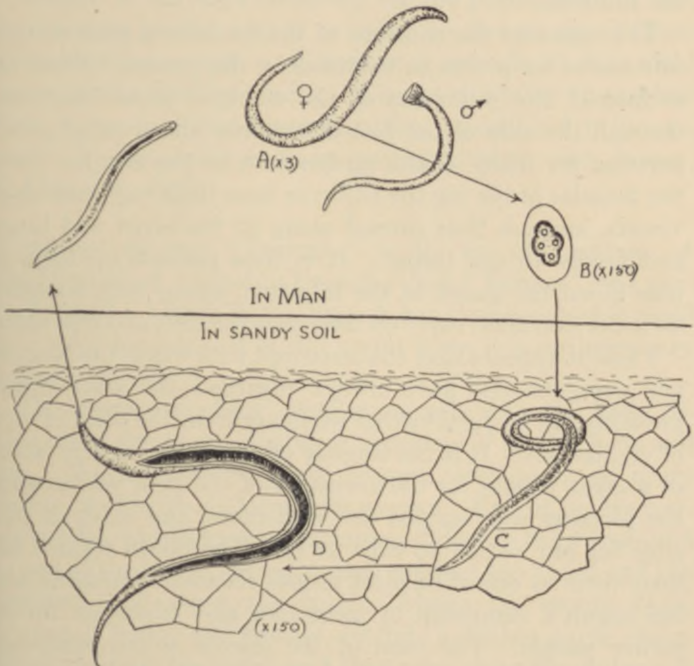


Fig. 16. The Life-History of the Hookworm. Enlarged.

A, male and female; *B*, egg; *C*, young embryo in soil; developed young in soil; young in stage ready to enter soles of bare feet of person. (Redrawn from Chandler: *Animal Parasites in Human Disease*, John Wiley and Sons.)

plains in large measure the shiftlessness and the physical weakness of that class of our fellowmen in our Southern states known as the "poor whites." For some unknown reason the Negroes of the South are immune to the hookworm.

The hookworm lives in its adult stage in the intestine of its victim. It burrows into the wall of the intestine, sucking the blood, and instilling into it a poison which tends to prevent the blood from coagulating. Internal bleeding may thus continue for some time; hence the pale appearance of the sufferers.

The eggs and the embryos of the hookworm pass out and often exist for a time in vaults or on the ground. From the surface of the soil some of the embryos make their way through the skin of the feet of children and even of grown persons, for many adults go barefoot in the South. From the muscles of the leg the embryos bore their way into blood vessels, and are thus carried along to the heart and lungs, and finally to the throat. It is then possible for them to pass down the gullet to the intestine, where they complete their development, carry on their parasitic life, and reproduce.

Thus, it appears that the contempt with which the Negroes and everyone else have always regarded the poor whites probably has no justification whatever from the point of view of civilization. It is the tragedy of what was once the stock of a great people, for the ancestors of the poor whites were the pioneers who opened the wilderness, and made it possible for our nation to exist at all. The South regards the hookworm as one of its most serious economic problems, and has begun a campaign of sanitation and education for its poorer people. The cure of the disease is comparatively simple, but its prevention and extermination depends upon the ability of the people to learn methods of cleanliness and sewage disposal. This, however, may require a long time.

Incidental to economic changes going on in the South, many entire families of the poor whites are being employed in the factories. There they live in large measure away from the kind of places where they formerly were exposed to the ravages of their enemy, the hookworm. On this account, the discoverer of the hookworm in the South, Dr. C. W. Stiles, maintains that the poor whites are far better off in the mills that they would be on the land. There may be some doubt of this, however, since the chief interest of many mill owners in the poor whites is probably not in their racial regeneration, but rather in the product of their labor.

Indeed, it has been necessary for the public-spirited men and women of the nation to come to the rescue of these twice-blighted people, and to start a crusade to stop child labor in the Southern mills. The poor whites themselves have begun to demand opportunities to work out their own economic and spiritual regeneration in their own homes, and upon the land.

Summary of the "Vermes."——In an old system of classification of animals a Branch called "Vermes" was generally used. Although the Branch has long been subdivided into other branches, it is still useful when it is not necessary to be technical.

The Vermes are long, slender animals with the body divided into numerous somites or segments of similar form and size. When appendages are present they occur on every somite, and serve as locomotor organs. Except in degenerate species, worms have a continuous digestive tract from end to end of the body. Blood vessels conduct the blood and the digested food about the body. Above the mouth there is a small brain, and from it extends a double nerve chain, which encircles the gullet, and then runs along the under side of the intestine to the hinder end of the body.

CHAPTER VII

INSECTS AND THEIR NEAR RELATIVES

The House-Fly.——There was a time, and not many years ago, when the nursery rhyme,

"Baby-bye, here's a fly;
Let us watch him, You and I,"

indicated the indulgent attitude of civilized mankind toward these numerous and over-familiar members of the tribe of insect. As a more accurate expression of feeling in the matter at present the author suggests,

"Baby-bye, here's a fly;
Let us 'swat' him, You and I."

At the same time, the habit of "swatting" or killing flies, though relieving our pent-up feelings of wrath and disgust, really does very little good. Even kind persons apparently find satisfaction in seeing flies dead, being impressed with the concrete evidence of their prowess. The author once counted 789 dead house-flies that he had captured in one day by the use of fly-paper. But during the time he was preparing the paper and counting the flies, he might have been employed more efficiently by doing something *to prevent the existence of house-flies.*

The operations of communities are slowly becoming more intelligent in the matter of dealing with the house-fly and the trouble it carries on its feet. Part of our campaign against house-flies has been waged indirectly through the great popularity of the automobile. It is said that in certain districts of New York City, where private and public horse-stables were formerly very numerous, house-flies were an ever present pest. The places of these stables have been taken largely by automobile garages. The direct result has been a very great reduction in the number of house-flies in that portion of the city.

House-flies breed in stable manure and in garbage. The

FIG. 17. THE HOUSE-FLY.

a, The insect is shown here regurgitating or "unswallowing" some of its food, thus making possible the distribution of typhoid bacteria it may have consumed; *b*, Foot and leg of insect. Filth and bacteria could be held among the bristles. (From Ross: *The Reduction of Domestic Flies.*)

complete elimination of these materials by removal, or by treatment with chloride of lime, would eliminate house-flies within one season. It is only by the coöperation of entire communities that the desired result may be brought about. But we shall get coöperation only after long effort. When public sentiment becomes strong enough in this as in any other matter, vigorous and effective action will be taken.

But why should we try to get rid of all the flies? Because it is now known that one of the ways typhoid fever is carried is by the "germs" being transported on the feet of the flies from the common breeding ground of the two organisms. Rid ourselves of flies, and we rid ourselves of one of the means in which human beings contract typhoid fever. Is it not worth while to give intelligent battle for the protection of our kind?

Fig. 18. Pupæ of House-Fly on Rotting Cloth.

(From Ross: *The Reduction of Domestic Flies.*)

The house-fly lays about one hundred fifty eggs. These hatch in one day as footless, white "grubs" or larvæ. They feed on the material about them, and within a week form around themselves a tough, brown case. They remain in this pupa stage (Fig. 18) for less than a week, at the end of which time they emerge as adult flies of full size, with their six legs, two wings and other organs completely formed. There are no "baby" flies, unless one considers the larvæ as such. In a short time the young female flies may lay eggs. This goes on all summer, and enormous numbers of the pests are produced.

The Mosquito.——Some of the most important points in connection with the life of the mosquito have already been dealt with in Chapter II. In this place the life-history and also the means of recognition of the mosquito, will be given.

Everyone is fairly familiar with the tiny "wrigglers" that by jerking their apparently weighted bodies back and forth make their way downward from the surface of the water in a rain barrel, or in a pool of water. These are the larvæ of the mosquito. Possibly not so many persons have seen the little boat-shaped mass of eggs floating on the water, but it can be seen if one is looking for it. The larvæ change

FIG. 19. MOSQUITO "WRIGGLERS."

The black mass or "boat" is composed of eggs which are hatching. The wrigglers are escaping and swimming downward. (Model. Courtesy of American Museum of Natural History.)

their skins, or they "molt" a few times, living in the meantime on microscopic impurities in the water. They breathe through a small tube at the hinder end of the body, by floating with the tube opening to the air, and the body hanging downward. That is what they are doing when you jar the barrel, or come near enough to frighten them. Their habit of breathing at the surface has given the scientist his opportunity of attacking them at one of the most vulnerable points in their lives. Kerosene oil poured upon the water covers the breathing tubes of the larvæ, and smothers them as well as any eggs that may be unhatched. Incidentally, every other living thing in the water has its supply of air cut off.

The pupa stage follows the larva stage in a few days. The pupa is active, swimming by its tail, and breathing by tubes on the middle of its back. Naturally, the pupæ also are destroyed by the oil treatment. After a few days in the

FIG. 20. MOSQUITO CONTROL.

Kerosene oil is pumped over the swampy region infested with mosquitoes. The oil resting on the water destroys all life by excluding air from all breathing surfaces touched. (Photograph. Courtesy of American Museum of Natural History.)

pupa stage, the young mosquitoes come to rest at the surface, and the adult forces its way through a break in the skin.

The mosquitoes that bite you are all females. Few persons have ever seen the males to know them. They suck the juices of flowers, and apparently never trouble us. Several other blood-sucking species of flies have similar differences of habit. There may be an advantage to the species in the opportunity the habit of blood-sucking affords in obtaining in a short time a considerable amount of rich food already prepared. The energies of the female may thus be given more immediately to egg-laying.

It is important for one to be able to recognize especially the dangerous malarial mosquito, and to relieve our minds of anxiety by being able to distinguish it from the ordinary mosquito. The malarial mosquito (Anopheles) comes to rest with all its legs on the support, and the hinder end of the body tipped upward, while the common mosquito (Culex) rests upon its first four legs, the hinder pair being stretched backward and upward without touching the support. In Culex the beak is directed downward, while the body is horizontal to the support. In Anopheles the body and beak are in the same plane. We speak of the malarial mosquito as being dangerous; but it should be understood that it really is not dangerous until after it has bitten a human being who has malaria. The chances of this happening in a malarial country are of course considerable.

The Honey-Bee.——Everyone has a good word to say for the honey-bee. It has been held up as a model of efficiency for human beings and as a satisfactory demonstration of what we ourselves could do in living and working together for the common good, if we only would. Efficient they certainly are, but many other insects are quite as much so. Working for the common good as we understand it involves the solution of pressing problems and the meeting of new difficulties incident in minds that are active in the human attribute of thinking. Honey-bees have no new problems to solve, and they do not think. But they are worth our interested study, nevertheless.

Colonies of honey-bees contain many thousands of individuals. There are a few hundred males in the early part of each season, and all the rest are females. One of the females, called the queen, is larger than the others, and performs the exclusive labor of laying eggs from which the young hatch. The remaining females do not have the power to lay eggs, and for that reason are said to be sterile, and are called "neuters." They are also given the name workers, because upon them devolves all the labor of the colony. The males are called "drones," because they do no work at all. Nevertheless, they are necessary since they fertilize the eggs to be laid by the queen. After their function is performed, they are all cast out of the hive to die, or they are killed by the workers, and are then thrown out.

FIG. 21. SWARMING OF HONEY-BEES.

The first of a lot of swarming bees when alighting cling to some exposed surface. The remainder cling to these, and form a solid column sometimes several feet long. Many thousands of these insects make up this column. (Photograph. Courtesy of American Museum Natural History.)

Owing to an intelligent selection of productive varieties made by breeders of bees, an enormous quantity of honey is often produced in a single season,—much more than the bees themselves need. There is nothing unusual about such an act on our part, and it is quite in line with our way of levying upon nature for our pleasure and sustenance. We require many other animals to put forth far more than the amount of energy that would be requisite to keep them in food. Thus it appears that we ourselves are responsible for the remarkable industry of the honey-bees. But we did not invent their skill in mechanical construction, nor do we even know the chemistry by which they transform the simple nectar of flowers into the delectable honey.

A large quantity of honey eaten by the workers furnishes the raw material from which they distill small quantities of wax in little pockets on the under side of their bodies. Other workers than those that furnish the wax, take it and mold it into the familiar honeycomb. The six-sided form of the cavities naturally results from the crowding of soft, cylindrical cavities of the same size, because each cylinder is touched by six other cylinders.

The next step in the work of the colony is the collection of nectar from the flowers. The nectar is sucked up by the tongues of the bees from the bottom of the corollas of the flowers of many species of plants. On the same visits the bee may collect in shallow pockets on the outside of the hind legs little pellets of pollen. The nectar is swallowed as far as the "crop," a pouch next to the gullet, and there changed chemically into honey, and then "unswallowed" into the cavities of the honeycomb. When a cavity of the comb is filled, it is sealed with a thin layer of wax. The pollen is made into "bee-bread" to feed the young.

Certain cavities of the comb are reserved for the "nursery." In each of the cells in this department the queen deposits an egg. When the eggs hatch, the workers in charge feed the young with honey mixed with liquid material from certain glands opening into the mouths of the nurses. Soon the food is changed for bee-bread; that kind of food is given to the larvæ until they are full grown. The cavities are then sealed by the workers. In the cavities, the larvæ spin thin cocoons of silk about themselves, and slowly change into the adult form, finally cutting their way out. This is the history of the production of workers.

In the early part of the season, or in emergencies later in the season, queens are produced in a most remarkable way. Three cavities are turned by the workers into one by tearing down the partitions. If there are eggs in all three cavities, two of the eggs are destroyed, and the remaining one when hatched is fed throughout its larval life with "royal jelly," a whitish jelly-like material produced from glands in the mouth of the workers.

When the young queen emerges from the cocoon there is an interruption in the business of the hive, and mortal fray begins between all the young queens, if several emerge at the same time. This continues until all but one have been slain by royal stings, a weapon that is used only for this specific purpose. If but one queen emerges while an older queen is in possession, the old queen tries to kill the young one, but is usually prevented by the workers from doing so. In that case the older queen is forced out of the hive, and takes with her a considerable number of workers and drones. This is called the "swarming" (Fig. 21). If new hives are not available, the new colony will find a hollow in a tree, and proceed to construct a home in it. The young queen left in the old hive, flies from the hive for a time with the drones. In this flight the eggs are fertilized by the drones. The queen then returns to the hive and settles down to her work as egg-layer to the colony.

All the activities of swarming are connected with the need of keeping the species alive. Without swarming the colonies would become too large for convenient management, and would tend to destroy themselves by overcrowding. Human beings seem in a measure to be imitating the bees when they migrate from the crowded countries of Europe, and from the crowded regions of our own country to less crowded parts. Both bees and people are greatly benefited by the change.

Ants.——Around a summer camp, or on an excursion, or even on a short trip through the woods, you must have come upon small colonies of ants while turning over flat stones. What a hurrying and scurrying you must have seen! In July you often see ants with wings running to safety with the wingless and more active ones. These winged ants are males and females, and the others are workers or neuters.

You would scarcely believe the winged ones ants at all, if it were not for the ant-like form of their bodies, and for the fact that the workers seize the winged ones, and hasten their flight into the tunnels beneath. Two or three workers often coöperate in dragging their queens along.

FIG. 22. ANT COLONY.

Section of large ant hill, showing the habitation of many thousands of ants, and indications of numerous tunnels. (Photograph. Courtesy of American Museum of Natural History.)

There are other burdens and responsibilities to be looked after in the serious emergency of unwarranted invasion by the tyrant man. Little cream-colored oblong bodies, sometimes nearly as large as a grain of wheat, are picked up in the jaws of the workers one at a time. These are the pupæ or cocoons in which the young pass the last stage of their existence just before emerging as adults. The eggs one seldom sees because they are very small. The larvæ also are inconspicuous.

One fact that is very impressive when one observes the commotion of the ant colony disturbed in this way, is that the worker individuals are not afraid for their own safety at all. Their sole concern seems to be the safety of their dependent ones, the less active males and females and the undeveloped young. This habit is at the bottom of their success as colonial tribes, and incidentally provides the interest that all human beings have in ants. We are in the habit of holding up these insects, and bees also, for our own kind to pattern after.

As we ourselves classify emotions there appears to be no selfishness whatever in the individual ant for its own welfare, but there is extreme "selfishness" for the colony. However, we might call this emotion for the large group by the name of patriotism, as we do when we give a name to our concern for country. Beside patriotism ants have high courage in battle with other colonies, and even with higher animals and with man himself. This courage is manifested effectively through a pair of tong-like jaws, operated by a set of muscles in head and body that make ants in general strength veritable insect Samsons.

For a few days in August the male and female ants from different colonies of the same species leave their nests under rocks or in hills, and fly through the air, mating meanwhile. Sometimes at night during this time they will visit the campfires of man literally in thousands, rushing to their death in the flames. After the so-called marriage-flight the males soon die, and the females drop to the ground, and pull off their own wings. Or the wing-pulling may be done for them by the workers that discover them.

In the new colony, which may be started in some cases by the queens even without the coöperation of workers, the queen is soon busy with laying eggs, and in emergencies with rearing the young until there are enough workers to do this work. A queen is capable of laying thousands of eggs.

The eggs are placed in special chambers in the nest, and are watched over and the young fed by the nurse-workers. In some cases, at least, it is known that food for the young is obtained from glands in the mouths of the workers very much as is done by honey-bees. Adult ants eat animal and vegetable food. Some species, such as the agricultural ant of Texas, actually raise certain grasses on their hills, and harvest and store the grain obtained. Other species levy upon species of plant-lice for "honey-dew." This is obtained from two minute knobs on the backs of these little creatures. The ants stroke the backs of the plant-lice, and the little servants liberate a small amount of their liquid secretion. In apparent exchange for this, the ants often care for the plant-lice through the entire year, keeping them in their nests during the winter, and taking them to the trees and other vegetation to forage during the warmer seasons.

There are many counter suggestions against the advice that man is inclined to give himself, while holding up some other species as a model. It is likely that man does not take his own advice seriously when advocating the virtues of bees and ants. And there is a point of historical interest in the fact that what man has come to believe is wrong for him to do, for example, to hold slaves, has long been done and in all probability will always be done by certain species of ants. Curiously enough, also, the workers of one species are so dependent upon their slaves that they cannot feed their own young, or even themselves, being able only to fight. Now, mankind has learned that those who, for one reason or another, do not look after or care for their own young cut themselves off from the most blessed of human experiences. Ants would never learn that, for they do not think. They look after their young, of course, but they cannot try a new way of doing it. That is beyond their capacity. Let us not take our life-ideals from the ants. Man is his own best stimulator and example-giver.

Wasps.——Nine o'clock was just a trifle late for breakfast, and the cook was very deliberate about getting it ready, but it was a pleasure nevertheless to wait at the margin of the mountain road, while she worked over the "deviled" caterpillar, gnawing it, pounding it, and turning it over and over, until it was just right for the palates of the little white wasp larvæ in some nest not far away. There is nothing like waiting, if you really want to see Nature in actual operation.

FIG. 23. WASP NEST.
Showing two cells still sealed with wasp-made paper, the cells containing partially developed wasps. An adjacent cell shows a young wasp about to emerge. (Photograph. Courtesy of American Museum Natural History.)

Wasps are what are called predaceous insects; that is, they capture other animals, chiefly insects and spiders. In some cases they immediately kill the victim and make mince meat of it for the young. In other cases they sting the prey, as they do with spiders, paralyzing the nervous system, but allowing the victims to remain alive until the young of the wasp are hatched, and can turn about and devour their helpless cell-mates. Wasps also feed upon the sweet products or the sap of plants. If one visits your plate of bread and jam while you are in camp, it may be not only generous, but it may be even wise, to permit it to take a nibble in peace. Do what you like with what they leave; it has not been harmed.

Even without the experience, you probably know that wasps can sting—and they *will*. The famous injunction, "Do not annoy the animals," may be said to apply with especial force to wasps. At the same time, a person may walk along the road and meet hundreds of them from summer to summer, and never be stung at all. Even if you are stung by chance, a paste of baking soda, or even of mud, will soon make you forget your troubles. The worker and the female wasps have stings, but the males do not.

Some kinds of wasps live in colonies, and for that reason are called social wasps; the individuals of other species live by themselves, and are called solitary wasps. Naturally, the social wasps live a more interesting existence. A colony starts in the spring of the year with a female that has lived alone through the winter in some crevice under old bark, or about barns or houses. She builds a simple nest by chewing up bits of weathered wood and flattening it out into layers, which are formed into six-sided cavities grouped together very much as the cells in the honeycomb are arranged. In one genus, *Polistes*, the small comb is suspended by a short stalk to the under side of eaves of roofs or logs. Another genus, *Vespa*, commonly known as "yellow jackets" or hornets, makes the same kind of combs one above another, leaving high galleries between, and covers the whole with layers of the same material, strong enough to protect the interior from storms.

The main work of making the nest is done by the workers, which soon begin to appear from the first eggs laid by the female. After the colony is quite large, and in the early autumn, males and females develop from the eggs. The males fertilize the eggs in the females, and soon after die. The workers also die on the approach of cold weather, and the females are left alone to weather the storms of winter.

Gall-Flies.——So many persons are curious about "What makes those little lumps on this leaf?" that some account of the insects that cause the lumps seems necessary.

There are several kinds of insect that make lumps or balls of various forms on leaves; some are real flies, members of the same order as the house-fly, some are plant-lice, but the great majority are members of the same order as the bee and the wasp. It is incorrect to call them flies, but the name given many years ago still clings to them.

The Gall-flies are all small insects, so small that most persons do not distinguish them from many others. The

Fig. 24. Gall Insect.

Insect has just emerged from gall in which it developed from egg. (From Linville and Kelly: *General Zoology;* Ginn and Company.)

females lay their eggs under the epidermis of the young leaves of oaks, witch-hazel, willow and other trees, and also on the leaves and stems of weeds of many kinds. When the larvæ hatch, they appear to irritate the plant tissue adjacent to them, causing it to swell up into a form of enlargement which is characteristic for each species of gall-fly. That is, from the form of the gall, a specialist can determine the species of the insect that caused it, without seeing the little creature at all.

When the larva has grown to its full size by feeding on the interior of the gall, it commonly changes to the pupa stage, and when the adult form is produced, tunnels out, and flies away.

By cutting carefully into a green gall, one can usually see the little larva, or several of them. Sometimes one can find scores of inhabitants in different stages of development, varying from larvæ to adults. In some cases, members of the motley group are guests, uninvited to be sure, but still allowed to remain.

The June-Bug.——For several nights in succession one summer, the author had the curious experience of having

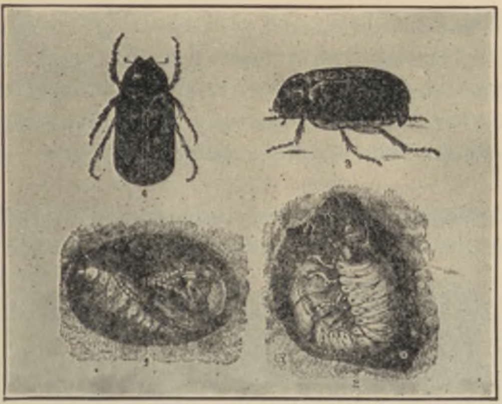


FIG. 25. JUNE-BUG.

1, Pupa; 2, grub; 3, side view of adult; 4, upper surface of adult. (Courtesy of American Museum of Natural History.)

his camplights visited at exactly ten minutes to nine o'clock by scores upon scores of lusty June-bugs. Clocks might have been set by their coming. But let no one assume that June-bugs are by nature adjusted to keeping time, for they are clumsy, blundering fellows, likely to upset and disarrange, rather than to put in order, the life in a camp or in an unscreened room, and they will do it after dark, in the summer season, if you have an exposed light.

Everyone who does not know already is likely to wonder where these big, brown beetles come from so suddenly, and where they stay in the daytime. They come from the trees near by, where they have been feeding upon the leaves, sometimes doing considerable damage. The larvæ, too, make extensive levy upon plants, feeding at the roots of many kinds in meadows and gardens. They are the fat, white grubs with brown heads that one comes upon while spading. Pigs and fishes find them much to their liking.

The pupa stage is passed in a chamber in the ground, and emerges in May, becoming at that time very noticeable. It has been suggested by some authorities in insect lore that a better name for these creatures would be May-beetles, and accordingly they are thus called by some.

The Lady-Bug.——Most persons regard with patronizing indulgence the little hemispherical lady-bug, with its red or

Fig. 26. Lady-Bug.

Larva at left; pupa in middle; adult at right. (Courtesy of American Museum of Natural History.)

yellow shell-like wings and black spots. It looks so much like an animated and ornamented bead running up and down on your clothing, that its appearance provokes amusement rather than fear. It is nevertheless a dangerous animal to certain other insects, the scale-insects (Fig. 31), those lowly forms that prey upon our fruit trees, especially apples and oranges. It is probably not too much to say that we should have been deprived of all the oranges that come from California, and possibly in time of all that come from Florida, if it had not been for the timely importation from Australia and from China, of two species of lady-bug that preyed upon scale-insects. The scale-insects had been imported unintentionally with orange trees from those countries.

One reason that lady-bugs are so effective as scourges of these insect pests is that the lady-bug larvæ also feed upon the same insects. With the old and the young making war against them, the scale-insects have been kept in a partially subdued state. This is more than man could have done alone.

The larva seems far less peaceful and amusing than the adult. In fact, it looks as if it would be a nuisance to man; and doubtless many of them are killed by him on account of their appearance. They are abundant in early June on the leaves of trees. The larvæ have flattened, tapering bodies, and are about a half inch long, with black ground color and dark reddish spots and tufts of short spines, rather ugly all in all. The only effective defense for the lady-bug larva against man's enmity against insects in general is *knowledge* on the part of man. It is obvious, too, that here and elsewhere knowledge is the best protection against man's interference with his own welfare.

The Click-Beetle.——You are probably familiar with the fact that many insects, especially beetles, "play 'possum." That is to say, they draw up their legs against the body, lie on the back, and remain quite motionless until it appears to them that the danger is over. If you are patient, you may see them slowly extend a leg or two, and cautiously right themselves, and scamper away. But you may not be prepared for the click or snap, as of a hidden spring, that has hurled a little brown insect several inches into the air. If it falls back downward, snap! it will go again, and again, until it alights feet first. The snapping is done by the muscles of the head and middle-body (thorax) operating across the joint between, causing the head to strike suddenly against the ground.

FIG. 27. CLICK-BEETLE. (From Kellogg: *American Insects;* Henry Holt and Company.)

The larvæ of the click-beetles you seldom see. They are hard, light-brown, and round, and are called wire-worms, because of their resemblance in form to a bit of wire. They are about an inch in length. They are extremely abundant, and their food necessities cause considerable loss in the crops of corn or other grain.

The Fire-Fly.——In these days of a popular movement for efficiency, the attention of experts in artificial lighting has been drawn by scientists to the high efficiency of the phosphorescent light of the fire-fly. It is known that when the fire-fly makes its light under the control of its nervous system by a form of oxidation, it produces no heat at all. Man has never been able to produce light without at the same time setting free, and wasting, a considerable amount of heat. In burning kerosene, gas, or electricity for lighting, a great deal of energy escapes as heat, and we have not learned how to prevent the waste. The fire-fly has unknowingly given us a suggestion, and electrical experts are trying to see what can be done with it.

Fire-flies look like flies more than like beetles, which doubtless accounts for their being called flies. Their wing-covers are flattened and soft, being quite flexible. Their bodies are less than one inch in length, and are dark-colored and sometimes margined on the wings with yellow lines.

FIG. 28. FIRE-FLY.

(From Kellogg: *American Insects;* Henry Holt and Company.)

Some of the fire-flies fly in the daytime, and are abundant on the golden rod.

The Black Swallow-Tail Butterfly.——In the early morning of August days, one often sees black swallow-tail butterflies balancing on gorgeous thistle blossoms. It requires little skill to approach and watch them as they thrust their quivering, black, tubular probosces into the slender flowers of a thistle head, for there is a bountiful supply of nectar there for them and for other insects whose tongue or proboscis is long enough to reach it.

The butterflies never give up any of their nectar to man or to their young. They keep it for themselves, swallowing it as it is drawn from the flower. And when they are through with a particular flower, they coil up their tubular pumping organs like a watch-spring and fly away. That is the reason you seldom see the proboscis while the butterfly is resting on a leaf or a twig.

The swallow-tail butterflies, of which there are several species in this country, bear an extension at the back of each hind wing. There is thus a fancied resemblance to a swallow's tail. The general color of the wings is black. There are two rows of circular yellow spots across both pairs of wings, and another row around the margin. The spots are brighter colored in the males than in the females.

Over the head and body of the butterfly there is a mat of

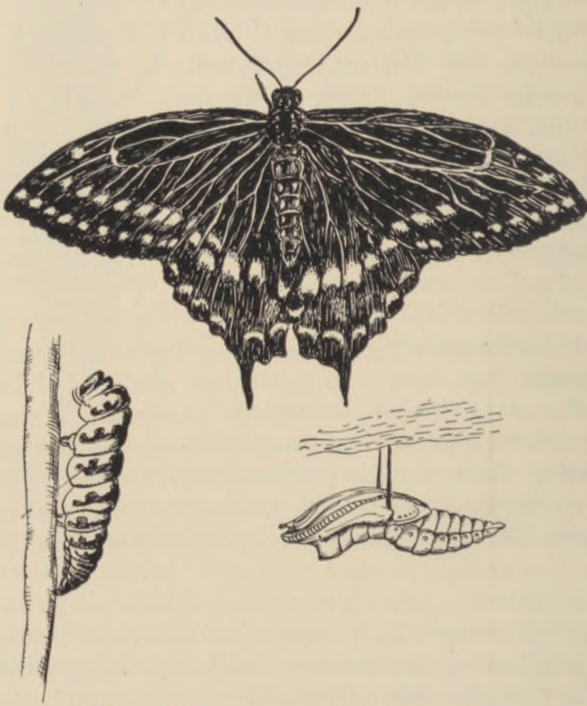


FIG. 29. BLACK SWALLOW-TAIL BUTTERFLY.

Larva at left; pupa suspended from wood by silk woven by caterpillar; adult above. (From Dickerson: *Moths and Butterflies;* Ginn and Company.)

long, soft hairs. Over the wings there are microscopic *scales*. These are thin plates, growing from the membrane of the wings, and overlapping like the shingles on a roof. All butterflies and moths have these scales. Although the color pigments are in these scales, it is impossible to detect any color in single scales.

Of course, you are aware of the fact that many species of animals could not recognize their own young, if the task of doing so were presented to them. And we cannot blame them, for in nature all that many of them have to do with their young is to respond to the stimulus to produce eggs which in turn produce the young.

After the eggs of butterflies and many other groups of insects come the larvæ, which are so different from the adults in form and in habits of life that close studies of the development had to be made before scientists were sure of the connection of larvæ with particular adult forms. Early zoölogists believed that the caterpillars, for example, really contained an insect in adult form, and that the form of the caterpillar was only a mask for what was concealed within. Therefore, they gave to all such animal stages the name "larva," which is the Latin word for mask. Nowadays, we know that the adult form does not exist in the larva, but gradually develops from the complete breaking down of all the larval organs and the construction of new ones.

The larva of the black swallow-tail butterfly is a smooth green caterpillar with black rings around the body, and with scattered yellow spots. Like other caterpillars, it feeds with biting mouth-parts, and lives on wild parsnip leaves, and other plants of a similar kind. When full grown, it attaches itself to the under side of something in a protected place, changes to a triangular pupa, anchoring itself with a strand of silk (see Fig. 29). From this pupa case, not a cocoon, it emerges in two broods in June and in August.

American Silkworms.——While the trees are busy with producing their harvest of nuts and winged fruits, their leaves are yielding up some of their substance to fattening the aldermanic bodies of some giants among the race of caterpillars. In August and September, while the hickory nuts, chestnuts, and acorns are ripening, and you are looking about for some hoped-for early ones, your surprised nerves will some day pull you up suddenly at the unexpected presence of a bigger caterpillar than you ever saw before.

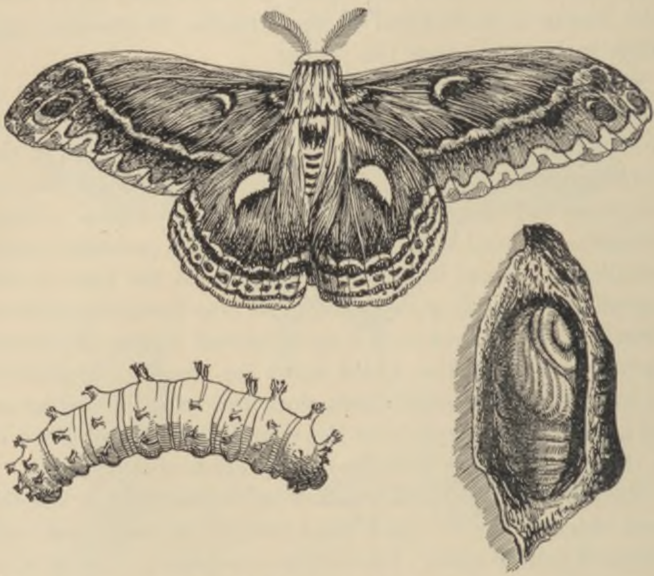


Fig. 30. American Silkworm.

Larva below at left; pupa in cocoon at right; adult above. (From Dickerson: *Moths and Butterflies;* Ginn and Company.)

And the caterpillar may be as much surprised as you are, if its clumsy efforts to get over the ground rapidly are any indication of its feelings.

There are few larger caterpillars than the larvæ of several species of American Silkworms. The largest of the silkworm caterpillars is the Cecropia moth caterpillar. It grows to the length of about four inches. It has been described by the late Professor Comstock as "dull bluish green in color. The body is armed with six rows of tubercles, extending nearly its entire length, and there is an additional short row on each side on the under surface of the first five segments following the head." The larva lives on the leaves of many species of forest trees, and on apple and plum leaves.

When the leaves have fallen from the trees, the cocoons of this and other species of silkworms may be seen attached to the twigs. When the caterpillar is ready to pass into the pupa stage it finds a place of attachment, and begins to spin silk from certain glands in its mouth, first making a band of silk about the twig to insure its staying on its support. Then the larva begins to roll itself up in a seemingly endless thread of silk. At the conclusion of this process, the caterpillar is inclosed in an extremely tough waterproof silken shell, where it remains until the following spring.

Cutting into the cocoon one would find a brown, mummy-like pupa, still alive, but powerless to do anything except to wiggle its abdomen slowly. The caterpillar has ceased to exist in every particular. But the outlines of organs of the future adult form are present on the surface. They are the feelers, the wings, the legs, and the mouth-parts,—all organs of the adult form.

When the period of transformation is over, the adult splits its brown shell along the middle of the back, and crawls out, leaving its mummy-case behind. It then cuts its way out of the cocoon. On the surface of the cocoon, the young moth rests probably exhausted after its arduous labor of coming into its new life, and meanwhile its blood flows into its soft rumpled wings, filling them out. When the surface tissues are hardened, as they are in an hour or two, the moth is ready to fly away.

The adult of the Cecropia moth is about six inches wide in stretch of wings. The chief color of the body is dusky brown. Distinguishing marks are a red spot near the apex of the forewings, and near the center of each wing a crescent-shaped white spot bordered with red.

The silk of these silkworms is not commercially valuable.

The Ant-Lion.——In the soft earth, under the eaves of the cabin in the woods where this account is being written, there are perhaps one hundred small funnel-shaped pits. They are less than two inches in diameter, and seem at first to have been made possibly by the dripping of rain water from the roof. But it is bright sunshine now, and a rain-drop, which at present does not exist in this place, could not create that commotion in the microscopic depths of the pit.

A small ant has toppled into the hole, and is trying to get out. Every time it tries to crawl up, the unsteady slopes give way, and besides, an eruption beneath carries upward a fine shower of particles of earth. Finally, the ant slips all the way to the bottom of the crater, and some concealed living thing seizes it.

If you try the experiment of making a little disturbance at the margin of the pit, with a stick or with a particle of earth, the chances are you will learn nothing, except that the hidden creature appears to know the difference between you and its usual victims. But gently excavate the loose earth of the pit, and if you are looking for something motionless, with six legs and the color of earth, you may find the ant-lion. It will be "playing 'possum."

After several minutes, the ant-lion will exhibit a nervous sign of life by giving two or three twitches backward into the soft earth. If left undisturbed it will build itself another pit by pushing the earth backward with its abdomen, probably throwing some earth up with the aid of its head.

Ant-lions are very abundant under the edge of cliffs, or under the eaves of buildings in the country.

The pupa of the ant-lion is formed by the larva surrounding itself with grains of earth, and lining the covering with silk.

The adult is a four-winged insect, with netted wings and slender body, about half the size of a dragon-fly, which it somewhat resembles.

Scale-Bugs.——The little brown specks on the surface

Fig. 31. Scale-Bugs.

(Photograph. Courtesy of American Museum of Natural History.)

of oranges look quite harmless, and so they are, as far as your personal health is concerned. But they are not harmless to the orange tree when present in large numbers. As has already been said in a previous section, one of the main reasons they are not present in large numbers is the fact that the lady-bugs destroy them.

Scale-bugs live on the bark and to some extent on the fruit of apple, pear, cherry, orange, lemon, and many other fruit trees, in conservatories, and on pine trees and other forest trees. They perforate the bark of the tender shoots, the epidermis of the leaves and of the fruits, and suck the juices of their plant victims. They always interfere with the best growth of the plants, and sometimes kill them.

Some of the scale-bugs form about themselves a white powdery wax which resembles cotton. Others secrete a flat scale of wax under which the insect lives. Still others have a flat form, but secrete no scale. The females are wingless. The males have one pair of wings, and after they have reached the adult form, lose their mouth-parts, and thereafter have no way of taking food; yet they live for a long time.

To fruit-growers scale-bugs are a constant menace. The activities of the lady-bug must be supplemented by the use of sprays of lime, sulphur, etc.

The reputation of the family to which the scale-bugs belong is partially saved by certain ones which furnish dye-stuffs. The best known of these is cochineal. The dried bodies of these insects are ground up to make the dye. One species secretes a resinous wax from which shellac, a valuable varnish, is made.

Grasshoppers.——A few score grasshoppers springing up more or less airily as we walk along through the grass of the meadow suggest nothing of devastation and nothing of famine. But the author's early childhood was strongly impressed one summer in the '70's with seeing the sun obscured as in an eclipse with swarming myriads of famine-bringing grasshoppers. He recalls seeing a fine field of green corn, on his grandfather's farm in the Missouri River Valley being visited in the early morning of a midsummer day by millions of grasshoppers. In the afternoon, nothing but the stumps of the corn plants remained. Not satisfied with the corn and other green things, the insect hordes consumed everything eatable, beside some things not considered eatable, namely, harness leather.

Occasionally, there are small migrations of this Rocky Mountain Locust, but the farmers now know more about their habits, and can prevent their former great destructive-

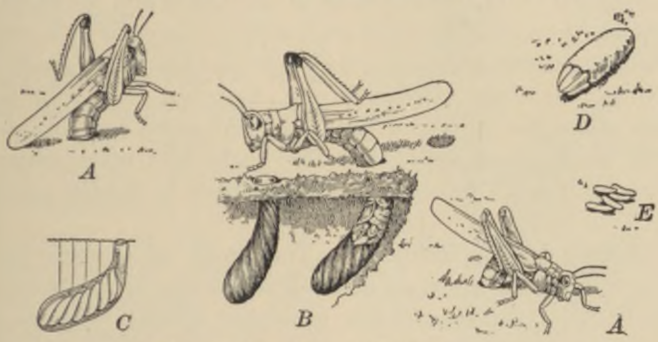


FIG. 32. RED-LEGGED GRASSHOPPERS.

A, *B*, Females laying eggs; *C*, nest of eggs; *D*, a nest excavated; *E*, a few eggs separated. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

ness. A near relative of the Rocky Mountain Locust is the red-legged locust or grasshopper. It never becomes a serious menace.

There are many other kinds of locusts or grasshoppers distributed throughout the country. There is the giant, wingless grasshopper of the South and West, the Clouded Locust of dirty-brown color, that makes a crackling sound with its wings when flying, and the Carolina Locust with dust-colored upper wings and yellow-bordered under wings showing in flight.

You may have heard the expression, "Some men plan their future like grasshoppers," which means they do not plan at all. For, as it goes in the story of the Ant and the Grasshopper, the grasshopper "sings" and eats all summer, and loses its life in the fall. But this is not until eggs are laid in the ground, or in logs or stumps.

These eggs lie in their places through the winter, hatching in the spring. You may recall that you never see grasshoppers until the summer is pretty well under way, and even then only small, wingless ones. These wingless young correspond to the inactive pupæ of the beetles and the butterflies and moths. Thus, the grasshoppers never have a great change in their bodily form, their development being gradual. Every time they increase in size, however, they split the skin along the middle of the back, and crawl out, the soft skin swelling suddenly, and the wings and other organs growing quickly before the skin has time to harden again.

Summary of the Insecta.——The group of animals just described makes up the Class called Insecta, or the insects. They come into very close economic relation with man, and hence are better known than are most other Classes.

Insects have bodies that are divided into three regions, *head*, *thorax*, and *abdomen*. On the head are the eyes, the mouth, the mouth-parts consisting of appendages, and *antennæ* or "feelers." The thorax bears the wings, sometimes one pair and sometimes two pairs, as well as the three pairs of legs. The abdomen is composed of clearly defined somites (sections or segments of the body), approximately ten in number, and the somites are not provided with appendages.

The digestive tract extends from end to end of the body, and is quite complex. Colorless blood in a complete system of vessels carries digested food from the intestine. The nervous system is constructed on the same plan as it is in Vermes. Reproduction takes place usually by means of eggs and spermatozoa, which are developed first from ovaries and spermaries inside the bodies of females and males.

The Lobster.——After a considerable sojourn in the air and on the earth of the forest, the field, and about the homes of man, following the lives of insects, let us return to that vast environment where life probably began—the sea. Persons who study animals in the sea have often expressed wonder at the marvelous variety of form and color exhibited there. Although the water looks pretty much the same wherever you are, there are many factors that bring about very complex conditions, indeed. For example, the temperature varies with the depth and with the distance from the equator, and with the nearness of great ocean currents, like the Gulf Stream. There is the variety of depth itself, and of light dependent on the depth. There are rocky and sandy shores, and inlets filled with river water from the land, and there are islands of soil and of coral.

Fig. 33. Lobster.

(Photograph. Courtesy of American Museum of Natural History.)

Wherever there are crevices or chasms, there seaweeds abound, and among the seaweeds crowd multitudes of sea creatures seeking escape from one another, and securing it, too, by unconsciously imitating in color and in form the general or special features in the environment.

Here and there we find animals that gain protection from others by being too small to be seen. Such are the medusæ described on page 16. Others cling to the bodies or live within the bodies of larger and more assertive kinds of seafarers. These are the parasites. There are the sea-rovers themselves, the strong ones that prey upon the little ones, or take their chances of escaping the teeth of others perhaps a little stronger. They are the whales, the sharks, the porpoises, and the sword-fishes.

A large number of sea animals bear on the outside of their bodies heavy or crust-like coverings, such as the clams, mussels, crabs, and the lobsters.

As successful as any of these has been the lobster. Whatever lessening in number the lobster has suffered, and it has suffered much, has been due to man himself. The lobster's shell is no protection against the devastation of man.

Before the flesh of the lobster came to be so much prized by those who set and those who follow the fashions in eating, there were lobsters in the sea that seemed large enough to hold their own even in a physical contest with man, if they had been disposed to exert themselves. The giants of the race weighed over twenty-five pounds, and were over two feet in length. Nowadays, the largest are so small that the stories of large ones are likely to be discredited as "fish stories."

Lobsters belong to a group of animals that have the head and thorax united into one piece as far as the shell is concerned. The abdomen is composed of six segments jointed together. The head has two pairs of antennæ instead of one as in the insects. The eyes are on movable stalks, a fact that enables them to see about them more easily. There are six pairs of complicated mouth-parts, which work sideways in holding and chewing the food.

The large claws or nippers are constructed like the first two pairs of legs, but are larger and adapted to holding and crushing their prey, which sometimes consists of clams. The third and the fourth pairs of legs end in a point. The abdomen is provided with smaller organs of "Y" form which are called *swimmerets*.

The lobster can walk slowly when partially supported by the buoyancy of the water. Its most successful method of locomotion is by swimming. This it does by suddenly contracting the muscles in the abdomen, and catching a large amount of water in the scoop-like flange of the tail. The result of the contraction is to send the body backward with great force and swiftness.

When the female lobster is about ten inches long she lays several thousand eggs which immediately cling by their glutinous surface to the swimmerets, and remain there until the next spring when the young hatch. The young at once float to the surface of the water, where they molt several times, growing larger by stages. When they are not an inch in length they sink to the bottom, and from that time on remain there, living under seaweeds and under the projecting ledges of rocks.

Owing to the great demand for lobsters in the market, they are protected by law in all the maritime states, but rather inadequately protected. The consequence is that lobsters are captured and sold before they have had the chance to reproduce, being immature. Naturally, this means extermination in comparatively few years. It is easy to see that law-makers should have studied biology.

Spiders.——Spiders are among those unfortunate beings that suffer calumny and often death at the hands of man because of an undeserved reputation, Nearly everyone shrinks from a spider, while freely permitting the house-fly to walk over his hands, his face, or even over his food. Yet the spider is doing its natural best to exterminate the greater enemy of man.

Grown persons at the present day have largely ceased teaching children to dread imaginary "bears," "witches," and the "bad man." When we have prepared a generation of boys and girls with the facts about some of the unfairly dreaded animals, teaching them incidentally to dread the really dreadful ones, we may hope that the children of the future may be the truly great of our nation, by showing their superiority to the superstition and ignorance of the present. We must acknowledge that it has been ignorance and false teaching that has made us lenient with the house-fly. May it not have been ignorance and false teaching that has made us dread the spider?

FIG. 34. GARDEN SPIDER.
Male at left; female at right. (From *Cambridge Natural History*, Macmillan Company.)

Spiders live in dark corners and in protected places to escape their enemies, among whom are man and the wasp. They come out into the open to capture their food, or to secure it when it is entangled in their webs.

The mouth-parts which enable spiders to overcome their insect prey are the pair of sharp pointed claw-like mandibles. Near the point of each mandible is a minute hole through which poison passes into the body of the victim. When persons are bitten by spiders, this poison sometimes has no effect at all. Oftener it seems to cause about the same soreness as the bite of mosquitoes, or sometimes as the sting of bees. Only rarely does serious inflammation result.

Spiders are often spoken of as insects, but they are not correctly classified as such. Spiders all have eight legs, borne upon the thorax of the body. The abdomen is a sac-like division of the body without segments. There are eight eyes on top of the head, but in spite of the large number they cannot clearly see with them at a distance of more than four or five inches.

At the hind end of the abdomen are three pairs of organs called spinnerets, from which the silk is spun out. The silk is used by the web-forming species to construct enmeshing traps for their prey. In all species of spiders silk is used to contain the eggs; it is used for tubes or passageways by the ground spiders, and for "floats" by the "flying" spiders.

The young of spiders are hatched in the silken sacs. In some species the sac of young is carried about by the mother for awhile at the end of her body. After hatching, the young in some species ride on the mother's back for a time, but soon leave and provide for themselves, after the manner of their species.

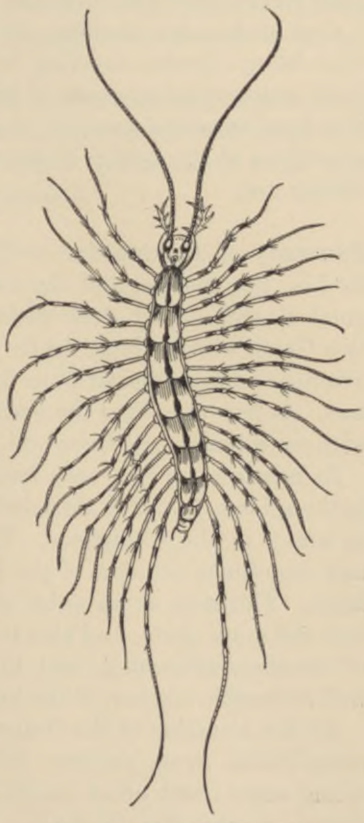


FIG. 35. HOUSE CENTIPEDE.

Common about houses, not poisonous. (From *Farmers' Bulletin*, U. S. Dept. of Agriculture.)

Centipedes.—On the plains of Texas and northward, there is a species of centipede that measures five or six inches in length, and this one is said by the cowboys to be poisonous. But the cowboys are much given to telling improbable tales to amuse themselves, and the chances are small that this many legged, and not very handsome, creature is dangerous.

In the Eastern states one frequently finds under decaying logs and under stones a small species of centipede, not more than one and one-half inches in length.

Centipedes are slender, flattened, segmented animals with horny, brown covering for each segment or somite. Each segment bears a pair of jointed legs, ending in a point. The head supports a pair of heavy mandibles, similar to the mandibles of the spider in general form, and adapted to a similar use.

Summary of Arthropoda.——The insects, the lobster and its kin, the spiders, and the centipedes, are members of a great Branch called *Arthropoda.* The name is made up of two Greek words which signify "animals with jointed feet." The appendages referred to as feet are more accurately called legs. As legs they bear the bodies of their owners sometimes with considerable swiftness and directness.

In number the legs vary from six in the insects to eight in the spiders, to ten in the lobster and its near relatives, and to many in the centipedes. The skin of the legs always, and sometimes the skin of the body, is made up of a horny layer. This acts as an outer skeleton which serves to protect the inner parts, and also to make possible the activities of running, swimming, and flying, which require rigid as well as flexible sections of the body.

All the members of the Branch have a distinct head, with complicated eyes, slender, jointed feeling organs, hard, biting organs and other mouth-parts which move from the sides to meet in the middle line. The remainder of the body is divided into a variable number of sections called "somites" or segments. These are grouped in all except the centipede into the two body divisions called *thorax* and *abdomen.* The thorax bears the legs and the wings whenever these organs are present.

On the abdomen, and sometimes on the thorax, there are minute openings called *spiracles,* which are the entrances of the system of breathing tubes that permeate the body. By means of the tubes called *tracheæ,* every organ is supplied with oxygen, and from every organ carbon dioxide is carried to the exterior.

The young of all the Branch hatch from eggs, and in some groups they pass through two distinct stages in development before they reach the adult stage. In the adult stage eggs are laid again for the next generation.

CHAPTER VIII

MUSSELS AND THEIR KIN

The Fresh-Water Mussel.——The destruction of animal life has become so much an incident of the lives of human beings as to be accepted for a matter of course. In fact, as our civilization advances, and our real or supposed needs increase, new industries develop and become enlarged and systemized for still greater levies upon life other than our own.

It is not generally known even in the region concerned that several states of the Mississippi Valley contain fresh-water mussel fisheries. Those operating these fisheries dredge the bottoms of the rivers for mussels, destroy the animals, and cut their two-valved shells into disks and make buttons of them. This is the source of our familiar pearl buttons. Occasionally, rounded pearls of considerable value are found in the sand or mud, or in the softer parts of the animals.

Men and muskrats are the greatest enemies of the fresh-water mussels. Against neither has the bivalve any effective defense. Down in the mud and sand it plows its way laboriously along, seldom visible except for a fringed opening through which food and water and air enter between the valves. A passing shadow of a rake, or of the body of its furry pursuer, will cause the mussel to withdraw its food-siphon, but probably too late.

In an aquarium, fresh-water mussels can be observed with comparative ease. A thick fleshy "foot" is the plowing organ. This muscular organ extends forward from between the valves, pushing aside the mud, drawing after it the rest of the body. This foot and the fringed siphon are the only organs of the body that appear outside the shell.

The mussel is an animal without a head, and without eyes. The food, consisting of microscopic animals and plants and air, is drawn in by the siphon at the hinder end of the body. This incoming material is carried along by the action of microscopic thread-like lashes called *cilia*, similar to the locomotor organs described in the Protozoa. After passing thus along the cavities outside the body proper, the food reaches the mouth, a tiny opening surrounded by four thin triangular tentacles. The air passes over two pairs of thin-ribbed "gills" that spread out broad and flat over the sides of the body. Outside the body and the gills, and lining the valves, are two thin layers of muscular tissue which are called mantle-folds. It is between them and the closely fitting valves that pearls are sometimes formed. These valuable by-products of mussel life are probably caused by the irritating presence of a parasitic worm that crawls between the valve and the mantle.

FIG. 36. FRESH-WATER MUSSEL. External layer of shell removed, showing material from which buttons are made. (Photograph. Courtesy of American Museum of Natural History.)

Without the help of a very important "friend-in-need" the mussel would have a hard time in life. This friend, or rather friends, are various species of fresh-water fishes. When the embryo mussel reaches a certain stage in the gills which serve as "brood-pouches," the young are forced out into the water. They fall to the bottom, and lie there open with the back of their tiny shells downward. From the small body proper a thin sticky thread floats upward into the water.

FIG. 37. SOFT-SHELL CLAM.

Specimen at bottom. Long siphon extending from clam to water above. (Photograph of Model. Courtesy of American Museum of Natural History.)

A fish swimming along near the bottom comes in contact with this thread. The embryo is thus picked up, whereupon it clings to the skin, or to the gills, of the fish by two small hooks that grow out from the margin of each valve. A fold of skin forms on the fish over the embryo, which thus becomes a temporary parasite. After a few weeks when the young mussel has reached a more advanced stage of development, the inclosing skin dissolves, and the mussel falls out, and makes for itself a home in the mud, possibly many miles away from its birthplace. The friendship of the fish is after all not friendship, since it is not intentional.

The Soft-Shell Clam.——Some fine morning at the seashore when the tide is out, and a broad mud and sand flat, firm enough to walk upon happens to be within walking distance, you may take it into your head to go out as far as you can, and see what you can find. There will be patches of stranded seaweed, a few shells of dead clams, mussels, and snails, and many other cast-up treasures of the sea. But as you walk along, small "geysers" of water will shoot up here and there, and after the geysers holes will remain to show where something happened. It will require more than a child's spade to dig and find out. But in a little while you will reach a wrinkled, black object that will prove to be the siphon of a soft-shell clam.

A soft-shell clam can move, but seldom does move, from its place in the mud, which is frequently as much as one foot from the surface. The siphon, however, stretches the whole distance from the shell and body proper, and draws in the food and air, and through an adjacent opening permits the wastes to pass out. When you disturb a clam of this kind at low tide, the siphon contracts, thus reducing the space within the valves, sending the water through the siphon with considerable force.

The soft-shell clam has organs very much like those of the fresh-water mussel, except for slight differences in form. The mantle is grown together into a continuous fold except where there is a small opening for the foot. The shell is almost white in color and rather thin and somewhat flat.

The young attach themselves to grains of sand until they are large enough to make holes and live under the same conditions as their adult relatives.

The Oyster.——Apparently the flavor of the oyster when stewed or fried is what gives to this bivalve its money value. The total of all plates of oysters and all bowls of clam chowder may be expressed in great sums of money. But neither animal in reality is important as a food for human beings. One of the great problems met in trying to teach economy in our national habits of eating, is the difficulty experienced in some large cities in persuading persons to substitute nutritious, inexpensive food for highly flavored, expensive food. Oysters are one of the least nutritious, and one of the most expensive, of all our foods.

Although the mussel and the clam bury themselves in the mud, they maintain connection through the siphon with the water outside. The oyster cannot endure lying in the mud, because it has nothing that can act as a siphon. Moreover, if its body should be accidentally covered with mud, it could not escape as could the other two animals, because its body is connected inseparably by the left valve to other shells, or to a rock.

FIG. 38. OYSTER.
(From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

Within the valves of the oyster, the mantle-folds, the gills, the mouth and the tentacles, are all very much the same as these organs are in its relatives. Since the adult oyster has a fixed position, the absence of a foot is a perfectly natural fact.

As you know, there is a season in which it is not possible to obtain oysters in the markets. This is the time when the eggs and spermatozoa are being sent out upon the water, and the formation of oyster embryos is taking place. The number of embryos formed by the fertilization of the eggs is exceedingly great, but countless thousands lose their lives as they float about at the surface of the ocean for the first few days of their existence. Those that escape extinction sink to the bottom and affix the left valve of the shell to some solid object.

Each year they add to the size of the shell and the body until they are ready for the market. In order to make oysters especially valuable, they are sometimes taken up from their homes in bay or sound, and placed where the water is somewhat brackish, owing to the mixing of sea water with fresh water. Here many microscopic organisms abound. The fattening of the oysters on these organisms gives them finer flavor.

Snails.——In the ocean from the shore line out to considerable depths, on the land from valleys to mountain tops, in brooks, rivers, and lakes, there are snails of one species or another to be found. Their numbers are legion, and their shapes many. Their architecture and their colors are attractive in the extreme.

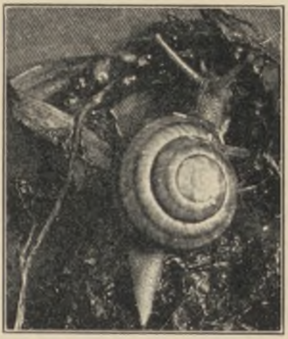


Fig. 39. Land Snail.
Photograph taken at night.

All snails agree, however, in having a flattened foot upon which they move, and most of them have a shell of one piece, with one or more spiral turns in it. They also have in the mouth a tongue provided with a rasping organ which is capable of tearing into small particles whatever food they need.

The surface of the body gives off large quantities of slime, upon which the foot slides in locomotion. The slime is also exuded as a means of protection when they are attacked.

Many snails, even water snails, breathe by means of a lung, which opens to the exterior by a single opening on the right side of the body. With this lung they breathe at the surface of the water and in the air. Some of the snails have gills with which they breathe in the water.

Unlike their bivalve relatives, snails have a distinct head which is provided sometimes with one pair, sometimes with two pairs, of tentacle-like organs. In case two pairs are present, there will be found on the tips of the second pair two little black eyes, which can be extended and drawn in with facility. When but a single pair of tentacles is present, the eyes lie on top of the head.

Everyone who keeps an aquarium should be aware of the fact that snails are good scavengers for aquaria. The little black or brown snails can be found easily in almost any pond. They would consider it a special favor to be protected from frogs and large fishes by being allowed to keep clean the water-ways of a goldfish aquarium. They feed on the green scum that frequently forms on the interior of the aquarium.

Those who keep greenhouses feel differently toward snails, and especially toward their shell-less relatives, the slugs. But in nature there are so many checks and balances that it is the business-like thing to do to look for the enemy of any species that is getting more than its share of the earth's products. The once despised toad will help you out of your troubles, if you have troubles of this kind.

It may be worth your while to know also that the little masses of round, light-colored bodies from the size of radish seeds to the size of sweet pea seeds, the largest of them looking like small lumps of boiled tapioca, are the eggs of different species of slugs. Pond snails lay their eggs in small oval masses flat against the surface of the glass if they are in an aquarium, and on leaves and sticks, if they are in a pond. The eggs of sea snails are laid in masses of many curious shapes.

The French people consider snails a great delicacy for the table. That other people do not, may be thought at least by the French as one of the vagaries of taste. We need not forget that among the French are to be found the world's foremost authorities in matters of cooking.

The Squid.——If you have not lost that natural curiosity mentioned in Chapter I, you must have wondered at the nature of the hard, white and oval object at which you have seen canary birds pecking. This white object is all there is of the skeleton of a cuttlefish, a close relative of the squid. This skeleton lies within the tissue of the main part of the body just behind the head. The squid (in Fig. 9 at right) has a thin, horny skeleton of no particular value to man. But all cuttlefishes and squids produce something of value in the black fluid from which India ink is prepared. The ink is also valuable to the animals themselves, because of their ability to force it out of the body into the water when they are being attacked by stronger enemies, thus setting up before them an impenetrable black curtain. In the cavity of the cigar-shaped part of the body extending to the exterior there is a siphon force-pump, with which the squid shoots out the ink and also water strongly enough to carry the owner backward out of danger.

The squids and their immediate relatives live only in the waters of the ocean. They feed upon small fishes, and are themselves fed upon by larger fishes, if the fishes are quick enough to capture them before the black curtain comes down.

The ten arms are provided with two rows of sucker-disks, extending the entire length of one side. The prey when brought to the mouth is seized in the parrot-like beak. Large eyes are present on the sides of the head.

Other relatives beside the cuttlefish are the Octopus and the Chambered Nautilus. The latter has been made famous in the well-known poem by Dr. Oliver Wendell Holmes.

Summary of Mollusca.——The mussels, the clams, the oysters, the snails, and the squids, and the near relatives of all of them, are members of the Branch called *Mollusca.* The word means "soft," and applies especially to the character of the body proper. Although we might question the value of the word soft on the ground that it might apply equally well to other animals not in the Branch, yet we must admit that softness and lack of apparant organization is peculiar to those members of this Branch that we are familiar with.

The appendages of every member of the Branch are without joints, and the bodies have no segments or somites. The snails and the squids have a fairly distinct head, but the others have no head at all. Those that have heads have a pair of eyes, but in the others eyes are commonly absent.

Locomotion is accomplished in practically all except the squid group by a single muscular organ under the body called the foot. This organ operates on a bed of slime which is sent out in front from numerous glands.

All members of the Branch have a thin enveloping organ of one or two parts called the *mantle.* The chief work of this organ is the formation of the shell. The shell is present in two parts, in clams, in one part, in snails, and as a concealed plate, in squids.

Mouth-parts when present at all, occur as a rasping organ, in snails, or as a parrot-like beak, in squids. Around the mouth in clams and their near kindred there are four unjointed, flat organs that wave inward and carry food to the mouth. The squid has ten long arms provided with flat suckers all adjusted to bringing prey to the mouth.

Most of the members of the Branch breathe by means of flat, thin gills that lie on either side of the body floating out into the water inclosed by the shell. Some of the snails breathe by a lung to which a single external opening enters directly.

CHAPTER IX

THE FISHES

The Sunfish.——After you have been busy at the bank of the creek an hour or more with shiners, or chubs, or bullheads, you are in a proper frame of mind to really appreciate a gorgeously colored sunfish, be it ever so little. There are few persons so devoid of a love of color as to fail to admire these little fishes, with sides spotted over with all the colors sunlight contains.

Sunfishes are nearly everywhere in the fresh waters of our country, in lake, river, and brook. They like the companionship of their own kind, for they go about in "schools." Their attitude toward the fisherman's bait is to "stand and wait," while members of more aggressive species take the hook, and are drawn up on the bank. But when they are very hungry, even earthworm bait is sufficient to induce them to try their luck at the white man's game.

Sunfishes never get very large. You might work with your line a long time and never see one longer than six inches, although some species of sunfishes do reach the length of twelve inches. Their bodies are flattened from side to side or "compressed." This gives them the appearance of being very slender when seen from above in the water.

Like all fishes the sunfish swims nearly altogether with its tail fin. The other fins, the back or dorsal fin, and the anal fin which is beneath the body, and the two pairs of fins—all aid the fish in balancing, and to some extent in turning.

One of the most characteristic details of the coloring of the sunfish is the blue, or red, or black, conspicuous spot just above the front or pectoral pair of fins, at the end of what is called the gill-cover. These gill-covers open and close periodically, permitting currents of water to come out from the mouth cavity.

If you notice a fish resting in the water of the brook, or in the aquarium, the opening and closing of the gill-covers seem to be connected with certain movements of the mouth. The water is filled with air, or at least as much as can find room between the molecules of water. When a mouthful

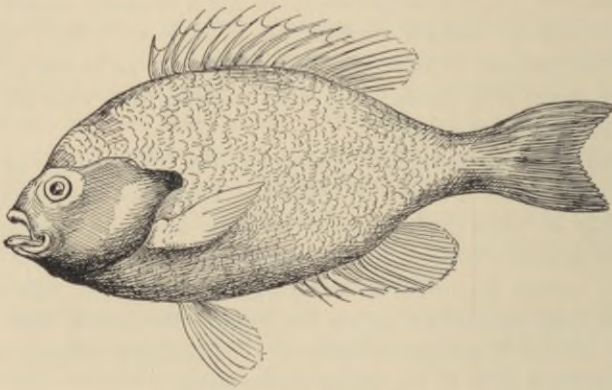


Fig. 40. Sunfish.
(From Goode: *American Fishes.*)

of water goes in, the red, blood-filled gills absorb the oxygen, and at the same time permit another gas which is a waste of the body to pass outward. This waste comes out into the water from beneath the gill-covers.

The oxygen that is taken into the blood flows back into blood vessels extending through the body. Atoms of oxygen come into contact with atoms of carbon in stored food in the muscles of the fish, especially in those muscles which do the most work. The combination of these atoms forms carbon dioxide. This compound passes as a gas into the blood, and after going through the heart and into the gills, it is expelled there with the water.

The process by which oxygen combines with another element is called oxidation. A very important manifestation of oxidation is the setting free of a certain amount of *energy*. This may be either in the form of actual work done by the muscles, or of heat.

The breathing of the fish is merely an exchange of gases through the delicate membrane of the gills. That is all that really takes place in breathing in our own bodies.

Fishes can smell, as you must have thought when you have seen them swimming up and " nosing " your bait, and turning away from it with apparently unconcealed contempt. Their nostrils are two small openings just above the upper lip. The nostrils do not extend into the mouth opening as ours do, but nerves connect the cavities with the brain. It is the nerve connections with the smelling organ that enable the fish to smell, and to know that it is smelling, and sometimes what it is smelling.

The eyes of fishes are movable, but they are without lids. They have ears, but they are internal. The waves of sound reach the ears by going through the bones of the skull.

The Eel.——There are person who will have nothing to do with eels because they believe they are snakes. People of that kind are of course prejudiced against snakes. But an eel is just as much a fish as a sunfish is one. Moreover, eels are a mysterious kind of fish only because of the fact that it was as late as the close of the last century that the reproduction became known. From the time of the Greeks, learned men have believed impossible tales of the origin of eels, among others that eels develop from the slime of the sea.

We now know that when eels are full grown they swim down the rivers to the sea. At the mouths of the rivers the females lay their eggs, and the males spread their "milt" or spermatozoa over the eggs as is done by other fishes. Both male and female eels then die. The young hatch from the eggs in a few weeks, and soon begin their instinctive traveling upstream. Until the young reach adult size, which is about two or three feet, they live constantly in fresh water.

Eels feed voraciously on other fishes, and also on dead animal matter. They are said to be a nuisance in rivers where shad are caught in nets. In the confined area of the

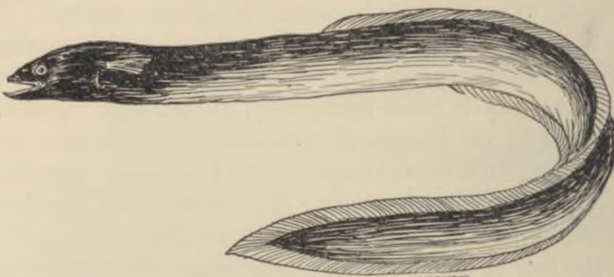


FIG. 41. EEL.
(From Goode: *American Fishes.*)

net, they can easily reach their prey, and consume large quantities of them in a short time.

The characteristics of structure which ally the eels to the fishes are the possession of gills and fins. Unlike most other fishes they are without scales, having a perfectly smooth skin.

Sharks.——There are sharks of only two feet in length, and there are giants of forty-five feet. The little ones are called dogfishes, and are nuisances to the fishermen of the North Atlantic coast. The largest are called the Basking Sharks. There is but one species of shark that is known to be sometimes dangerous to man, and the living specimens of this one, the great white shark, are very rare.

In general appearance the shark is a fish with a very slender body, and a pointed head with the mouth beneath the head. The crescent-shaped mouth has rows of very sharp, triangular teeth. The region of the gills has five slits opening directly to the exterior. There are no gill covers. The skin of the shark is covered with sharp, hard scales, so closely placed that the skin is sometimes used for polishing wood.

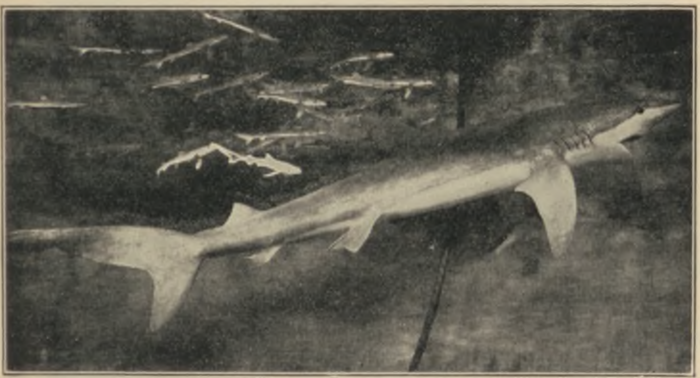


FIG. 42. BLUE SHARK.

(Model. Courtesy of American Museum of Natural History.)

It is called "shagreen." The tail in sharks has the upper lobe longer than the lower one.

Sharks are among the strongest and the most ferocious inhabitants of the sea. Ordinarily, their food consists of small, more or less defenseless animals, such as small fishes, squids, crabs, and lobsters, but they have been known to attack, and to carry on a battle royal with swordfishes.

The Codfish.——If you happen to know anyone living in far away New Foundland, or in Nova Scotia, or if you happen to live in either province yourself, you probably are aware of the fact that catching codfishes is not surrounded with any of the atmosphere of the holiday that you may have felt in catching sunfishes. Everything connected with catching codfishes means work, hard work, dirty, slimy work, and dangerous work.

If you should watch the best-equipped outfits as they are preparing to leave port, you would see the men loading the small fishing steamer with provisions for a voyage of several weeks on the Grand Banks of New Foundland, a great stretch of ocean where the water is not as deep as it is farther out, and not as shallow as it is near the land. The men are also putting in a supply of squids (see Fig. 9) on ice for bait. There are many tubs on deck filled with thousands of feet of fishing line, coiled around and bearing at intervals pendent lines and hooks.

Fig. 43. Codfish.

A large specimen just released from net. Photographed on board ship. (From *Codfishing in the Atlantic*, Courtesy Beselar Educational Film Co.)

Swinging from the davits are the dories, the fishing boats, in which the men go out when they reach the Banks.

The equipment for a dory is two pairs of oars, two buoys or floats, tubs of line with baited hooks, and food and water for several days. The boats scatter in different directions from the steamer, and when they have rowed a sufficient distance, one end of the line is attached to a buoy, the buoy anchored, and the line "paid out" until the other end of it is reached, when the other buoy is attached and anchored. Thus the trawl is set and left with signals by which the men may find the line when they return the same day or the next day. Then the men row further and set another trawl, and another, until their work of setting is complete.

On returning to the trawls, the men begin to take up the line at one end. When they reach the drop lines, they draw them up, remove any fish, rebait the hooks and let them fall again.

All this is hard work and little fun, because the cod is not a game fish in the sense that he may lead one a merry chase

FIG. 44. SCENE OF CODFISHING.

Fish net being opened, and huge catch pouring out on deck of fishing steamer. (From *Codfishing in the Atlantic*. Courtesy of Beselar Educational Film Company.)

over the briny deep. Sometimes when the men are busy, a storm comes up, or a fog settles upon them. It is not uncommon for men under these circumstances to lose their way and starve, or to be wrecked. When the cleaning, salting and packing is done, the steamer or sailing vessel returns to port, sometimes with signals set at "man lost."

Several hundred sailing and steam vessels and several thousand poorly paid men of this country and Canada are employed in the industry of codfishing. The product is extremely valuable, and has been made the occasion for exact treaty regulations between the two countries.

Codfishes live near the bottom in water from twenty to seventy fathoms. They migrate from New Foundland and Labrador south as far as Virginia, but are not captured in large quantities farther south than New England. In size codfishes vary from seventy-five pounds down. Naturally, the longer the fishing industry continues at its present rate of capture, the smaller will be the size of the fishes captured. However, the governments are propagating the young artificially, and rearing them to a sufficient size before letting them go into the sea again. The results of this artificial propagation are very satisfactory.

In Labrador the families of the fishermen live in great poverty, with few of the joys of life that go with existence for most of us in our own country. In this connection, you may find the opportunity to read what Dr. Grenfell, an English physician, has done in helping our fellowmen in the frozen Northland.

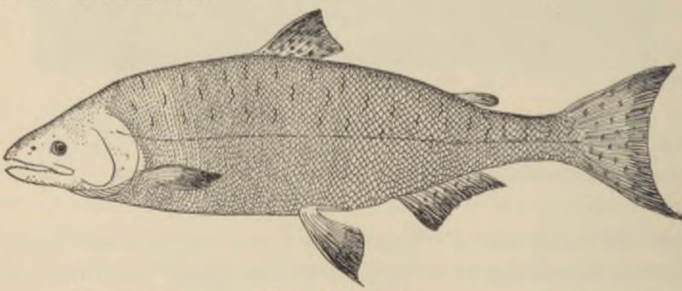


FIG. 45. SALMON.

(From Goode: *American Fishes.*)

The Salmon.——A little trip of three thousand miles across the continent brings us to the part of the country where salmon are worth fishing for, although the rivers of

Eastern Canada and New England also contain salmon. The market value of the entire salmon catch of our west coast including Alaska is said to be $13,000,000, annually. This makes the salmon of the Pacific coast the most valuable of all the fishes in the world.

When fishes are caught, they fall victims to some trap that man lays for them. He studies their instincts, and makes his plans accordingly. In most cases fishes are caught because they need something to eat. However, fishes may be abundant in a given region at certain times and food correspondingly scarce, and they will pay no attention to human temptations. When, for example, the chinook salmon is making its way literally by the millions up from the mouth of some river in the spring, they are well fed, and apparently can live for days or weeks without eating. The instinct carrying them along steadily day after day is the instinct of reproduction. The females are carrying millions of eggs, and the males many millions of spermatozoa.

The fishes swim along three or four miles a day until they arrive at the headwaters of some tributary where the water is comparatively shallow, and the bottom gravelly. The male digs a shallow "nest" in the gravel with his snout and tail. The female then deposits her eggs, and the male expels his milt over the eggs. The two cover the eggs with gravel, and soon afterward both die. When the eggs hatch the young make their way down to the sea, and live there until they in turn are mature.

Except for some trawl and line fishing in the ocean, the great fishing for salmon is done when they are on their way up to the spawning beds. The arrangements that man has made for the capture of the fishes on their instinctive journey, seem almost diabolical, for he actually makes the fishes capture themselves.

Imagine the much enlarged reel of a reaper machine, which may require your having seen a reaper. Extend the radially placed blades of the reel down nearly to the supporting axle, and insert other blades between them. At the circumference, the radially placed partitions are about two feet apart, and near the axle, less than one foot apart. The length of the reel is perhaps about fifteen feet. It is supported horizontally from a supporting stage on the bank of the river, in such a way that the lower edge of the reel extends two feet or more into the water. Around the axle there is a considerable space in which is adjusted a trough that leads outward and downward to great low tables on the bank, or into a flat boat.

FIG. 46. SCENE OF SALMON FISHING.

A fish trap on Columbia River; different construction from trap described in text, but operated by current. (Photograph by J. T. Nichols for American Museum of Natural History.)

When the reel is lowered into the water the current sets it in motion. Now, the salmon swimming upward keep fairly close to the bank. When they swim into a segment of the reel, they find themselves lifted out of the water by a force greater than their own weight. When they approach the highest point in the revolution, they slide down into the trough, and then outward by gravity to the preparing table. Before long they are in cans.

The characteristic pink color of the flesh of the salmon is present only when the fishes are caught in the earlier portion of their journey. In a measure, the color is a measure of their vitality. However, the flesh from which the pink has faded out partially is not less palatable to an appreciable extent. Nevertheless, it is not marketable and is thrown away. Thus the enormous capture is attended with very great loss, both from waste and from the death of untold millions of eggs, from which would have developed the young fishes.

Summary of Fishes.——The fishes are the lowest of all the backbone animals, and constitute a fairly distinct group. Their structural characteristics are very definite. The body divisions are head, trunk, and tail. The head bears a pair of eyes, and two nostrils that are the seat of the sense of smell and are not connected with the breathing system. The mouth is provided with numerous teeth, and connects with the digestive system, as well as with the gill chambers at the sides of the head.

The skin is filled with scales that overlap like the shingles on a house. Their arrangement and the presence of slime glands in the skin facilitate the passing of the body through the water. However, the pointed head, the heavy middle where are stored the numerous internal organs, and the long, flattened, muscular tail are all more important adjustments to life in the water and rapid progress through it.

Fishes lay great numbers of eggs to which very few species of the Class are inclined to give any attention during the period of development. But those which do, like the sunfishes and the sticklebacks, offer a basis of interest for human beings that suggest greater expectations as we go up the scale of animal life.

CHAPTER X

FROGS, TOADS, AND SALAMANDERS

The Leopard Frog.——Unless you live west of the Sierra Nevada Mountains, you are probably as familiar with the leopard frog as with any other,—possibly more so. For its gray skin with the two rows of irregular dark spots are conspicuous enough to make a positive impression on one. If they have not impressed you, then the leopard-like leaps, valiant, strong, and ready, should have won your admiration.

You are likely to come upon a leopard frog in a pond, or a spring, or in a meadow. They wander away from what is supposed to be the natural place of living of all frogs as far as fields and orchards. But their wandering is not the result of aimless whim. Where their food goes, there the leopard frogs also must go. The grasshoppers themselves have some ability as jumpers, and frogs are fond of grasshoppers.

Far as a frog may go from water, it is in water after all that it belongs, for its soft, naked skin, only slightly supplied with slime glands must not become entirely dry. An extensive network of blood vessels covers the interior of the skin, and permits the oxygen to penetrate to the blood. The frog is adapted in other ways to life in the water. The strong athletic hind legs, although very effective on land are still more so in the water, on account of their having between the toes a thin web which may be stretched wide like a duck's foot. When the hind legs are drawn up sharply, and shot out quickly, they send the animal darting further than it could possibly go at one leap on the land, besides carrying it safely under a lily pad, or into the concealing mud.

Long have you waited expectant, perhaps, for a disappearing frog to come to the surface again. And when it did come up, you wondered at its ability "to hold its breath." If the frog does not come to the surface immediately a few feet away, with its nose just behind a stick possibly, it may stay under several minutes, for the oxygen absorbed in the water will penetrate the skin and afford all the animal needs for the time being.

When the frog arises again, it begins once more to "swallow" its air, for that is what it must do. The air coming into and through the nostrils lies in the cavity of the mouth until it is forced down into the lungs by the contraction of the throat. This is an odd way of breathing, because ordinarily air goes down into the lungs of animals because the chest-walls expand and give increased space for air to rush in to fill a forming vacuum.

There are some other strange facts about the frog which appear especially interesting to us, because we are now getting near to types of animals that resemble man in some ways. The opportunity to make comparisons brings out the contrasts. For example, the frog can close its eyes, but how strange for the closing lid to come up from below like some of those window shades at school. It is also queer to see the eyes disappear into their sockets, when touched lightly. Where could they go but into the mouth? And the ears also make us think of that important part, the drum of our own ears, which receives the waves of sound and enable bony structures to carry them to the nerves within.

But the frog is much behind man in ability to defend itself. It has nothing at all to fight with. It must depend on seeing its enemy in time to jump and hide. Its ability to hide depends largely on the fact that its skin resembles to some extent the surroundings in which it lives. At least, the back and sides are quite inconspicuous against the mud and water of the frog's home. In addition, the frog benefits by the fact that it is able to produce a great number of young. Otherwise this and many other species that also have numerous young would be exterminated.

After the winter's sleep in a burrow under a log, or in a crevice in the leaf-covered rocks, the male and female frogs go to the ponds in March or April. There the eggs are

FIG. 47. DEVELOPMENT OF LEOPARD FROG.
Young in different stages of transformation; swimming in shallow dish.
(Photograph by the author.)

laid by the female and fertilized by the male. The eggs are little black dots, resembling in size and color the head of a small black dressing pin, each one imbedded in a clear sphere of jelly larger than a pea. The mass of eggs, as much as you could hold in your hand, are fastened by the female to a submerged stick, which prevents the eggs from being carried away in chance currents of water.

In about ten days, the little "pin-heads" have changed to tiny tadpoles with tails and minute, fringed gills at the neck. Escaping from the egg-case, they fall to the bottom or cling to the egg-case for a while, because they have no mouth yet. During this time they live on the yolk of the egg which the mother has supplied. When the mouth forms, the tadpoles venture further, and begin to feed upon the slimy covering of submerged leaves, or on tender plants beneath the surface of the water.

Their troubles begin immediately, for some of the voracious water insects which were the occasional food of the parents of the tadpoles now seize the little wriggling creatures as they pass, and soon thin their ranks. Fishes, too, prey upon them. But they are numerous and they grow rapidly. By July and August the tadpoles have formed hind legs, and soon afterward fore-legs appear. Then the tail begins to be drawn in, and it finally disappears. For a a day or two it is a very critical period for frogs, for the energy expended in making these extensive alterations in the anatomy leave them exhausted. But the young frogs can leave the water, and usually do leave the water, even before the anatomical changes are complete. Otherwise, the race of frogs might be exterminated by fishes. Only a little while, and the frogs are capable of leaving for the meadows and the orchards, where the grasshoppers live.

Toads.——The author of *The Frog Book*, Miss Mary C. Dickerson, gives, incidental to an extremely interesting study of toads, a few paragraphs on their money value. She says, "It is found that 88% of a toad's food consists of insects and other small creatures that are considered pests in the garden, grain field, or pasture. It is estimated that in three months a toad will eat 9,936 injurious insects, and that of this number 1,988 (16% of all its food) are cutworms. Counting the cutworms only, the estimated value of a single toad is $19.88, if the injury done by a single cutworm be put at the low figure of one cent per year."

It is of course very unfair to the toads to leave the matter there, for with a far higher and a more exact estimate of the money their presence saves us, our treatment of them would probably be more considerate. If everyone knew about this feature of the toad's career, we would respect their welfare more than we do, although we might not feel like paying for one even a fraction of its economic value. But in France gardeners would pay you well for toads. There the people generally make more use of their resources than we do in America. One American author, Professor Hodge, of Reed College, Oregon, suggests that we make of the toad a domestic animal, and care for it as we do other domestic animals. At first, the suggestion strikes us as being amusing, but the toad all unconscious of our amusement, goes on increasing the store of our national wealth an incalculable amount.

Fig. 48. Toad.

(From Dickerson: *Nature Library;* Doubleday, Page and Company.)

The fact that a toad's skin is warty will not lead to your skin becoming warty from handling the toad. One fact has nothing, or can have nothing, to do with the other. Neither is the toad poisonous, except to certain animals that seize and try to swallow it. When necessary for its own defense against devouring creatures, the toad exudes from a pair of glands behind the ears an extremely irritating fluid, which seriously annoys every creature that preys upon the toad, except snakes and skunks. The ordinary handling of toads by human beings does not result in annoyance either to the toads or to the persons. Ordinarily, the skin of the toad is dry, and entirely agreeable to the touch.

It is true that the toad is "dumpy" in appearance and generally unattractive looking, but its very appearance is one of the important reasons the species is with us to-day. The dusty color and the warty back serve to render them inconspicuous as they lie in their shallow pits during the daytime. Unless you should actually touch one at such a time, or frighten it and make it jump, you would scarcely notice it at all, and neither would snakes, another heartless enemy of toads.

FIG. 49. EGGS OF TOAD. Strings of eggs in gelatinous case entangled in water plant. (From Dickerson: *Nature Library;* Doubleday, Page and Company.)

About dusk and as long as there is light, and in the early morning, toads take their chances, and go abroad in search of food. As their squat figures hop along, it would seem that a lively insect would be stupid indeed if it permitted the toad to catch it napping. But the insects do not know until it is too late that the really dangerous part of the toad is its tongue. If you see a toad's nose within two inches of a house-fly, you may suddenly realize that the fly is no longer there. This is because the toad's tongue with its sticky surface is capable of being thrust out so quickly, and withdrawn again, that one cannot even be sure he has seen the tongue. The fact that the tongue is fastened to the lower jaw at the front makes a long reach possible. For insects that are further away than two inches the toad makes a swift little spring, and all is over as before.

Everything is business with the toad—the business of getting enough to eat—and it keeps steadily at its business as long as it can see at night, and in the daytime while the sun is not too drying on its skin. When cold weather comes it hides away in burrows, or under leaves and logs, becoming very cold but not freezing.

In the spring, the warm days take the chill from their benumbed bodies, and they come out. Immediately all the toads, males and females alike, go to the ponds where we may hear the males making their trilling whistle when there are few other signs of spring. In a few days, all the females have laid their eggs in long, jelly-ribbons, and have left them in the water. From the eggs of one female, 7,000 to 12,000 young will emerge in four days. One of the familiar sights of the margin of almost any pond in May and June is thousands of tiny black polliwogs feeding on the scum of submerged leaves. Shortly afterward the tadpoles have changed to toads very much as frog tadpoles change to adult frogs, but much more quickly.

When the young toads leave the water, they hide in the daytime, and come out at night or during a rain. Sometimes they seem to come down with the rain. But that is another myth.

The Salamander.——At the margin of the lily pads, where the pickerel ought to be, something will draw down your float feebly, and with some misgiving you will lift your line and find clinging to the bait one of the many hundred salamanders or newts to be seen swimming lazily about the boat. They are nuisances under the circumstances, but independent of the particular circumstances they have their own features of attractiveness.

Examined in your hand, a newt shows at once that its mode of life must be quite different from fishes. In the water it swims slowly along with its flattened tail waving from side to side. The four legs lie idle at the sides. Once in a while it comes to the surface, for it is an air-breather. After it has gobbled a mouthful of air, it goes back and swims about for a while, before it needs to return to the surface.

These newts are about three and one-half inches in length. They are olive green above with a row of orange-colored circular spots along either side the middle of the back. The under surface is yellow with black dots.

All the newts found in this stage in the water are at least

FIG. 50. SALAMANDER.

Floating in water. (Photograph. Courtesy of American Museum of Natural History.)

three years old. Their preliminary career is interesting. In early spring the females lay their eggs singly in the axils of the leaves of certain water plants, and inclose them in the branches, sealing all together with sticky slime from the egg glands. Little slender tadpoles with fringed gills emerge and grow larger through the spring, and until August. In the meantime, four tiny legs come out at the proper places, and are used by the tadpoles in crawling over submerged rocks in the brooks and pools. In the autumn of their first year they develop lungs in place of gills, and leave the water to live on the land. For the next two or more years one may see them in a vermillion skin, bearing a rounded tail. After a rain while the air is still damp, they come out in large numbers, looking for insects.

In the third or later year of their existence the skin changes to the olive-green of the adult, the tail becomes compressed, and they take up the final stage of life in the water.

The salamander just described lives in the eastern United States. In the state of New York and westward to the Mississippi Valley there is a species of salamander, called the mud puppy, technically known among zoölogists as *Necturus*. It is eight to twelve inches long, mottled black in color, and bears external gills throughout life. It also has lungs.

Summary of Amphibia.——The Class Amphibia is called by that name because the members of the Class all "live both" in water and on land. Frogs, toads, and salamanders have not only this characteristic, but also several others in common. For example, the young are hatched from eggs in ponds and brooks, with a pair of feather-like gills growing just behind the head. The external gills in most species give place to internal gills, and finally to lungs. While bearing gills, the animals must live in the water; on the land they may have lungs. This fact gives the habit basis for the Class name.

At one time or another, all the members of the Class have head, trunk, and tail. The adult forms of frogs and toads also have tails, but the organ is not visible, on account of the tail bone being withdrawn into the body. The skin of the body is without scales, being very smooth. In some species the skin is very thin, and is supplied with blood-vessels into which oxygen easily passes from the air. Glands that produce slime keep the skin from becoming dry, and in some species protect the animals against capture by the acrid nature of the secretion.

Typical external organs are four legs with eighteen toes in all. All have two eyes with eyelids, nostrils that connect with the lungs through the mouth cavity, and in frogs and toads ears that have the drum as an external part. The mouth is provided with teeth for holding prey.

CHAPTER XI

SNAKES AND OTHER REPTILES

The Blacksnake.——Perhaps if you got a blacksnake or a blue racer "in a corner" it would show fight. Of course it would not give a person a comfortable feeling to be jumped at by four feet of black, nervous wrath, notwithstanding one knows the animal is less harmful than a mosquito. And if you had not been trained all your lives to fear what has been feared by all the generations of human beings before you, a snake might even appear to be a creature with some rights of its own.

In fact, even when the blacksnake is in its "corner" you can see that it is afraid you will do it harm—and you probably would. The author once came suddenly upon a blacksnake nearly five feet in length. It started to run toward him, striking with its head, and nervously waving its tail in rapid vibration, causing the grass to play a crackling tune. True to an age-long education, the author walked away as rapidly as seemed necessary, whereupon the snake turned and made off with amazing swiftness. The blacksnake is really and truly a "racer".

Most observers do not make positive recommendations regarding our proper attitude toward blacksnakes. It is generally acknowledged that they destroy a great many birds' eggs and nestling birds, but they also capture and consume field mice and moles. Independent of the important matter of percentages of good and evil done by these snakes, it nevertheless should appear that *any* song birds destroyed would be a large price to pay for even a large number of field mice destroyed. A reduction in the number of blacksnakes might help to solve the great problem of saving the song birds for our fellow citizens of the next, and the next, generations.

The examination of the under surface of any snake reveals a single series of narrow, transverse plates, the front edge of each overlapped by the hinder edge of the one in front. This provides the snake with numerous sharp-edged plates which can be set partly on edge by muscles which control

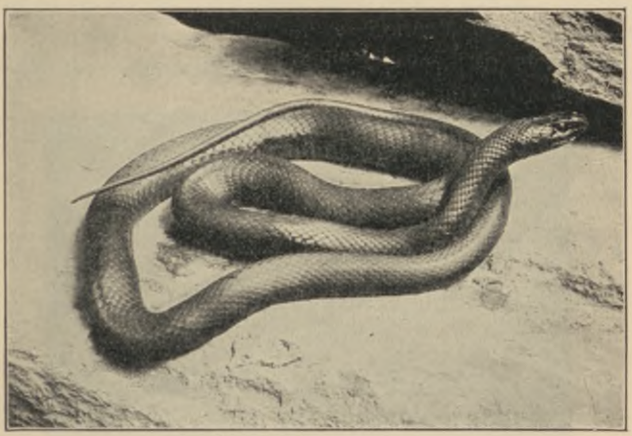


Fig. 51. Blacksnake.

(Photograph. Courtesy of American Museum of Natural History.)

them from within. By the rapid working of these muscles against the grass, the snakes get along very well without legs.

The body of all snakes is covered with overlapping dry scales. Snakes breathe by means of lungs from the time they are born. Their eyes are not provided with lids. The tongue is forked, and in fear is extended and withdrawn with great rapidity, being used chiefly as an organ of touch. One of the baseless "snake stories" is that they "sting" with the forked tongue. Such a thing is not possible.

Some snakes lay eggs which hatch in protected places in the heat of the sun; others bring forth their young alive. But in the latter cases the eggs are first developed to hatching in the body of the female.

The Rattlesnake. The rattlesnake is one of the few poisonous snakes in America, and everyone of its dozen species is becoming exterminated rapidly. Even when they were numerous, it was a rare occurrence for a person to be bitten by one.

When we hear a dangerous animal mentioned, most of

Fig. 52. Rattlesnake. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

us have at least a momentary feeling of fear, forgetting that man himself is the most dangerous of all the animals. When the need arises, he can and usually does overcome his enemy of a lower race. All the lower animals that have some of man's intelligence realize this instinctively, or learn it by bitter experience. The rattlesnake always tries to get away, but if it cannot, it coils, shakes its tail just as the blacksnake does in its excitement, and strikes with its mouth open.

The rattle, which is composed of the terminal unshed remnants of numerous moltings of skin, acts through its vibrations as a warning. There is no reason to suppose that this snake desires to warn its enemy. That would be ascribing to a non-thinking animal more thought of consideration

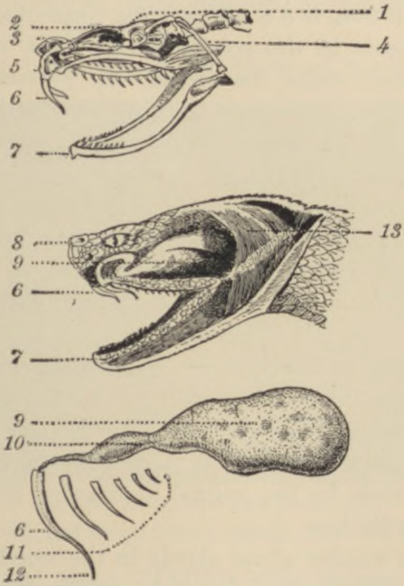


FIG. 53. MOUTH OF RATTLESNAKE.

Above, bones of head with teeth and fangs; *middle*, showing position of fangs and poison glands; *below*, poison gland, with reserve fangs. (From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

than human beings would show. The snake is merely excited, and the rattling is an incident to that excitement. Fortunately, man and other animals profit by it, but it is doubtful if rattlesnakes do. Naturally, it would lead to their destruction by man. Deer kill snakes by stamping on them, as do other large animals.

The mouth of the rattlesnake is provided with small teeth around the upper and lower jaws, and also with two poison fangs, bent scimeter-shape somewhat like the claw of a cat, and lying sheathed in the roof of the mouth. Near the tip of each fang is a small opening connected with a fine tube which leads to the poison glands back of each eye. When the fangs strike the victim, the pressure upon the glands forces the poison down the tube into the wound. The poison of the rattlesnake is fatal unless counteracted by medical treatment, in which permanganate of potassium and liquid strychnine are the principal factors. This treatment would apply in any poisonous snake bite. But let us not worry, for no more than two persons of the hundred millions in our country die from snake bites each year.

The Box Turtle or Tortoise.——Some time when you are not expecting it, you may be startled by the scrambling of a box turtle or tortoise in a pile of brush lying in the field. Or you may stumble upon one in the woods, and hear the sinking hiss made by the animal in drawing its head back into safety in its box.

Box turtles wander about slowly in the woods and fields, and are found throughout the greater part of our country. They are among the oddest of animals. Perhaps they would seem more so, if we read about them as living in some little explored country.

When the turtle withdraws into its shell, the lower section of the shell, called the *plastron*, closes at the front protecting the head, and at the back protecting the tail. The closing is accomplished by muscles working on a hinge across the plastron. The upper section of the shell, called the *carapace*, is made up of plates of hard, horny material which enlarge around the margin of each as the animal grows and requires more space. No animal but man can possibly injure the turtle when it has closed its shell.

The shell of the turtle is considered by some casually as the skeleton, but the true skeleton is inside the cavity. The backbone lies along the middle line of the carapace, and the other main parts of the skeleton hinge to the backbone. The shell is nothing but an outer skeleton, corresponding roughly to the skin of other animals.

Turtles live largely upon the larvæ of insects, and upon

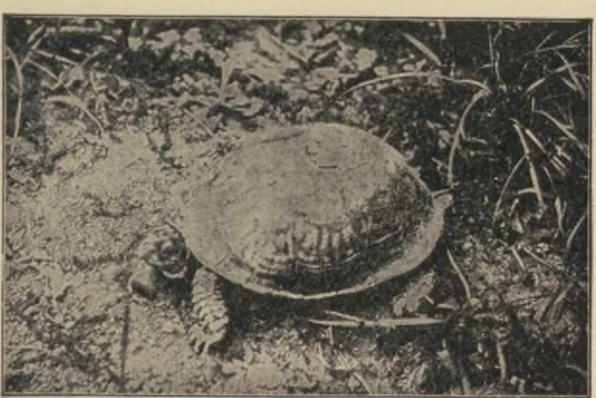


Fig. 54. Box Turtle or Tortoise.
(From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

earthworms and slugs. Turtles seem to come into slight relation to human beings, and for that reason we commonly have no fear of them. For this they should be grateful.

Young turtles are hatched from eggs, which are laid by the females under leaves, or in the soft earth. When winter comes, the turtle burrows a foot or more into soft earth, and there hibernates.

The American Chameleon.——About the year 1893 it was a passing fashion for ladies to "wear" living chameleons. These tiny lizards were fastened with a gold collar and chain, and allowed to clamber about the shoulders of their owners. Since that time, many persons really interested in these color-changing lizards have kept them as pets, but with greater feeling for their animal rights.

The chameleon is about seven inches in length. Its body is covered with small overlapping scales. The four legs are slender and strong, and the toes are provided with adhesive pads enabling it to run up smooth, vertical surfaces. It is

FIG. 55. CHAMELEON.
(Courtesy of American Museum of Natural History.)

found in this country in the coast region from North Carolina to Texas, where it lives in trees, and feeds on insects.

This lizard possesses to a remarkable degree a quality that is characteristic in some measure of several species of lizards in this country. Mr. R. L. Ditmars, in *The Reptile Book* gives a full and very interesting account of the color-changing ability of the chameleon. While sleeping, it is pale green above and clear white beneath. When badly frightened, it becomes green all over. During normal conditions in the early morning, and in the late afternoon the colors are slaty or yellowish. Often in the brightest sunlight the color is a dark, rich brown. The change of color is brought about principally through temperature and light, and by anger, fear and sleep. Surrounding colors in vegetation and elsewhere have no influence upon the occurrence of these colors, but doubtless there is considerable advantage to the animal in a green color during sleep as well as while it is being attacked by an enemy among the leaves of a tree.

Changes in color are under the control of nerves which contract and expand masses of color pigment in the skin beneath the scales. These nerves can bring about a striking change from one color to another within three minutes.

Mr. Ditmars recommends to persons who keep chameleons as pets that special care should be taken to sprinkle their box or cage inside with water, or better, to sprinkle leaves in the cage with water, since their own method of getting a drink is to lap one from the dew on leaves. They will capture flies for themselves about the room, or will take mealworms which are easily raised in the winter months when flies are not to be found. They will eat cockroaches too, which may make the presence of the lizards extremely welcome.

The Alligator.——In the early geological days of our country, many millions of years ago, there lived a great many kinds of giant reptiles. They and their descendants passed out of existence long before man appeared upon the earth. The alligator, familiar to many of us from visits to zoölogical gardens, seems to us like a giant. And it is the largest of all that are left. However, the collection of a good museum that contains the fossils of extinct monsters would make the alligator appear small indeed.

Alligators sometimes reach the length of twelve feet and the weight of over five hundred pounds. Large ones may be found only in the wild swamps of the southeastern coast states. Even there they are being rapidly exterminated by hunters who desire their skins for the leather market. The eggs are taken from the conspicuous nests of sticks and leaves and are sold to be eaten. Curio hunters buy from dealers in the South little alligators which they cannot raise, thus further tending to annihilate a species which is of great value.

Although alligators are credited with being dangerous to man, they really are afraid of him, and will try to escape whenever escape is possible. However, when they are cornered or wounded and prevented from reaching their native element, the water, they will attack a man. With their powerful tail, they can knock a man down, and with their

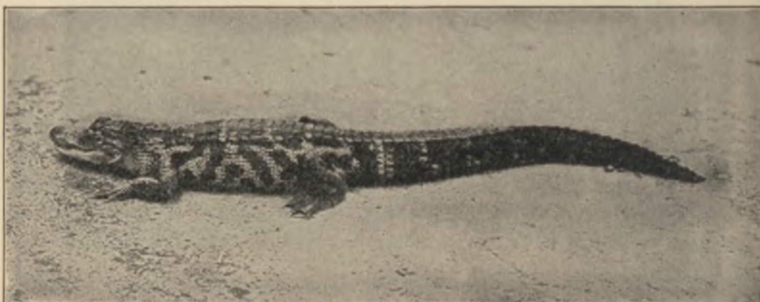


Fig. 56. Alligator.

(From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

strong and merciless jaws and teeth, they would prove dangerous in the extreme.

In the water, alligators dive and remain out of sight when danger threatens, or when stealing upon a swimming bird which they want to capture. They drag their prey beneath the surface and drown it, but they must come to the surface to swallow it, in order to avoid strangling when the valve to their own lungs is opened. When they are not seeking food or escaping enemies, they spend much time basking in the sun on the banks of streams and lakes.

With the plentiful supply of food that these regions afford, and the hot moist air of the banks, it is small wonder that the alligators contract the habit of sleeping long hours, and growing with great rapidity.

Summary of Reptiles.——The Class Reptilia comprises animals of still higher development than the Amphibia. Some of the members of the Class live both in the water and on the land, but none ever breathes by gills. However, the undeveloped young have gill-like organs while still in the egg. This fact is true of still higher animals, the birds and the mammals, tending to show that the higher animals review in their development the general history of the lower forms.

All the members of the Class have head, trunk, and tail. The skin of all is dry, and is covered with overlapping scales, or with plates. The organs of the head are eyes with lids, except in the snakes, with internal ears, and nostrils. The mouth is provided with teeth. The typical number of legs is four, with five toes on each foot. The snakes have only the rudiments of legs.

The brain is larger in proportion to the rest of the nervous system than it is in the Amphibia and in the fishes. The heart shows the beginning of a separation into four chambers, whereas the Amphibia has three chambers, and the fishes only two.

Most of the representatives of the Class come from eggs deposited by the female under ground. In some snakes the young are hatched from eggs within the body of the mother, and born in an active and developed condition.

CHAPTER XII

BIRDS

The Ruffed Grouse.——With the great increase in the population and the wealth of our cities, we have formed the habit of sending to distant rivers, lakes, forests, plains, and gardens for more and more rare and expensive foods. The habit of eating extravagantly has kept in touch with the habit of living extravagantly in other ways. Moreover, in the case of foods that cannot be replaced easily, the excessive eating makes the food more expensive, and in time tends to eliminate it altogether.

Less than two generations ago there were in our country many species of game birds in large numbers. To-day several species are all but exterminated. The ruffed grouse is one of them. In that part of New York State, for example, included in the limits of the Catskill range of mountains, it has not been many years since flocks of ruffed grouse were plentiful. To-day a person familiar with the woods rarely sees more than one or two grouse at a time, rarely coming upon any at all. The Catskills are all within one hundred fifty miles of New York City, and the "pot-hunters" range the mountains in the "open" season to the extent that they seem like a human pestilence. As Dr. William T. Hornaday, the author of *Our Vanishing Wild Life* truly says, "If we desire to prevent the extermination of this species, we must stop the killing altogether."

The ruffed grouse seems to be known to most persons by some other name. In the Catskills it is always called the "partridge." In other parts of the country it is called the "pheasant." Mr. Ernest Thompson Seton has helped to fix its correct name, ruffed grouse, in the minds of nature-lovers in connection with the fanciful name "Redruff"; and besides, he has made its bold and dashing characteristics familiar to thousands of readers who might never have thought of distinguishing it from other game birds of large size.

The chief features of the ruffed grouse are a ruffle of feathers about the neck of the male just in front of the shoulders. Both male and female birds have a topknot of feathers on the head. The color of the bird is rusty brown, with mottlings of black, gray, and white. As one sees the bird in the woods it appears to be the size of a nearly grown barnyard chicken, but with a much longer tail.

FIG. 57. RUFFED GROUSE.
(Courtesy of National Audubon Society.)

If you are afraid of having a palpitation of the heart, it might be well to try to see a ruffed grouse before one springs into the air a few yards away from you, for his setting off is the burr-r-r-r of the sudden turning of a mighty electric fan. There is a vigor about the sound as well as the sight. In all the quietness of a summer morning in the woods the suggestion of alertness and winged power is boldly emphasized.

Again in the springtime, the dum-dum-dum of the drumming male as he stands upon a log and signals to the female by beating his wings against the air (see Fig. 57), giving a sound like the boom of a distant drum,—this further gives us the feeling that here is the vitality of animal life personified in a most attractive form.

And then in August, when we suddenly come upon a sorely crippled hen-grouse, fluttering helplessly but with suspicious persistence in a given direction, we nevertheless follow her, wondering if we may not help the poor thing. Then we remember what someone has told us, or what we have read about the tricks of the mother-grouse and all her partridge tribe, and we try to find the little ones. We probably got a glimpse of them at the flush, but the sight went out of our minds,—startled out. We look everywhere for them, but they have probably flattened their bodies against the soil or against the similarly colored leaves and spaces between, and we walk over them and miss them altogether.

FIG. 58. RED-TAILED HAWK.
(Courtesy of American Museum of Natural History.)

The Chicken Hawk.——It is claimed by bird-lovers that there never was a greater injustice done to a bird than in giving to the red-tailed hawk its commoner name of chicken hawk. It is not denied that this hawk does capture a few chickens, but the act is exceptional. It is very easy for one to assume that any hawk that catches a chicken is *the* chicken hawk. But it may be the Cooper's hawk, which is a real stealer of chickens, as well as of many other valuable birds.

The red-tailed hawk has a rusty-brown tail. There is a broken, black band across the breast of the adult. Cooper's hawk and the sharp-shinned hawk, both guilty of great interference with the welfare of man, have conspicuous cross-bars above and below the tail.

In order to obtain definite knowledge of the relation birds bear to our economic interests, investigators have conceived the plan of first killing a considerable number of a given species. The stomachs of the birds are then examined with great care. After an investigation by this method, it was found that 85% of the food of the red-tailed hawk of 562 specimens was made up chiefly of small destructive animals like field mice.

Thus, it is apparent that without definite information as to the kind of hawk one sees flying about the farm, it is very likely that an excitable person may kill one of his best friends.

FIG. 59. WHIP-POOR-WILL.

(Courtesy of American Museum of Natural History.)

The Whip-Poor-Will.——Far off in the woods on cool summer evenings in June or July one may hear the whip-poor-will give its striking call, with the quick, snappy "whip," the long, full "poor," and the sharply accented "will." You count forty to fifty repetitions of the call, and sometimes you become tired of counting before the bird has finished its calling, and has gone off somewhere on the wing to open wide its cavernous mouth, scooping in the night-flying insects.

A little later one hears perchance a queer "pwt" in a tree near at hand, and then the "whip-poor-will" call comes again, so strong and earsplitting as to cause you to marvel at what an insignificant bird can really do. Some persons claim that the whip-poor-wills make them nervous with their wild cries, keeping them awake far into the night. Perhaps they do; such persons should stay in the country longer. It may be that the elevated trains and the roar of other wheeled traffic, and their own feverish activities, gave them their "nerves."

A whip-poor-will may be startled by your trying to see it. It will fly away but you may not hear it go, for the wings are feathered so softly that it makes practically no sound on the wing. This fact may make the capture of its insect prey much easier.

During the day the dull, gray color of the bird makes it very inconspicuous as it rests upon the ground in the woods. The eggs of the female are laid, two in number, upon dead leaves, with scarcely any appearance of a nest.

The whip-poor-wills go south in October, not to return until the following April or May.

The Crow.——One of our best interpreters of bird life, Mr. Frank M. Chapman, author of *Bird Life*, says of the crow, "No one of our birds is better known, and still how ignorant we are of his ways! I am not sure that he does not know more about ours." This refers of course to the shrewdness of the crow in understanding and anticipating the acts of his arch enemy, man. It is often said by farmers that crows engaged in stealing in a cornfield pay slight attention to scarecrows, and even to a live man when he is armed with nothing more dangerous than a stick. They respect only a shotgun. At the same time, they appear to exhibit wholesome dread on account of the fate of one of their number whose dead body they may observe swinging in the wind from the top of a fence.

Another bit of evidence of the intelligence and adaptiveness of the crow is their frequent disposition to raid the nests of other birds that are under the direct protection of man. They overcome obstacles and take risks which while frequently turning out successfully for the time, bring down upon them the vengeance of man. This kind of thing, and the general stealing of corn, has tended to make the conviction of man certain that the crow is a nuisance to be rid of.

Fig. 60. Crow.
(From *Birds of New York*.)

At the same time, we are forced to take the findings of painstaking inquiry concerning the facts. The United States Department of Agriculture has reported that the examination of nine hundred crows' stomachs shows that the amount of good done by this bird in destroying grasshoppers, June-bugs, cutworms, and other injurious insects exceeds the loss caused by the destruction of corn.

The Department recommends that before planting corn, the kernels be soaked in water over night, and then dropped into a solution of soft tar. The coated kernels may be transferred to wood ashes or plaster of Paris to be made fit to handle in planting. Crows will not touch grains of corn treated in this way, nor will they touch the seedlings that develop from the grains. Farmers who really make the soil produce its best are listening to all such suggestions that lead toward scientific farming.

In the summer time, one frequently notices groups of three or four of these black birds sitting in a field or calling to one another from tree tops. The alertness of their actions and the vigor of their harsh *caw*, *caw*, with its manifold variations of emphasis make all hearers think they are holding a council in preparation for a raid. Some old nursery rhymer has given us the direful song of a crow council, beginning:

> "There were three crows sat on a tree,
> And they were black as crows could be;
> Said one old crow unto his mate:
> 'What shall we do for meat to eat?'"

In the winter, crows congregate in large numbers, and visit the tree tops of a definite set of trees throughout the season. In March they begin to mate, and in April they build large nests of sticks and bark in the forks of trees about thirty feet from the ground. They lay from four to six eggs that are bluish green in color, with dots of brown.

The House-Wren.——Perhaps every grown-up whose childhood was spent on a farm bears with him through life cheerful recollections of the family of house-wrens that nested and sang about the wood shed, the grape-arbor, or over the high cellar entrance under the wistaria vine. Their diminutive size, their bobbing bodies, with sprightly, upturned tail, their stream of abandoned song, and their winsome fearlessness of man,—all appear to have met the generous approval of everyone.

No student of birds seems to have concerned himself with the question of whether wrens are economically important to man, or not. It appears to be sufficient that they bring happiness. This of course is more important than money saved, or money made.

Wrens will make their own nests about the house, or they will build in any little box set up on a pole, or in a tree, for their benefit. Mr. Chapman recommends that the hole be made no larger than a silver quarter of a dollar. Sparrows cannot enter the box then. Wrens fill the box full of twigs, no matter what its size. The nest proper they make of dried grasses. Six to eight speckled, pinkish brown eggs are laid. The house-wren goes South in October from the middle and northern states, and its place is taken through the winter by the winter wren, that has been nesting further north.

FIG. 61. HOUSE-WREN.
(Courtesy of National Audubon Society.)

The Nuthatch.——The White-breasted Nuthatch is a common bird in Eastern North America to be noticed climbing up and down, and going round and round the trunks of large trees. It is more skillful than any other bird in this sort of acrobatic food getting, and appears not to think the work hard, for it repeats a metallic, but not disagreeable note constantly while searching the bark for insect eggs, or larvæ. It stays with us all through the year.

Although the habit of visiting trees just described should be enough to enable one to recognize this bird, the black cap, the white sides of the head and the throat and breast, and the gray-blue back will make its identification doubly sure.

About the twentieth of April, the female lays five to eight eggs. They are white in ground color and evenly and thickly speckled with reddish brown and lavender.

FIG. 62. WHITE-BREASTED NUTHATCH.
(Courtesy of American Museum of Natural History.)

The Hermit Thrush.—The family to which the hermit thrush belongs contains some of our most famous songsters, as well as birds less wonderful as singers but interesting for other reasons. The great singers are the veery, the wood thrush, and the hermit thrush. Near kin are the ever friendly robin and the shy bluebird.

FIG. 63. HERMIT THRUSH.
(From Chapman: *Bird Life.*)

It is not often a satisfactory way of giving information about birds to try to describe their way of singing by transposing into English syllables the notes of their music. It is almost as difficult to give an idea of the quality of a bird's song that would help a person in recognizing the bird. But there is a quality in the song of the hermit thrush which has often been described as being like the rich tones of an organ, measured and stately. This is an accurate description, and in the great arches of the forest the wonderful, ringing notes fill the aisles with overpowering melody. If you hear a hermit thrush, you will probably never forget it.

The hermit thrush is smaller than its relative, the robin, being only about seven inches long. Above, it is cinnamon brown. Beneath it is white with black spots in rows on the breast.

The migrations of this bird extend from our northern states in summer time to the Gulf of Mexico in winter. While migrating, it travels by woodlands, but spends a great deal of time near the ground. The eggs resemble the robin's in being bluish green.

Summary of Birds.——The Class Aves (Birds) is so distinct from all others that anyone could give the characteristics. Although birds spend much of their time on land or in the water, they are especially adapted to life in the air, and on the wing. Their wings are broad and are controlled by very strong muscles that are able to lift the body and send it forward with great power. Only the lowest birds like the ostrich and the cassowary are unable to fly. The possession of feathers is indeed more characteristic of birds than is the ability to fly, for bats, squirrels, fishes, and insects can fly, but members of no other Class than birds have feathers.

Birds have eyes with eyelids, ears with an external opening as in man, and nostrils. The mouth is without teeth; but as a compensating organ, there is a gizzard into which the food passes from the gullet to be ground up by strong muscles, working against pebbles and grains of sand that have been swallowed before the food enters.

The brain of birds shows a still larger relative size than does the brain of reptiles. The heart is divided into four separate chambers with the result that birds have a more perfect circulation of the blood than is possible with lower animals. Connected with the perfect and complete circulation is a greater oxidation, and the resulting heat in the body. The body temperature of birds is several degrees higher than the temperature of human beings.

Most birds after the egg-laying incubate the eggs until the embryos have developed into fully formed young. After the hatching, the adults feed their young for varying periods of time. Thus begins in an organized manner the habit of caring for the young beyond the period of birth. Still greater development of this habit takes place in the next Class.

CHAPTER XIII

MAMMALS

The Opossum.——The most primitive animal in our country that suckles its young is the opossum. In a very definite sense it is an immature mammal, for the young are born in a partially undeveloped condition. They are placed

Fig. 64. Opossum.
(Courtesy of American Museum of Natural History.)

when born in a pouch under the body, where they must remain for a time drawing nourishment from the mother until they are strong enough to exhibit some sign of independence. Not until the young are five weeks old are they able to venture away from the mother.

Our species of opossum is called the Virginia opossum, although it is found from New York, Michigan and California southward throughout South America. It is best known, however, in our southern states.

Wherever the opossum lives its habits seem to furnish amusement for everyone, except the farmer whose chickens the vandal steals. Nearly every southern country boy has had his encounters with the opossum, and doubtless has enjoyed the experience of being occasionally outwitted by a creature so generally slow-witted and comical.

The opossum is a short-legged, long-bodied, gray, bristly-haired quadruped, about fifteen inches in length. The head is white, pointed, and set with eyes that resemble two black shoe buttons. The tail is about twelve inches long, and is without hair.

Everything is grist that comes to the opossum's mill. It feeds on fruit, vegetables, insects, eggs and birds in the nest, chickens, and roots. It is a night hunter, and sleeps during the day in hollow logs and in trees.

While the opossum is hunting, it may also be hunted. Anyone can capture an opossum, for it cannot run fast, and will fall over "dead" at the least assault. It may then be picked up by the tail, and carried until you get tired and lay it down for a moment. When your back is turned the opossum will get up and slip away. Even when you bear it to the kitchen, it will not resist. The fact that roast 'possum is good has taught it nothing.

In spite of the defenseless makeup of the opossum, it is holding its own more successfully than are many other animals that are preyed upon by man. Without question much of the success of the species depends on the fact that a great many young are born. The young stay with the mother about two months, and soon thereafter another litter is ready to take the places of those that have left. When we realize that seven to eleven young are born at a time, we understand the secret of their success as a species.

The Right Whale.——Whales are mammals. The external fish-like form adapts them to swimming through the water. The tail being placed horizontally adapts the animals to the constant necessity of swimming to the surface for air. There is no hair on the bodies of whales except for a few bristles about the chin. Whales are kept warm by a non-conducting "blubber," a dense layer of fat immediately under the skin. The fore-limbs of whales, though reduced to mere paddles with no power of motion except at the shoulder joint, have all the bones, joints, and even most of

Fig. 65. Right Whale.
(Courtesy of American Museum of Natural History.)

the muscles of the human arm or hand. Rudiments of the hind-legs are found deep in the interior of the animal.

The Greenland or Arctic right whale (*Balæna mysticetus*) attains the length of forty-five to fifty feet. The head exceeds one-third the entire length of the animal. The cavity of the mouth is greater than that of the thorax and the abdomen together. The upper jaw is narrow, greatly arched backwards, increasing the height of the cavity and allowing for the great length of the whalebone blades. The floor of the mouth has the shape of an immense spoon.

The blades attain the number of three hundred eighty or more on each side. Those in the middle are sometimes twelve feet long. They are black and highly elastic, and fray out at the inner edge into long delicate hairs. By this apparatus the right whale is enabled to capture and swallow immense masses of the minute crustacea and pteropods that are abundant in the seas. The large mouth enables it to take in at one time a great deal of water filled with these small organisms, and the length and delicate structure of the whalebone provide an efficient strainer by which the water can be drained off.

Whalebone is horny in character, and is very elastic. It is largely replaced now in commerce by steel, but it is still used among dressmakers and milliners, and in the brush trade. As much as $12,500 a ton is now paid for whalebone.

The "blubber" of a whale supplies from two to three tons of fat which is stripped off after the captured whale is fastened to the side of the ship, or after being towed to a harbor.

Whales are attacked from small boats by means of harpoons which are short spearheads attached to a pole and a long rope. They are also shot with a harpoon-gun from a vessel. Explosive harpoons have been used since about 1865. Whale-fishing is still going on in all parts of the world, but with very few vessels of the various nationalities.

The Prong-Horned Antelope.——In Africa there are scores of species of antelopes; in America we have never had more than one. Up to about the year 1875 our species, the prong-horned antelope, was abundant from Canada to Mexico throughout the great plains region as far west as California. To-day there are but a few herds in any part of its former range.

The prong-horn is related to the deer and also to the wild goat. It is a graceful, swift-running antelope, about thirty-eight inches high at the shoulders. The male has two horns about twelve inches high, hooked at the top with one fork extending over the eye. The female is without horns. As is the case with the deer, the horns are shed every year. In color the antelope is yellowish brown on the back and part way down the sides, and white below. The rump is conspicuously white.

When the prong-horn was plentiful, great herds of them roamed the prairie, being successful in maintaining themselves against wolves and other enemies, until the railroads penetrating the West brought man into closer relation with them. Hunters slew them for their valuable flesh, and wire fences prevented them from reaching places of shelter in the winter, thus causing the loss of thousands by cold and starvation.

Fig. 66. Prong-Horned Antelope.
(Courtesy of American Museum of Natural History.)

It would be difficult to find a more splendidly endowed wild creature than the prong-horned antelope, or one that has been pushed to the wall more quickly. Its great power of vision, superior to that of the deer, and its fleetness, also superior to the running ability of the deer, might have made it possible for them to persist as the deer have done. But antelopes do not breed in captivity as do the deer. For this reason it has not been possible to establish herds of antelopes.

Nevertheless, it is quite a simple matter to tame an antelope, and in a short time to make an interesting pet of one. The author still has tender recollections of a pet antelope owned by him in his boyhood days on a Western Kansas ranch. He captured the little fellow, then perhaps but three weeks old, with the help of a dog and a cow-pony, after two consecutive chases of a half-mile each. During the long five-mile ride of boy and antelope to the ranch, it seemed that it would be impossible for the great, frightened eyes of the timid creature ever to show any sign of becoming reconciled to a human being. But that night it drank readily from a pan of milk, and the next day when experimented with in the corral, it followed its master about. After that, the pet followed everywhere, even when the master was on horseback, dodging the curious cattle with great skill. One night after the antelope had been under the care of human beings for three weeks, a sudden storm drove it away from the ranch house. The next day its little body was found in a near-by gulch.

Many persons have had successes with making pets of antelopes, and it appears especially unfortunate that we cannot save the species because of its failure to breed in captivity.

The Chipmunk.——The chipmunk is a diminutive but a typical representative of the group of mammals called the gnawers. It has the typical sharp front gnawing teeth, so well exemplified in the gray or red squirrel, or in the rabbit or the rat. And what is more important to our purpose, the chipmunk is accessible in a friendly way to everyone who cares to watch it with patience. As a matter of fact, one cannot help watching it.

Whatever the species, the habits of all chipmunks are very much the same throughout our country, except that the particular environment or kind of fence may make the habits appear different, for a fence is just as necessary to a chipmunk as are the nuts it finds and the young lettuce and carrot leaves it steals from your garden,—which you should not begrudge if you can possibly spare them. Trees are used for shelter, too, but trees are not the best places for chipmunks, because they are not swift runners, and they cannot fight off hawks and crows.

Into the crevices of rocks and under rails and boards, and also into burrows in the ground, the chipmunks may go, but not entirely free from the pursuit of their most dangerous enemy, the weasel. Chipmunks do not fight back. But they are able to prevent their own extermination by having many young, and by never going far from home. One other factor that operates in their favor is that their

Fig. 67. Chipmunk.

(Courtesy of The University Society, Inc., publishers of the "Nature Lovers' Library.")

successful enemies, the weasels, the foxes, the mink, and the hawks are occupied with other matters beside. This fact always helps to maintain those complicated relations of creatures to one another which we may call the balance of life chances.

As soon as the nuts and grains begin to ripen in the summer, you may see chipmunks making many trips along the fences to their larders beneath. They are carrying cheek pouches full of the products of the country to store them up for the winter. They stay closer at home than ever during the stormy days that follow, but when the sun shines brightly they come to the light even in the winter time and enjoy themselves in it.

In old stone fences one often sees hickory or butternut trees growing from the midst of the rocks, far from older overhanging trees. Doubtless most of these trees developed from nuts that were stored but overlooked by chipmunks.

FIG. 68. BAT.

(From Linville and Kelly: *General Zoölogy;* Ginn and Company.)

Bats.——Of bats of all kinds it is customary for people to believe the worst. Whenever persons are ignorant of facts they usually do believe the worst. There are two reasons why we are generally ignorant of the facts about bats. One is that they are inhabitants of the night; the other is that our ancient prejudices concerning anything and everything that we hear disagreeable tales about tend to keep us from *wanting* to know about bats.

There are many kinds of bats scattered throughout the world in the torrid and temperate zones. Practically all the bats of our country belong to one family, and are spoken of as the common bats. They are small mammals with a head and body two and one-half inches to three inches in length, and with a short tail. Their bodies are covered with red or gray fur. The front legs are very long, and the toes or fingers of this pair are extremely long and spread widely apart. These fingers form the framework of a naked membrane that stretches from the first finger back to the hind legs and even to the tail. The thumb is very short; the thumb-nail is hooked, and can be used for climbing and for supporting the body when at rest. But the customary position when at rest during the daytime is that of hanging by the hind legs, head downward.

After sunset and until dark, many of the "birds" you see flying swiftly about, turning suddenly, and flopping this way and that, seeming a trifle awkward, but getting through the air and around obstructions with amazing skill, are not birds at all. By this time you must have guessed, they are bats. They are looking for insects, and they capture enormous numbers of them. They are not bearing live insects of unwelcome species in their fur, which may in that way enter your house, nor will the bats disarrange your hair. These bats do not interfere in the least with human welfare, but promote it as vigorously as toads do.

In the daytime, bats sleep in darkened protected places, as of the roof of barns, or in caves, or even among the leaves of a chestnut tree.

The Fur Seal.——In the tragic story of the fur seal we learn a great deal about ourselves, how within a generation of men an animal little known or prized came by dint of "advertising" and business promotion to be considered the most valuable of fur animals. We also learn how the fur seal came to be the occasion of serious international complications. It is not the fault of the fur seal, nor of any other enemy than man, that within forty years the number has decreased from millions to limited thousands.

The fur seal belongs to the group of marine mammals known as sea lions. They have four legs that have become modified into flippers adapted to rapid and skillful swimming. The front pair are triangular in form, and are without hair or claws. The hind pair show the toes with webs between. The head bears small, sharp-pointed ears, and strong bristles about the mouth. An adult male will reach the length

Fig. 69. Fur Seal.
(Courtesy of American Museum of Natural History.)

of seven feet and the weight of over four hundred pounds.

The fur seal has its headquarters on the Pribilof Islands in Bering Sea. The seals live on these islands from the first of May to the end of November. During that time the young are born. When they are about six months old, they and all the seals of the islands "go to sea." They migrate southeastward toward the coast of southern California, then bear north off the coast of Oregon, British Columbia, and Alaska, returning to the Pribilof Islands where they arrive again about the first of May.

It is a matter of history that Alaska and the adjacent islands were purchased from Russia by the United States in 1867. At that time there was practically no fur seal industry, but within five years the company to which the United States had leased the Pribilof Islands began to spend considerable sums of money to develop in London a trade in sealskins. In a short time the company was able to get good prices for the 100,000 skins of young males which the government had given them permission to kill on the islands.

With the encouragement produced by wide advertising in the centers of fashion in Europe and America, the price went up, and the demand became greater than the supply of 100,000 skins permitted by the contract. The result was that many independent ships from America and Canada at first, and from Japan and Russia later, began to kill the seals indiscriminately during their migration in the sea, as well as females that went to sea on short trips from the islands to obtain food. Naturally, many of these seals were females bearing unborn young. The effect of this indiscriminate killing was a considerable reduction in the number of seals that returned to the islands each May, and a gradual extermination by the destruction of the unborn young, as well as the young that had starved because their mothers had been slain while at sea in search of food. Our government seized many ships that were engaged in what was considered illegal capture, and began negotiations with other governments to stop the stealing.

Negotiations have been going on since 1887, with varying success and loss of money in damages by our government, for the control of the high seas is a matter that no nation is willing to yield as a principle. No satisfactory settlement of the problem of the right to destroy the seal has been reached yet. Death by killing and death by disease has greatly reduced the ranks of the fur seal, and to-day it is practically doomed to extermination.

The interest of the Treasury Department of our government has always been in the financial returns from the two little dots on the map of Bering Sea. Already they have brought us more money than the entire cost of all Alaska. Besides, there are millions of dollars invested in the industry, and thousands of men making their living by it. However, one phase of the whole question has been given little thought, and that is the extent of the real need for sealskin furs. So far as we can see now, no condition of human life has arisen since the year 1867, which seems to require that our bodies should be wrapped in furs that cost from $200 to $1000 a set. If any such condition had arisen, life would go hard with those who could not afford to spare, or did not even have, that much money. Of course, we are fully aware of the fact that men engaged in promoting fashions find their greatest opportunity to get rich in the encouragement which they know how to give directly or indirectly to other men to purchase expensive attire for their wives and daughters.

The entire industry of seal-catching has been built up on the basis of advertising and human vanity,—and all to pile up riches. Besides, our government has been put to great annoyance through international complications for the profit of a company of seal-catchers. The men who do the hard work and make a poor living by the capture of seals get but a small part of the return. And they might be better employed in working to supply some real human need.

Furthermore, there is no question about the fact that seal fur as worn in the women's garments does not give any more protection from cold than is afforded by good wool garments, the manufacture of which does not involve the death of any animal, nor does it even involve pain.

The Weasel.——The weasel is one of the smallest flesh-eating mammals in our country, yet it has a look about its face that would make you stop and catch your breath, something as you do when the tiger at the "zoo" or circus looks at you through the bars. We do not need to consider what the weasel would do if it were five times as big as it is. For its own purposes it is large enough. With its present size and strength it can kill rabbits, grouse, ducks, and chickens, and they are each more than five times the size of the weasel. As already recorded in the story of the chip-

FIG. 70. WEASEL.
(Mounted Specimens; Courtesy of American Museum of Natural History.)

munk, the weasel can follow a chipmunk into its burrow. There is thus great range to the size of the weasel's prey, and abundant testimony to the persistency in its character.

The weasel is one of the most bloodthirsty of all flesh-eating animals. It is said to kill sometimes simply for the sake of satisfying a murderous disposition. Although its merciless inclinations are directed often against rats and mice, it is a question whether the benefits from that sort of activity overbalance the loss sometimes resulting from the trespassing of weasels on the precincts of the hen roost.

On the approach of winter, the fur of the weasel changes from brown to white. Doubtless, the white color helps to render the weasel inconspicuous to its intended victims. Thus, *protective resemblance* has its counter advantage in *aggressive resemblance.* Some animals gain advantage through the similarity of their color to the general surroundings by escaping the notice of their pursuers; the weasel and some others gain by the similarity in color to surroundings while they are pursuing.

Summary of Mammalia.——Like the birds, the mammals stand out clearly as a Class with definite characteristics. Mammals are characteristically land animals, although many spend some or all of their time in the water. Very few mammals can fly.

The skin of mammals is covered with hair. No other class has this kind of covering for the body. The two pairs of legs have a variable number of toes.

Mammals have eyes with lids, ears with external sound-collecting organs with passageways leading to the "drum," and a pair of nostrils leading to the lungs. The nostrils carry the air over sense-organs generally very keen in the recognition of odors. The mouth is supplied with teeth for crushing and tearing the food.

The brain of mammals shows the greatest size of any Class in relation to the extent of the nervous system and to the weight of the body. In this Class there is the highest development of mental capacity of any. The circulatory system is complete, there being four chambers in the heart, and a complicated set of blood-vessels carrying the blood away from the heart and back again.

The highest manifestation of caring for the young is to be found in the mammals. The young are born in an active but usually temporarily helpless condition, and are fed on milk produced by the mother. In many species the further care of the young extends over many months, while in man the period of care extends over many years, including as it does the training and the education in the period of youth. During the time of training and protection, the various species of mammals naturally impress upon the young the experience which the species has as part of its characteristics. In our own race, the better protected and trained the young are, the better it is for the individuals, and the better for the succeeding generations.

CHAPTER XIV

ANIMALS FROM THE BEGINNING OF TIME

The Fabled and the Real.——There have come down to us tales from mythology and from ancient natural history which describe animals stranger than any we have ever seen "in the flesh." But the efforts of the imagination of man as portrayed in the fabled unicorn, or in the impossible centaur, are far outdone by the actualities laid before our eyes in the record of the rocks,—records that contain the fossil remains of creatures uncommon in form and gigantic in size. Impressive as is the sight of a museum full of the animals of the past, it is still more impressive to consider the vastness of the time that must have intervened since these and other less conspicuous animals lived and moved about on prehistoric land, or in sea and lake.

The Vastness of Time.——Although we may feel inclined to warn against the unguarded use of the imagination in dealing with facts of science, nevertheless, scientific imagination must be employed in the effort to encompass the well-nigh inconceivable features connected with the study of life upon our planet. We have been accustomed to dealing with years in measuring time; now we must begin to think of millions of years. The time that has elapsed since life began to exist upon the earth is so great that it is practically unthinkable; hence, the effort to measure it in terms of years is almost hopeless.

Life began a long time after the planet itself was formed, and this early life must have been in small green plants, since small things logically precede large ones, and since green plants are able to build up their protoplasm out of inorganic materials, such as water, minerals in solution, and carbon dioxide from the air, while animals live upon the organic material obtained directly or indirectly from plants.

Life and the Rocks.——Our knowledge of animal life upon the earth is entirely dependent upon certain facts primarily dealt with in the science of geology. These facts have to do

FIG. 71. "POCKET" OF FOSSILS.
(Courtesy of American Museum of Natural History.)

with the wearing down of the surface of the soil by rains and by the action of the water in brooks and rivers, and with the subsequent deposition of the fine particles in lakes, or in the sea at the mouths of rivers. Animals that have shells, like the Foramenifera (p. 9), or the clams (p. 74), or the lobster (p. 65) tell the story of their presence when the deposits become hardened into stone, and are lifted above the water by an upheaval of the surface of the earth in that region. Likewise, the bones of the higher animals are preserved after their owners have lost their lives through the drying up of bodies of water, a catastrophe which would involve the destruction of fishes in the water and also of hordes of land animals driven there by droughts and weakened by being long deprived of water. Vast "pockets" of the fossils of animals have been found in solid rock in such condition as to lead to the supposition that catastrophes of this kind have happened many times; and they are still happening in deserts and in flooded areas.

Another very common occurrence is the discovery of fossils imbedded in the solidified dust of ancient volcanoes. As recently as the destruction of Pompeii (A. D. 79), the ash and cinders from Vesuvius covered and preserved entire the bodies of dogs and men. In Eastern Oregon a considerable portion of the country is a vast stretch of volcanic dust. From this region many fossils have been taken.

Fig. 72. Pompeii Excavated from Stratum of Volcanic Ash.

In all times the wind has been a very active agent in carrying dust and even sand to considerable distances, covering up and preserving the fossils of certain creatures. The wearing down of land masses, the deposition of the particles carried by the water, the solidifying of the soft material into stone, the subsequent elevation above the water by upheavals, the breaking up of rocks into soil, and a renewal of the wearing down of the new land masses, are phenomena that have been going on since the beginning stages of the earth's history. Depending upon the character of the minerals involved, the rocks have been limestone, sandstone, shale (composed of clay), or volcanic dust and lava. If a given portion of the earth, for example the Gulf of Mexico, remains undisturbed by upheavals for a long period of time the bottom of the area would come to have very great thickness. Layers or *strata* have been thus formed with a thickness of over ten thousand feet.

We know the thickness of strata only when we see great rifts, like that of the Grand Canyon of the Colorado, cutting through one after another, or when the strata have been tilted slightly by an upheaval, and erosion has cut off and exposed a diagonal section through many strata. If all the strata that have been formed here and there in lake and sea since the beginning of this process were placed one above another the mass, it is estimated, would be from twenty to twenty-five miles thick. Although there are many regions where strata lie superimposed, it is very rare that more than one period of time can be studied at or near the surface in a limited area, except where there are outcroppings as in the deep valley or gulch of a river.

Although many disconnected areas may have been formed by deposits at the same time, or may have belonged to the same *era*, it would be difficult to prove it if it were not for the evidence to be obtained from fossils. So important is this evidence that it acts as a great flood of light illuminating the history of the world from its beginning. In the first place, the simplest forms of animal life, the invertebrates

FIG. 73. MODEL OF GRAND CANYON OF THE COLORADO RIVER.
(Courtesy of American Museum of Natural History.)

or animals without backbones, are found in strata that from their position underneath others must have been formed first. The higher forms are found only in the upper strata. The most highly developed animals, the mammals, are the last to appear, being found only in the uppermost strata.

Changes in the Land and its Inhabitants.——It is a well-known fact in zoölogy that a given species is developed only where there is definite continuity within its range of distribution. For example, the chipmunk is found in Northeastern United States, and nowhere else. If it were found separately in another part of the country, or in Europe, the fact would call for explanation. We have the English sparrow occurring in America, but we know that the species was imported to this country within the past century.

Now, the rocks and soil of great stretches of territory in the states of California, Oregon, Montana, Wyoming, Idaho, and Colorado once covered in part by fresh water lakes contain the fossilized bones of lions, tigers, elephants, rhinoceroses, camels, besides other animals still more familiar to us through daily contact. They lived in vast hordes probably all over America, but the conditions for the preservation of their bones was favorable chiefly in the region named. The nearest present day relatives of these prehistoric animals are to be found in the wild state nowhere but in Africa or India. Two very important conclusions can safely be drawn from the facts related; first, there must have been land connection between America and Europe, or between America and Asia, at the time these animals lived in America, and secondly, the climate must have been very much warmer then than it is to-day. There are many proofs that there actually were land connections of considerable width across the Atlantic Ocean in the region where Greenland now lies, and also across the Pacific Ocean at Bering Strait. In those far off times palms grew in Canada, for we find their trunks and leaves in the coal strata there. Strange as it must appear, the conditions were entirely favorable for the migration of animals from America to Europe and thence to Africa by way of former land connections by way of Greenland or across "Bering Land" (where the Sea now is). Animals could have migrated quite easily from those countries to America, and they undoubtedly did.

Changes in Conditions and in Species.——Lions, tigers, elephants, etc., are easily distinguishable from one another; and it would be almost as easy to distinguish the species of those eras from animals of the same type found to-day. The fact is that species have changed very greatly, giving way to others more or less closely related to the old. In not a few instances general kinds or types of animals have disappeared altogether. For example, we have no more of the gigantic lizards which stood on their hind legs, reaching a height of probably twenty-five feet and a length of over eighty feet. We have none of the old type of giant bird, and no reptile-like bird. In fact, vast numbers of species have gone out of existence, although certain species or their very near kindred still exist to-day. Some explanation of these facts is called for.

FIG. 74. HEAD OF SABER-TOOTH TIGER. (Courtesy of American Museum of Natural History.)

It is already clear that the climate of the planet has been quite different from what it is now. Although Canada had tropical conditions of climate, it was not only once but even many times covered with a vast sheet of ice. Once the field of ice extended as far south as a line running from Long Island, New York, through Pennsylvania, Ohio, Indiana, Illinois, Missouri, Kansas, Colorado, Wyoming, Idaho, and Oregon. We know this from the occurrence of boulders brought down from the North in the gigantic glacier, and from scratches in the surface stone, and from other facts.

Evidence also goes to show that desert conditions have followed eras of excessive moisture when great swamps covered the land. And again, the deserts gave way to moist conditions.

Land was formed out of the sea and from the beds of lakes. Mountains were lifted out of the land by disturbances from within, or from the shrinking of the earth's crust. Over a considerable area the climate was altered by the elevation of the land, or by its depression.

The changes that occurred from era to era must have affected all animals, and all plants as well, but not all to the same extent or in the same way. But the food of animals would be changed undoubtedly by very slight changes in moisture and temperature.

How the New Arise and the Old Disappear.——It is a well-known fact of life in general that organic forms are showing constant change or variation in their own structural or color features. These variations extend in many directions, and seem to be always fluctuating from generation to generation, never the same, but except rarely never very different. The rarer but more important variations are called *mutations*, a word which means changes, but in a technical sense it means considerable or marked changes.

In ancient as in modern times an animal that shows a mutation which tends to fit it more favorably for a given condition or activity will thereby become better fitted to succeed and to live to hand on down to its young the characteristic which aided the parent or parents to be successful. If the mutation is in a direction which is not favorable to success, or if the surroundings or environment change radically, and the animal does not change, or manifest some ability to adapt itself to changed conditions, the animal and its species will disappear.

The most recent of all types of animals to develop has been the class of mammals. Mammals are more perfectly organized than are the members of any other class; they have greater activity, they are more adaptable to varying conditions, they are more inventive, and perhaps most important of all, they show in greater measure than the other classes the ability which distinguishes man himself, the ability to think. It has been thought by scientific men that the primitive mammals of predaceous type may have destroyed the eggs or the unprotected young of the great lizards. Thus, it would incidentally be apparent that those creatures which have a more perfect way of protecting their young, as the mammals have, would hold an advantage over less efficient beings.

How Life is Classified in Time.——Here and there in this chapter the word "era" has been used. We may now bring the term into more definite relation, and explain its connection with strata and with the succession of animal life. A table is given below in which will appear some interesting facts. In the first column will appear the names of the Eras; in the second column will be the names of the *Periods* or subdivisions of the eras; in the third column will be given the name of the chief class or branch of animals characteristic of the time. Beginning at the bottom of the table and reading upward, the student may understand that the higher types of animals are not in existence until we approach a period in connection with which the species, or class, or branch is named.

THE ORIGIN OF ANIMALS IN TIME IN NORTH AMERICA

Era	*Period*	*Chief Kinds of Animals Living*
	Recent or Present	Man
	Pleistocene (Glacial)	Man, bison, horse, mastodon, imperial elephant, bears
Cenozoic (Era of Newer Animals)	Pliocene	Megatherium, Glyptodon
	Miocene	Seals, walruses, deer
The Age of Mammals	Oligocene	Camels, titanotheres, rabbits, squirrels, cat family (tigers, lions)
	Eocene	Whales, ancestor of horse, Uintatherium, tapirs, rhinoceroses, Phenacodus, dogs, bats
	Cretaceous	Opossums, Hesperornis, Ichthyornis, Mosasaurus, turtles, Pteranodon, Triceratops
Mesozoic (Era of Middle Animals)	Jurassic	Pterodactylus, Stegosaurus
The Age of Birds and Reptiles		Brontosaurus, Atlantosaurus, Plesiosaurus, butterflies
	Triassic	Ichthyosaurus, Mastodonsaurus, Dragon-flies, crabs
	Permian	Pariasaurus, Sphenodon, Branchiosaurus, May-flies
The Age of Amphibia	Carboniferous	Cochroaches, spiders, oysters
		Bony fishes, lung fishes, sharks, pill-bugs
Palaeozoic (Era of Old or Ancient Animals)	Devonian	
	Silurian	Armored fishes, scorpions
	Ordovician	Barnacles, brachiopods, Bryozoa, sea urchins, crinoids, Foramenifera
The Age of Invertebrates	Cambrian	Peripatus, Eurypterida, Trilobites, cephalopods, gastropods, starfishes
	Algonkian	Coral polyps, hydroids, annelids
	Archean	Sponges, Radiolaria

Several of the names in the table above are of course unfamiliar to the young student. In most cases they are the names of animals that are extinct. Some of these existed through an entire era; others lived through but a single period, which in itself might be as much as a million years. The study of the extinct species where their fossils are found in succeeding strata, shows a gradual separation from allied species, a slow development in some cases into a species of wide extent, great size of body, and hence of dominating importance in relation to other species. The climax is sometimes followed by a rapid decline and final elimination.

FIG. 75. TRILOBITE.
(Courtesy of American Museum ofNatural History.)

The trilobites lived from the Cambrian to the Devonian, and disappeared completely. But their fossils may be found all over the world. The author once collected a number on the upper slopes of Mount Stephen in the Rocky Mountains of Canada. The locality is about ten thousand feet above the level of the ancient sea, where the animals lived. The dinosaurs (meaning *terrible lizards*) are found from the Triassic to the Cretaceous, within which period reptiles possessed the earth in the sense of dominating its organic life. The Thunder Lizard itself (Brontosaurus) living in the Jurassic period of the Rocky Mountain region was not great enough or adaptable enough to stem the tide of unfavorable conditions, when at the close of the Cretaceous period some catastrophe seems to have overcome the race of reptiles, leaving crocodiles and alligators to maintain feebly the reptilian age of terror.

At some time in the Triassic period there began the class of mammalian animals. They were small and of a lowly type at first, but in the Cretaceous the number of species became greater, while the type resembled our opossum and the Australian kangaroo; they were marsupials. That is to say, they brought forth their young alive, but placed them in a pouch beneath the body to complete their formation and to be fed from milk glands of the mother. It is

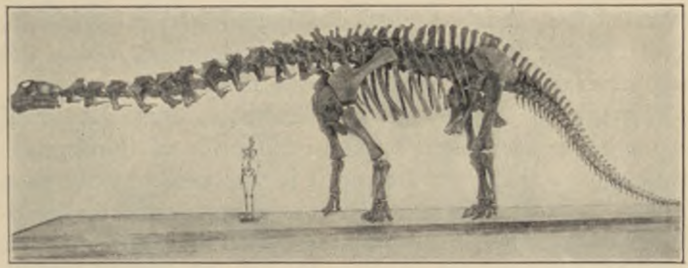


FIG. 76. BRONTOSAURUS.

(Courtesy of American Museum of Natural History.)

supposed that at this time Australia became separated from Asia, since the great island continent still has no native animals higher than the marsupials.

But in the Eocene period mammals developed wonderfully. Not only were there mammals of the perfect type of our most successful mammals of to-day, those that gave birth to perfectly formed young and nourished them and cared for them effectively, but there were also vast numbers of species of the type in existence in that day and age. However, it is well to remember that the climax of the age of mammals was not to come for a long time, and that the existence of man himself was a matter of some millions of years in the future. No animal like him then existed.

The horse began its long upward course of development in the Eocene. In that period Eohippus or the Dawn Horse made its appearance. This animal was between the height of a cat and a fox. Its head was shaped something like the head of a horse, except that the eyes lay about halfway between the nose and the ears. The neck was short, the back was highly arched, the legs were short, and there were four toes on the front feet and three on the hind feet. It is thought that a still more primitive horse must have lived in the Cretaceous, and that it probably had five toes on each foot. The record of the Eocene rocks shows that Eohippus migrated from Asia, on which continent it had its beginning, across Bering Land to western North America, where the long series of changes to the modern horse took place.

Through the long Eocene the diminutive horse developed into a larger and larger type, an outer toe of the forefeet gradually becoming smaller until it was present only as a "splint." In the Oligocene the race is represented by Mesohippus, a horse about two feet high, with three toes on each foot, the side toes still touching the ground and the middle toe bearing a small hoof or toe-nail distinctly larger than those on the side toes. Merychippus appeared in the Miocene, and was three feet high. It had three toes on each foot, but the side toes did not touch the ground. Moreover, long teeth especially characteristic of horses were present, and the eyes had shifted back toward the ears, thus making room in the upper jaws for the long teeth. Finally, in the Pliocene the one-toed horse appeared very much as we know it to-day.

In the Pleistocene period there were in North America as many as ten species of horses, some very small in size, and one larger than any horses now living. Some of these species became extinct; others migrated to every continent except Australia over the land bridges then existing. None was left in the Western Hemisphere. Our present day horse

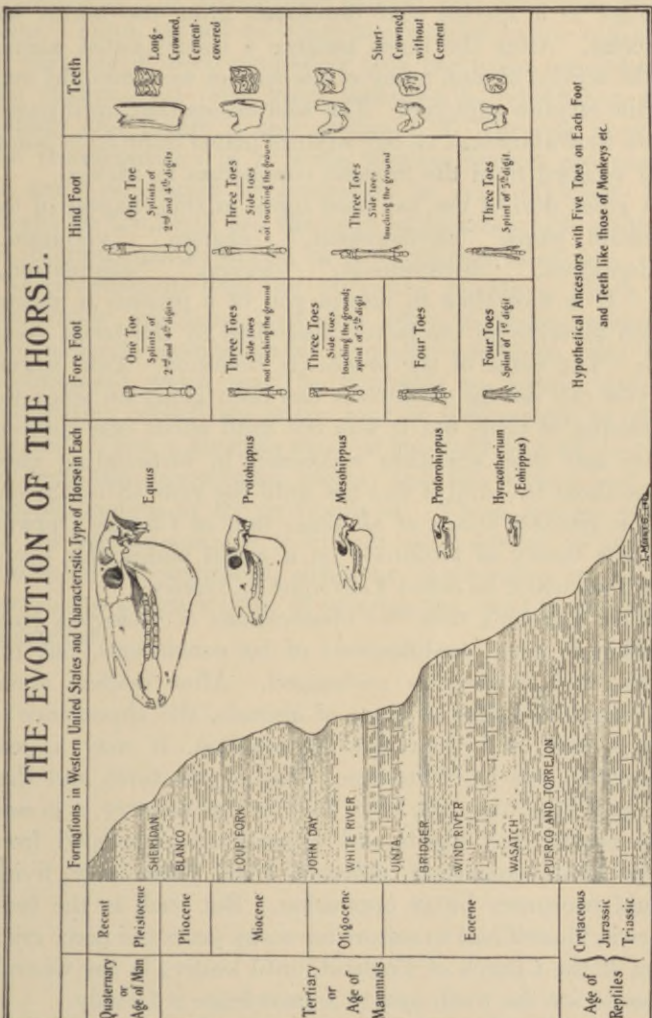


FIG. 77. EVOLUTION OF THE HORSE.

(Courtesy of American Museum of Natural History.)

belongs to a species that developed after the horses left America. After the horse became a domesticated animal in the service of man many of the species were brought over by the Spanish explorers. The wild horses that until recent years were abundant on our western plains came from bands that escaped from the Spanish conquerors in Mexico.

A great deal of use has been made in this chapter of the common words "development," "change," "variation," "adaptation," "environment," "decline," "elimination," etc. It is now time to inform you of a process in nature which involves all the factors described by the terms given here. The name of the process is *Evolution*. This process as you can see for yourselves has been going on since the beginning of time, but it was not until about one hundred years ago that scientists succeeded in formulating clear ideas about it. And it was not until the year 1859 that one of the greatest minds of all time, that of Charles Darwin, put the theory of Evolution on a sound philosophic basis, in a book which he called *The Origin of Species.*

Since Darwin's time the observations of biologists have resulted in some modifications of his conclusions, but the main principle remains unchanged. After reading about the rise and decline of races of animals, the appearance of new species and their final elimination, it may appear strange to you to be informed that at one time, and that not longer ago than the Civil War in this country, a person who taught that plants and animals are developed from other kinds somewhat different from those now living would encounter bitter opposition. But such is the fact. Darwin himself had to endure for many years the fierce criticism of the Church of England, until leaders in the Church came to see the truth and to acknowledge it frankly.

In brief, Evolution explains the origin of species of animals and plants by bringing into organized relation these facts: (1) Organisms vary in every generation. Sometimes the variations are of considerable extent; such are called mutations. Those mutations which are of value to the organism in adapting it more completely to a particular condition in the environment tend when inherited to establish a new variety and finally a new species. (2) Through heredity the characteristics of a newly forming species are passed on from generation to generation as an established line except for the small and the large variations which continue as internal manifestations of the germinal substance. (3) The environment does not cause the variations which are continually appearing, but does offer to these variations the chance to develop under favorable conditions. (4) The environment which may be favorable to certain species, manifesting certain variations may be unfavorable to other species. Thus, a struggle more or less indirect may develop between the unsuccessful species and the organic and inorganic factors in its environment. Those species which do not become adapted to fit into some relation to organic and inorganic conditions, either by degenerating or by advancing to a higher plane of organization, tend to disappear altogether.

CHAPTER XV

UP FROM SAVAGERY

Man's Origin in Time.——The apparently easy way in which the evolution of the horse has been worked out by students of paleontology [Gr. *palaeos*, ancient (life); *logos*, science] may lead us to think that the natural interest we have in our own race should have inspired paleontologists to busy themselves with the forebears of mankind. As a matter of fact, prodigious efforts have been put forth for many years in all parts of the habitable globe to discover traces of prehistoric man. It is true much has been ascertained, but there are still important connections in our line of progress upward from the lower animals which have not yet been proved. The future may hold in store for us much in this direction that will be interesting, but it is hardly likely that the main conclusions on the origin of man already reached by science will be altered greatly.

No one has ever discovered human bones showing that man existed in a period earlier than the Pleistocene, in which occurred the Great Ice Age or the Glacial Epoch. But crude man-made chips from flint rock have been discovered in the Pliocene of India. And there can be no doubt that man lived somewhere on the earth as early as the Miocene period, which would make the human race about one million years old. The evidence for this statement is somewhat complicated, but the main point of it is the fact that fossils of anthropoid apes, the nearest relatives of man, are found in the Miocene in central Europe. Since it is supposed from the evidence of bodily structure that the anthropoid apes and man came from a common ancestor, a creature that was more primitive than either, man must therefore have existed at as early a time as the apes that were developed from the same stock. In the Pliocene the apes were driven into Africa by the increasing cold of the ante-glacial period. We can only conjecture why no fossils of men of the Miocene period, or of the Pliocene period which followed immediately after, have ever been found. They may yet be found.

Man's Relatives.——Although there are very many similarities in bodily organization in the apes and man, there is a great difference in the size of the brain of the two races. Nevertheless, as was pointed out by Huxley, the first great scientist to study this matter carefully, there is a greater difference in this regard between the lowest of the man-like apes and the gorilla, the highest, than there is between the size of the brain of the gorilla and the brain of the most primitive men. This should be taken to mean that we are different from the gorilla more particularly in degree than in kind. It has been maintained by paleontologists that in all the great races of animals the mutations toward a larger brain have been of the first importance, since through the brain development there would arise the ability of the

FIG. 78. SKELETON OF GORILLA. (Courtesy of American Museum of Natural History.)

animal to adapt itself to new conditions. Thus brains have always been at a premium. It is believed that a considerable mutation in the direction of a larger brain must have been the chief step of our far-off ancestors away from the ancient stock.

His Birthplace and His Migrations.——The birthplace of man is still one of the unsettled points in his history. But the probability is that he began his existence as a distinct species in or near the country now called Tibet. From there he migrated to all parts of Asia, to Africa, to Europe, and to the Americas over the land bridge connecting Europe with Iceland, Greenland and Canada, or possibly from Asia when there was land connection to Northwest America.

Undoubtedly the migrations occupied long periods of time. But all we are certain of is that in the early part of the Pleistocene period, possibly 750,000 years after man's beginning, we find positive evidence of his presence in all the great continents. The material upon which our knowledge is based consists of a very few human skulls and other bones and of large quantities of stone implements. This material is found in the gravel of ancient river beds, under glacial drift of rock and gravel and sand, and in caves which served as the homes, the castles, and the stables of antiquity. From the stone implements we learn the occupations of our fellowmen of 100,000 to 200,000 years ago, and we learn the extent of their skill in making things. From the caves we learn their general habits of life, as well as their relations to the other animals of their time. From their bones we learn what manner of men, women and children they were in personal appearance, for the bones are not only the framework of the bodies of animals, but they even offer sufficient basis for reconstruction drawings that show what probably were the external characteristics of form.

The Old Stone Age.——The most primitive of the ages of civilization of man is known as the Paleolithic age (Gr. *palaeos*, ancient; *lithos*, stone), or the Old Stone Age. Sometimes it is spoken of as the Rough Stone Age. The age lasted from the beginning of the Pleistocene to something like 10,000 years ago in Europe. Many specimens of the crude, chipped, unpolished stone implements characteristic of the age have been found under the glacial drift in Minnesota, Ohio, Delaware, and New Jersey, as well as in the Pleistocene of South America, England, France, Germany, India, and Africa. These implements were arrow heads, spear heads, borers, and ax heads which probably

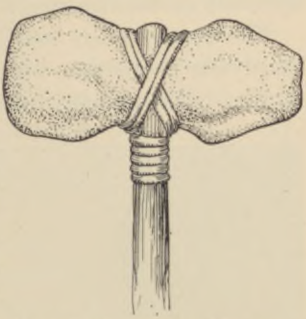


FIG. 79. OLD STONE HAMMER.
(From Evans: *Ancient Stone Implements*.)

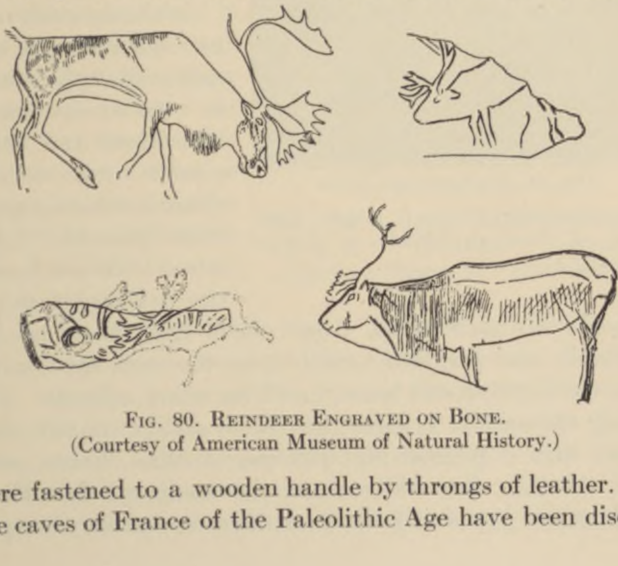


FIG. 80. REINDEER ENGRAVED ON BONE.
(Courtesy of American Museum of Natural History.)

were fastened to a wooden handle by throngs of leather. In the caves of France of the Paleolithic Age have been discovered also implements made of horn and bone, such as barbed spear heads, harpoon heads, and even a whistle made from the foot of the reindeer.

The caves which were numerous in Western Europe offered the protection which must have been welcome to a species still without effective means of defense against stronger animals. In these caves families were reared, domesticated animals were kept, preparations for the chase were made and the captures brought back to be devoured, whatever was not devoured on the spot where it was captured.

FIG. 81. NEANDERTHAL MAN.

(From Painting by Charles R. Knight. Courtesy of American Museum of Natural History.)

In the caves also the cave men left the evidence that they were as vain as savages of later date and other persons not usually classed as savages, for they painted themselves with red hematite. They wore ornaments of snail shells, ivory plates from the tusks of elephants, and perforated teeth from the wolf, the ox, the ibex, the reindeer, the horse, and from other animals. But among the ancient savages there were artists, too, for they traced with a pointed flint pictures of fishes, horses, reindeer, the ibex, the wild ox, and the mammoth or ancient elephant, on pieces of horn, bone, ivory and slate. Perhaps there is no evidence of the antiquity of man that we would be more ready to accept than this evidence that our ancestors possessed artistic feeling and the self-taught skill to portray the things they saw and knew.

The pictures and the bones of the animal neighbors of man serve to indicate that the climate of the ancient stone age in Europe was very cold,—much colder than it is to-day, as well as to fix more accurately the time of that ancient era.

Fig. 82. The Java Man.

(From Photograph of Model, prepared by Prof. J. H. McGregor. Courtesy of American Museum of Natural History.)

Within the last century some bones of Paleolithic man were discovered. Among the most interesting and instructive of these is the "Neanderthal Man" whose skull and leg and arm bones were found in 1856 in a cave in a small ravine near the River Rhine in Germany. At first it was thought that the bones were those of an ape, but later Huxley and other anthropologists (students of man) declared that they were the bones of Paleolithic man. In 1886 two skulls and other bones were found at Spy, near Namur, Belgium, lying near the bones of the wooley rhinoceros, the mammoth, the cave bear, the hyena, etc., five of the nine species being extinct. Other paleolithic remains have been found at Heidelberg, Germany, at La Chappelle and at Dordogne, France, on the Thames in England, and in the island of Java. The important features of these ancient men, as described by the late Professor R. Wiedersheim, of the University of Freiburg, Germany, "are a low retreating and contracting forehead and an inwardly shelving occiput (backhead) indicative of a primitive type of brain and of powerful neck muscles, a high temporal ridge and an expanded palate (indicative of powerful jaws and jaw muscles; and further, the presence of ape-like brow ridges appears also to have been a racial character." Some of the ancient men were tall, while some were short and not so powerful.

FIG. 83. CRO-MAGNON OR CAVE MAN.
(From Drawing by Charles R. Knight; Photograph. Courtesy of American Museum of Natural History.)

The New Stone Age.—Out of the Paleolithic Age slowly came the Neolithic or New Stone Age. Sometimes it is called the Polished Stone Age. In Europe the implements of the new stone age were probably made from 5,000 to 10,000 years ago, in America as recently as the discovery of the Continent. In that time man physically was the same as he is today. The climate also was the same, having long before become milder than the great cold of palaeolithic times. Without doubt the more favorable climate made it possible for men to develop industrially and artistically more rapidly than they had before.

Before the new stone age the mammoth, the rhinoceros, the Irish deer, the great bear, the lion, the musk ox, the reindeer, the chamois, and the hyena had disappeared, some exterminated, and others driven away by the changing climate. Newer forms came in and in some cases to be mentioned later were domesticated by man. There are evidences also that man ceased to be chiefly a savage hunter, and became a tiller of the soil and a consumer of the product thereof. Probably he cooked his food, for his paleolithic ancestors undoubtedly knew how to make fire.

The implements which by their appearance give the name

Fig. 84. Model of Lake Village.
(Courtesy of American Museum of Natural History.)

to the new stone age were ground to an edge and polished with great skill. There were arrow heads, knives, borers, scrapers, hammerstones, punches, pestles, and chisels. There is evidence that Neolithic men in some cases discovered implements left behind by their forefathers, and improved on them in accordance with the more modern methods of stonecraft. These implements are now often found at or near the surface of the soil, or in rubbish heaps where numbers of fishermen collected, or near ancient lake dwellings.

The lake dwellings or villages have been discovered in numerous sections of the shores of the lakes of Switzerland.

The existence of these villages dates from the Neolithic Age, and continued down to the days of Rome. Thus we have communities living through the new stone age and into the subsequent ages of bronze and iron. The lake dwellers were skillful workers in stone, horn, bone, and wood. The making of pottery was also general in the new stone age, but was unknown in the earlier age of man. By building their houses on piles the lake dwellers were able to avoid animal enemies and unfriendly beings of their own race, at the same time

FIG. 85. STONEHENGE.
Druid Monuments in England. (Courtesy of American Museum of Natural History.)

being near an inexhaustible food supply,—the fishes in the lakes.

Among the most interesting and enduring records of the existence of men of the Neolithic age in Europe are gigantic blocks of stone still standing, notably near Stonehenge, England, and at Carnac, in Western France. These stones in accordance with their number and grouping are called menhirs, dolmens, and cromlechs. The menhirs are single stones standing as a column; the dolmens consist in their simplest forms of three stones, two standing on end and one lying across like the top of a table; cromlechs are vast open-air temples marked off in rectangular form by enormous stones standing upright into aisles and spaces for great numbers of people. The cromlechs were probably primitive places of worship. The dolmens are supposed to have been places for the burial of the dead, and also shrines to be visited by those who might desire to pray to the spirits of the dead. The menhirs were probably set up as monuments.

An eminent ethnologist (student of the culture of the human race), Professor A. D. Haddon, of the University of Cambridge, England, gives it as his conviction that "the distribution of the racial elements in the population of Europe is very similar to that of late Neolithic times." Although the movements of peoples from one country to another have increased within historical periods, and especially since the means of communication have developed, the men of prehistoric times were themselves great travelers. This matter is of especial consequence when we come to consider the races of mankind and their origin.

The Four Races of Men.——As we know there are now four races of men, white, yellow, brown, and black, and many subdivisions of these. All of them belong to the same species, *Homo sapiens* (man wise). There is evidence to show that Paleolithic man and his ancestors were comprised of several species, but only one has come down to the present geologic era. How and when in the distant past the four present-day varieties of men branched off from a common stock of course we do not know. One thing we are certain of, however, is that the heat of the torrid zone had nothing to do with making men black, for many black men lived for long periods in South Africa in a climate quite as temperate as our own. Besides, there are other races living in the torrid zone that are not black. To be sure the facial and skin color differences between the races may seem considerable, but the technical methods of study of the anthropologists go deeper than these differences, and bring to light still other differences which in some measure overlap the differences we would notice, thus drawing the races into one great group. Some of these technical points we can appreciate easily. For example, we all know persons who have heads that appear much longer than they are wide; such are the long-headed types, called *dolichocephalic*. Others are more round-headed. The latter are called short-headed or *brachycephalic*. Long-headed types are found in the white race from the North of Europe (from which region most of us in America have come). They are also found as the regular form of head of the American Indian, the Negroes, the primitive Australian, and the Esquimaux. Short-headed types are general among the dark-featured people of the white race in France, Italy, Germany, Austria, Greece, Russia, and among the yellow race of China and Japan.

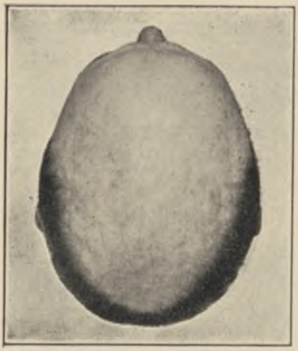


FIG. 86. DOLICHOCEPHALIC (LONG) HEAD.
(Courtesy of American Museum of Natural History.)

FIG. 87. BRACHYCEPHALIC (ROUND) HEAD.
(Courtesy of American Museum of Natural History.)

Other interesting details of value in measuring mankind for classification are the prominence of the cheek bones, the length of the lower jaw, the width and prominence of the nose, the slope of the forehead, and the height of the skull above the ears. It is interesting to note that all these characters are intimately associated with that part of the body in which is located the brain, that splendid organ which sets us off as superior to all other species.

The Continuance of Mutations.——You have already learned that man as a species first must have made his appearance through the same tendency to vary that characterizes other species of animals, and that the particular variation or mutation which gave man his start was the sudden appearance of a larger brain than his ancestors had. Associated with the developing brain must have been the gradual assumption of the erect posture. In the long ages that followed man's first appearance, and his migrations here and there, other mutations as they appeared would meet varying degrees of encouragement or discouragement in the environment. Considerable differences gradually developed and became permanent, and different species were established. The Neanderthal man was one of these. But his species as well as others related to him were finally exterminated for reasons which we cannot guess (possibly our own species had something to do with it), and the one species to which we belong became the sole human species. It is certain that the differences between races of mankind to-day which seem considerable to us are slight indeed in comparison with the many differences between any of us and the Neanderthal man.

Prince Kropotkin, a Russian scientist and publicist, has called attention to a factor in evolution which he claims is of vast help to every species which lives in groups. For example, a herd of deer, a drove of wild horses, a band of wolves, aid one another by being together. Likewise, man must have found the companionship of his fellowmen not only agreeable as he does to-day, but he must also have found it advantageous both for purposes of offense and defense. In this way we can see how tribes would be formed, why caves would be used, why crude encampments should be made, why villages should be established, why these should be provided with means of defense, and finally why nations of people should develop.

The Relation of Progress to Food Supply.——Professor Haddon has called attention to the fact that when a nation

FIG. 88. IMMIGRANTS ENTERING AMERICA.

(© Keystone View Co., Inc., New York.)

becomes numerous its food supply tends to run short. This must have happened very often with prehistoric peoples, because they had no commerce by means of which they might have exchanged things they had in abundance for the things they needed more. You may recall that in the chapter on the grasshopper it was stated that the fields of Kansas and other western states were overrun by these insects because there were too many grasshoppers at home for the food in existence there. Numerous interesting parallels are to be found in the history of man himself, not only in the migrations of men in prehistoric times, but even to recent times when the impoverished immigrants from Europe and Asia flocked to America in millions every decade.

The Up and Down Phases in Civilization.——One important difference to be noted in the comparison of insects and man in their relation to the rest of the world is that when man pours into an alien land he may temporarily destroy the evidences of civilization; but if he remains he appears not only to revive the stock of a declining race, but he even civilizes himself, no matter whether his motive in coming was to obtain food or merely to rob. To be sure, the nation may fall ultimately, as was the fate of Greece and Rome. But such catastrophes are merely the outcome of experiments in race development which did not succeed; they do not affect the physical character of the people. The brain which made man different from other animals makes it possible for him to experiment, and through experimenting to learn. Bees have a more exact industrial system and form of government than we do, but they do not experiment, and hence do not learn.

As thinking animals, constantly trying new things and remembering what succeeds and what does not, our race has learned much and has built up a marvelously complex civilization, part of which occasionally we have to tear down and rebuild because of new things we have learned. If sometimes men fear to tear down for lack of knowing what to build instead, it may indicate that the race needs a more far-seeing brain.

From the years 1914 to 1918 the world passed through the fearful experience of a universal war. War, indeed, is so common in animal life that heretofore it has appeared to man to be a necessity in his own affairs. Nations have been built because of war; they have also fallen because of it. But the strong have given the needed new life. Strong men have risen to control their fellows, and to organize the general energy of nations and to make them productive in every line of human activity. Some of the strong men have become the kings of governments; others have become kings of industry, or kings of wealth. The world is organized and is producing as never before. The World War was a well-nigh irresistible effort to still further organize and control the energies of men.

But while the great experiment in energy-control of the race has been going on, new ideas have been growing and making ready to burst forth from the pulsing brain of man. The essence of one of the most important of these ideas is that Mankind must be freed from the domination of the strong, for nothing is clearer than that the strong are leading on to destruction, probaby to self-destruction. Gradually we are coming to see that the factor of mutual aid which was pointed out by Prince Kropotkin has not been allowed to act for the human race as a whole, but only for a limited portion of it.

If, as one of the results of the World War the kings of the earth are compelled to release their hold on the rest of mankind, we may look forward to the era when not only the physical energies of man shall be free, but their minds as well shall be free.

The Human Brain, the Leader and the Hinderer.—— Scientific students of human culture (ethnology) generally agree that the human brain considered simply as an effective organ has not improved within historic times, probably not since Neolithic times. This statement at first may seem unbelievable, for is not our entire social system, especially that part of it connected with education, based on the understanding that the brain is improved by studying and by knowing? "Surely," we say, "'history is the record of the increasing power of the mind of man.'" It is true that man has made marvelous strides. He has gone into the unexplored parts of the world, conquered the savage peoples, and made the new countries yield their resources to the betterment of the more powerful people, though in doing so he has destroyed the former possessors and lost many of the best men of the superior race. Man has met the needs of commercial expansion by inventing efficient means of transportation and communication, ships, engines, railroads, automobiles, airplanes, the telegraph, the telephone; but he has also invented implements of warfare and death-dealing munitions, partly to defend the wealth he has already amassed through commerce and industry, and it is to be feared sometimes to extend the range of his commercial and industrial supremacy to lands controlled by other peoples, strangely considered his enemies.

Man has applied the scientific discoveries of his own mind until he seems only at the beginning of what he may do in commanding the resources of nature. The mountains and the streams have been made to give up their wealth of metal and precious stones with ease and profit. Knowledge of the chemistry of the soil has made it possible to obtain greater and greater yields of plant products, and the food of the world has grown in quantity and has improved in quality. The desert itself has been watered and made to produce through engineering feats in irrigation. The animal life of the world has been levied upon to yield food, clothing, and the luxuries of ornamentation. Inventions in industry have lead to the construction of millions of factories, the like of which did not exist even a century ago. In some of these factories the crude materials of food are prepared for the markets of the world. In others the materials for clothing are manufactured. In still others, the machinery is produced to be used to produce more mineral wealth, more plants from the soil, more food from plant and animal products, besides all the machinery needed to transport and to dispose of the countless products of man's industry. Yet with all our industry, many of those who help to carry it on have little enough to eat and to wear, and young children are compelled to labor in the factories and in the mines.

"But certainly," we might say," "the artistic, literary, and the scientific products of the mind of man should be abundant proof that his brain has improved." Although our paleolithic forefathers left the evidence that some of them knew how to draw and to paint, it is true they do not seem to have left a literature, or many traces of having made scientific discoveries. But perhaps we have already done the best we could with the brains we have in painting, sculpture, poetry, and story. There are many wise persons in the world to-day who think so. On the other hand, we seem still to be going ahead in scientific discovery. But whether we have a growing mind for continuing to do it is another question.

How the World Grows Better.——Ethnologists have a way of explaining the situation created by the growth of human achievements by human beings who themselves show few signs of improvement. Whatever one generation accomplishes is passed down to the next, not through the physical inheritance of persons, but by word of mouth, by written or printed records, by pictures, by statuary, by buildings, by machinery, by countless inventions and contrivances for doing things. In the course of centuries the things our race has learned how to do and to pass on, the ideas our experience has developed, the ideals toward which we may be striving, all form portions of a very complex civilization. The next generation of Americans, as well as the next generation of all other nationalities, may learn what has been done by the usual method,—communication.

There is no evidence of a scientific nature showing that because our ancestors for a great many generations have known how to walk that we learn to walk any earlier or any more easily. Neither does talking come any easier by reason of the experience of those who have done it before us.

Another way of considering civilization in relation to the matter of inheritance is to regard it as part of our environment,—that portion which has been created by human effort and set about us just as definitely as we surround ourselves with plants and animals, food, clothing, and other factors which affect us materially. The human being of a new generation simply finds himself in the midst of all these things. In some measure he may learn how to relate himself to many of them a little more satisfactorily than did his ancestors; if so, then we can say that our methods of teaching the young have improved. Let us hope they have.

Civilization and Education.——It is through education, by the way, that either in school or out of it in the school of life, we bring the accomplishments of civilization to the minds of the young. Practically the race derives a great deal of benefit from the academic and apprentice education of the young, first because the continuous growth of civilization is thus insured, and second, because the individual development of the learner to the full extent of his inherited qualities is provided for. In these two directions we have abundant reason for education, and also for improving education. But we cannot make better brains by that method.

Better Brains Our Great Need.——Perhaps it did not occur to our ancestors that the human race is in need of more perfect brains, as it occurs to us to-day. The reasons for our greater interest in the matter may be explained by our coming to realize that man has built up a civilization that is almost too complex for him to comprehend, a civilization involving incidentally some elements of injustice and self-destruction, and almost too big and overwhelming for him to direct into lines of profitable development. When our leading thinkers came to realize this, they began to analyze the factors in our civilization to see where we stand. It will be worth our while to go over the points briefly here.

(1) As soon as civilization began, we started to put a check on the operation of natural selection which in a state of nature allows the weakest to be destroyed. This check was necessary in a measure, for it was a part of our developing moral sense. The race did not know how to avoid lowering its quality, if indeed, it knew anything about quality at that time. It was interested in making war and in overcoming other groups of the species.

(2) No species has ever shown the ferocity in making war upon itself that ours has shown. Long and frequent wars take heavy toll from the best manhood of the nations, and tend to destroy the stock from which the best manhood comes. The weak are never destroyed by war, for they are not picked to fight.

(3) The strong members of our species have long taken advantage of their opportunities to control the energies of their fellowmen, and to gain enormous fortunes by virtue of that control. An important result has been that many millions of persons have had too little to eat, and too few of the conditions of environment that would have developed their minds and their bodies to their full capacities.

(4) Conditions of luxury as well as conditions of poverty, both the results of our present day civilization, have weakened the natural bodily resistance of man, and offered lurking places to disease and death.

(5) There are fewer and fewer children born into families where the parents are intelligent and physically strong, partly because of the increasing cost of living, and partly because of numerous social exactions.

(6) Because of ignorance, or because of indifference to the economic responsibility involved, there is constantly a large number of children born into families where the parents are poverty-stricken, or mentally enfeebled. The result is an increasing preponderance of persons living in bad conditions, as well as of persons mentally unfit.

(7) A great number of mentally well-endowed persons in the professions do not marry and become parents because of officially-imposed, or of self-imposed, restrictions upon marriage.

FIG. 89. A FEEBLE-MINDED MAN.
Type of feeble-minded person called a "cretin." Age, 31; height 4′ 4″; weight 139 pounds; mental age 7 years; able to read and write a little. Inmate of Rome State School (N. Y.). (Courtesy of Dr. Charles Bernstein, Superintendent, Rome State School.)

Our Crude Beginnings in Mending the Race.—Long before the factors here indicated had been considered by anyone, society was attempting by one means or another to correct the ills it knew to be in existence. We have had charity always, and within the present generation many organizations that have given out food, clothing, and money in a systematic fashion. But many of those benefited belong to the mentally defective class, and would never learn to be self-dependent.

For a still longer time than we have had charity organizations we have had insane asylums. In these institutions hundreds of unfortunates are confined temporarily or permanently in every state in the Union. In some of the states there are special asylums for the feeble-minded, where the attempt is made to have the inmates do simple work, permanently separated from society. But there are thousands of feeble-minded persons going about freely, never being put under control until they commit a crime. If the crime is serious, they are sent to the penitentiary for a term, and at the end of it turned loose to commit other crimes, later returning to prison again.

A very large percentage of the inmates of states' prisons are really feeble-minded. Hence these unfortunates are not responsible for their acts. In our crude methods of administering justice we take revenge on these irresponsible criminals, and after the punishment turn them loose possibly to become the parents of still other irresponsible beings.

Through education society has been trying to meet and solve the problems connected with the preparation of the young for life. Possibly in some respects we may have expected more from education than it could accomplish. We have expected it to improve the stock of the race, when that is not possible. We have tried to give everyone the same preparation for life by having them study the same things, but we have found that method to be limited in its usefulness.

A New Ideal for the Future.——One of the most important ideals now in the minds of the leading scientists, philosophers and statesmen of the enlightened countries of the world is the ideal of Social Control. The conviction is spreading that we have allowed our social matters to "go at loose ends" long enough, and now we should take hold and manage them and turn them in the proper direction. In 1875 Sir Francis Galton proposed the name of a new science called *Eugenics* which means "relating to being well-born." As the direct result of the studies Galton made and published the new science attracted many students. So important did the subject-matter of Eugenics appear to the leading men of England that organizations were formed to promote further study and observation, and later to make the facts known generally throughout the United Kingdom. Statesmen knew that the quality of the English people was in danger of deteriorating, because of the rapid increase of the mentally unfit — a very serious matter to a nation threatened continually with international trouble. When the final accounting was made of the losses of the World War, England and all other nations involved in the struggle realized that serious inroads had been made upon the most valuable resource they possess — their young manhood. But their mentally unfit are still with them. The revitalizing of the people of the warring nations is a far more serious problem than is the recovery from financial losses. A young man dead is gone forever, and with him the possibility of future men and women as descendants. But ten thousand dollars, which has been estimated to be the liberal money equivalent of a human life, may be earned back with comparative ease millions of times over by a working nation.

FIG. 90. A YOUNG SOLDIER.
(Courtesy of Wide World Photos.)

With us in America the problem of guarding and improv-

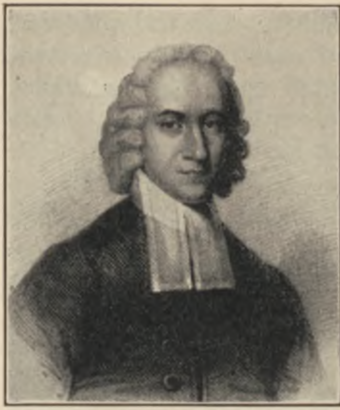


Fig. 91. Jonathan Edwards.
(From a Print.)

ing the quality of our racial inheritance is not yet recognized generally by our citizens as being serious. At the same time we have organizations of scientists that are engaged in the collection of data and the dissemination of information through publications of various kinds. If you watch the magazines and in the magazine sections of great newspapers you will see that the intelligent portion of our country's citizens are being supplied with the facts concerning heredity and with suggestions for future application to situations that exist everywhere in our land.

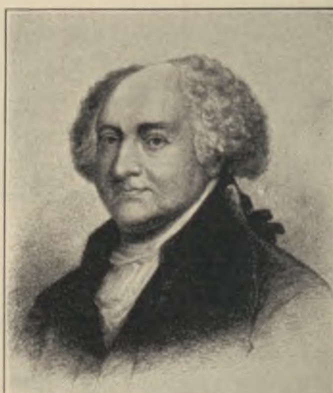


Fig. 92. John Adams.
(From a Print.)

At Cold Spring Harbor, Long Island, New York, there is a laboratory for the exclusive study of Eugenics. Investigators are sent out to study the history of families in which defective traits, as well as those of excellent quality, are made available for examination. Some of these families possessing defective traits have been found to have numerous members in public institutions, such as asylums, poor houses, and prisons. Other families possessing excellent traits have had representatives occupying many positions of honor and trust. We have many families in America who claim that their ancestors "came over in the Mayflower" just as in England large numbers "came over with William, the Conqueror." Perhaps it would be of more consequence if they could boast that "our family came over with physically strong and morally clean bodies, and with a superior quality of brains in our heads."

Two valuable and well-known families in America are those of the great preacher, Jonathan Edwards, and of the second President of the country, John Adams. On the other hand, we have the unfortunate "Jukes" family, that in several generations has supplied the penal institutions of the State of New York with many of their inmates, and the "Kallikak" family, the history of which has been studied scientifically at the institution for the feeble-minded at Vineland, New Jersey. In the Catskill Mountains where this chapter is being written, the author knows of several "native" families whose members are known as being "a little off in the head." Some have been away in prison for stealing; a considerable number have been taken to the asylum; many are shiftless and irresponsible. But most of them have children who in accordance with findings based on similar cases studied at the Eugenics Laboratory at Cold Spring Harbor are absolutely certain either to show the defective characters themselves, or to carry them on to their descendants, or to show defective characters as well as to transmit them.

The laws of inheritance have been quite elaborately worked out. The observations upon which they are based were made upon plants and upon several species of animals, among them insects, birds, and mammals. The most important of these laws is called Mendel's Law, which was discovered by an Austrian Monk, Gregor Mendel, about 1865. The observations referred to very briefly here will be explained in the next chapter, in connection with the account of domesticated animals. Reference will then be made to the light Mendel's Law throws on inheritance in man.

Social Control of Inheritance.——Enough is clear now, however, to show why our interest in inheritance should carry us to the point of deciding on some protective measures. In other words, society must soon begin to exercise some form of Social Control over inheritance.

We have long had laws forbidding the marriage of imbecile-minded persons, but imbeciles have no regard for law, and often become the parents of children out of wedlock. The only effective measure which is also humane is to limit the freedom of persons in whose blood there is proven to be the strain of inherited insanity or feeble-mindedness, and to permit them to work in small, controlled communities where they may be as happy and as useful as possible, but to prevent them absolutely from having offspring. We now have many laws designed to carry out this purpose, but they are not yet working effectively; and until they do work on a large scale they and our immigration laws, which touch the same problem, will not bring about the end desired.

When we get rid of our injurious strains of humanity, they will no longer dominate the healthy strains as they do invariably when feeble-minded persons marry into normal families. And the normal persons and the possessors of unusual traits will be free to show whatever favorable mutations appear in them.

Social Control Over Conditions.——Just as we learned in considering the outcome of mutations among the lower animals, so in man there must be an environment favorable to a mutation. Otherwise discouragement and final elimination are liable to result. For that reason it becomes a matter of much practical importance to see to it that our own species exercises the necessary social control to create the favoring environment. When we come to think of it, we are more fortunately situated in this regard than is any other species, for we have the intelligence and the power to really make our surroundings what we want them to be, not each person for himself, of course, but the race of civilized mankind for every individual member of the race. We can do it if we will. The leaders who have been working along the line of eugenics have kept this point in mind, and in sympathy with others vitally interested in the welfare of man have developed a sister science called *Euthenics*. This is the science of "being well-cared for."

When we get well under way in acting in accordance with the principles of Euthenics, our customs of dealing with ourselves and with other persons will show extensive modifications. We shall no longer slay one another in battle. We shall no longer grab the lion's share of every commercial or industrial opportunity, or if we do, there will be enough others who care for the rights of all to make us drop it. We shall no longer deprive those who work of their share of the results of their own efforts, and we shall make it a crime to force or to permit the children to work to make up for what their parents do not get.

We shall know the causes of disease and other factors that operate to weaken and destroy the bodies of our people, and then we shall eliminate the causes, and give the opportunity to bodies and minds to produce their best. We shall know the normal processes by which the organs of the human body do their work, and the food and other conditions that keep them in health and effectiveness.

We shall learn to care for the children from birth, for in them is the great hope of the future. We shall learn to save their lives, knowing that we have permitted only the best to come into existence at all.

Finally, we shall gradually revise our system of education, and with intelligence really prepare the young for happy and efficient living by finding out what manner of mind nature has given each, and training them accordingly. We shall not try to make them equal by presenting to their minds the same ideas and the same experience, for the children themselves are not equal. But we shall adapt our presentation of experiences and ideas to their capacities to understand and to enjoy, for there shall be equal opportunity, not equal power, for all to understand and to enjoy the heritage of the race.

CHAPTER XVI

DOMESTICATED ANIMALS; AND MENDEL'S LAW OF HEREDITY

Introduction.——Certainly since the early Neolithic Age, and possibly since the late Paleolithic Age, man has associated with himself various species of animals. Probably the dog was the first of these. But it was not as companion, but rather as reserve food supply, that the dog and other species were held by their master, man. The cave men would have the greater facilities for holding their captive animals than would those who lived in primitive shelters in the open. We can easily picture to ourselves those early experiments in capturing and holding for use the members of the species that were small enough to be captured by the means then available, and tractable enough to be kept and made to obey the will of man.

Whatever species man may have tried to dominate, it is interesting to note that the species that have yielded domesticated animals permanently are limited practically to two zoölogical classes, the mammals and the birds. On the score of intelligence and adaptability to altered circumstances the mammals are, of course, superior to any other class. But it does not follow that the most intelligent of the mammals would prove to be the best domesticated animals. In fact, horses, cattle and pigs are not noted for their intelligence, though they are among the most valuable of our domesticated species. And the wolves, remarkable for their intelligence, cannot be domesticated at all. The birds would not be considered intelligent as a class, or by single species; but they are more intelligent than the next class below, the reptiles.

Darwin called attention to the great differences between the various kinds of pigeons, and said that if pigeons were found living in a state of nature, they would most certainly be thought to belong to different species. As a matter of fact, all pigeons belong to one species, and are technically called varieties of the common rock dove, a European species. The same explanation applies to all our domesticated animals, with the possible exception of the dog. The ancestry of the dog is still an unsolved problem.

The Horse.——At the close of the detailed history of the evolution of the horse given in Chapter XIV it was stated that our present-day domesticated horses belong to one species. However, there appears to be at least one other species of horse living wild to-day whose line of traceable ancestry runs back practically unbroken into the Paleolithic Age; for, sketches in the caves have been found showing a horse closely allied to the wild tarpan which now lives in Western Mongolia. The tarpan is a small horse, practically a pony, with a big head and relatively slender legs. It is four feet (twelve hands) high, with a short erect mane, is dun in color, with a narrow stripe down the spine, a vertical stripe running down each shoulder and faint bars across the upper part of each leg. The colts can be captured and tamed, but the adults are untamable.

The several varities or breeds of our domestic horse seem more closely allied to a certain wild horse ranging the forests of Russia, Poland, Germany, and France until quite late in the Christian Era. These wild horses were mouse-colored, with a dark streak along the spine, and with dark mane and tail. The description exactly coincides with the so-called mustang of Texas, an American wild horse. The European wild horse was untamable, except as a colt. This horse was hunted for its flesh and for the skins.

The picture of the skeleton of the horse given in Figure 93 is meant to serve the double purpose of showing the framework of the present day horse and of offering the oppor-

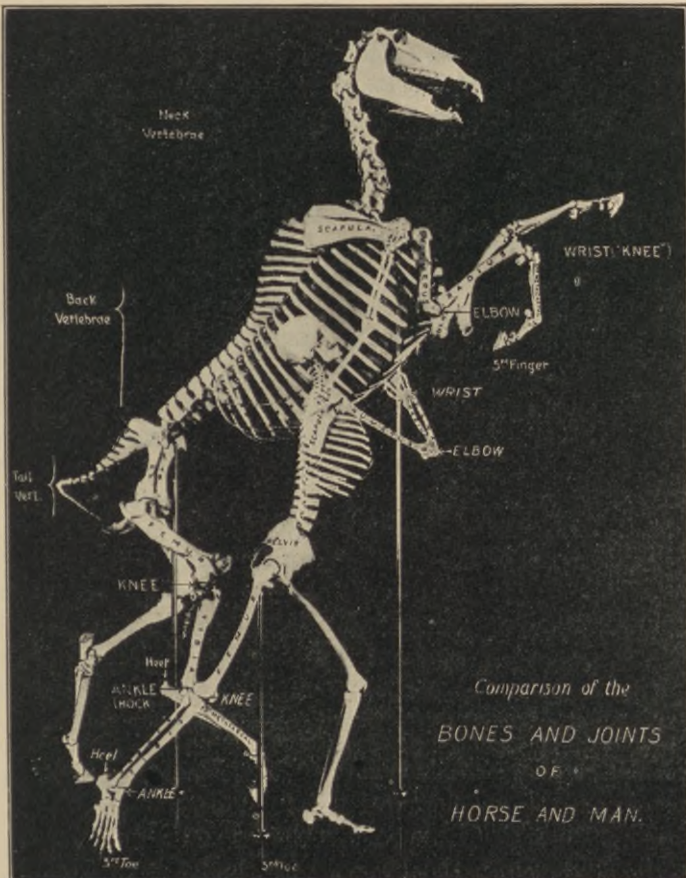


Fig. 93. Skeletons of Horse and Man.
(Courtesy of American Museum of Natural History.)

tunity for a comparison with the skeleton of man. The fore-legs of the horse correspond to the arms of man. The upper arm bone in the horse is short, and lies close against the body; the elbow lies about even with the under surface of its body. The two fore-arm bones are differently formed from the same bones in man, but their relative position is the same. The most striking difference is in the region corresponding to our wrist. In the horse the wrist begins at the so-called "knee" and extends to the fetlock. The main bone there is the heavy "cannon-bone"; it is borne company by the two "splint" bones, which are the relics of the bones that were connected with the ancestral toes. The remainder of the fore-legs are the single series of toe bones and the toe-nail or the hoof.

The modification of structure that occurred in the wrist of the fore-leg takes place in the ankle of the hind legs; but the high-standing "hock" (the heel) is more conspicuous than the corresponding point in the fore-legs. The real knee of the horse is much higher relatively than in man; it occurs in the flank of the horse. The comparison of the other bones of the horse and of man may be made easily, region by region.

Horses like persons, and most other mammals as well, have two sets of teeth, a baby or milk set and a permanent set. By the time the young horse is three years old its baby teeth begin to be replaced with permanent teeth which are larger. The substitution begins with the front teeth, called first incisors, and proceeds backward. At three and one-half years to four years the second pair of incisors in upper and lower jaws have pushed out their milk teeth, and at five years the third and last pair of incisors come in. At about the age of four or four and one-half in the stallion or male four tusks or canine teeth appear above and below in the long space between the incisors and the cheek teeth.

The incisors have curious pits or "marks" three-quarters of an inch deep from the top of the crown when these teeth are first protruded. As the teeth wear down, the pits disappear and incidentally aid in giving indication of the age of the horse. The pit disappears in the first or front pair of lower incisors when the horse is six years old; at seven the pit in the second pair of lower incisors disappears; at eight, in the third pair of lower incisors. In the corresponding upper teeth the pits remain about two years longer in each case. Thus, a horse that has no hollow depressions at all in the crowns of its incisors, either above or below, is very probably over ten years old. How much older it may be can only be guessed, unless the teeth are worn down nearly to the gums, in which case the animal would be from twenty to forty years of age. Forty years is an extreme age for horses.

The cheek teeth are six in number on each side in each jaw. The first three on each side in each jaw, called premolars, have milk predecessors, but the molar teeth have not. This is exactly the history of our own teeth, except that we have but two premolars for the three in the horse. The enamel in the teeth of horses runs in convolutions through the softer dentine, instead of lying outside as with our teeth.

The exterior of the horse's body is quite well known to everyone, except possibly the significance of the "chestnuts" or hard wart-like growths on the fore-legs and the hind legs. These are supposed to be degenerate scent glands, the like of which are found in many other gregarious mammals, as for example in the deer family. These scent glands in nature yield a secretion which has a strong odor that is carried a long distance on the wind, serving the species by enabling individuals to find one another. The fetlocks of a horse, the thick tufts of hair near the hoof, surround a reminder of the evolution of the race. This is the "ergot", a small hairless pad which is the ancestral sole of the foot.

We have in America several breeds or varieties of horses. All of them were developed in Europe, or in Asia, except the American wild horse. And that is the descendant of

European horses brought over by the Spanish conquerors, from whom its ancestors escaped nearly four hundred years ago. One type of our wild horse is the mustang, mentioned in a previous paragraph; the other is a larger and more tractable type generally of bay color that until about the year 1880 roamed our Western Plains in large numbers. The breed has been nearly exterminated by capture. The adults were captured in bands by a small group of men driving domesticated horses hitched to "buckboards" or other light and strong vehicles. When a band was first discovered, it made off at great speed, under the leadership of the master of the band, a stallion that had won his place as master by conquest over other stallions. After reaching a distant eminence the band would turn and watch its pursuers with curiosity. The hunters would follow leisurely but persistently for a week, if necessary, camping whenever they themselves desired, but gradually wearing down the resistance and taming the wild nature of the band by being continually near them. At length the captives could be driven in the direction of a distant corral, where skillful cowboys, armed with lassoes completed the capture. The "breaking" of a wild horse to the saddle is an event that tries the nerves and the skill of the bravest. But when conquered by one ride administered by an artist in the profession of Western horsemanship, the wild horse looks and acts like any other, unless it belongs to the tricky breed of mustang. The author in his boyhood in Western Kansas was the happy possessor of a wild stallion that had received his baptism of man-power from some one else. For several years this splendid creature gave daily proof by enduring long rides over the plains that he had won his right in nature to the leadership among his fellows,—a leadership from which only man had the intelligence and the skill to displace him.

For some years it has seemed to be only a question of time when the automobile would eliminate the occupation of raising horses. No doubt the increase in the number of motor trucks decreases the number of Percheron or Norman horses that will be demanded as draft horses. Limousines displace the handsome carriage horses of the city streets and the country estates; and the farmer's steam-plows and steam threshers may mean smaller stable room for the horses he has left. But the uses for horses are still numerous, and the prices of horses are still high, which is a good commercial indication of their continued usefulness. The police department of New York City cannot obtain a horse suited to the needs of mounted patrol service for less than $375.00. Farm horses also are very expensive. There is every prospect that our horses will be needed for a long time to come, and that the breeds will be still further improved, even for racing, in spite of the fact that the prospective elimination of betting in horse-racing may seem to some persons to carry with it a decrease in interest in that branch of horse raising.

The Mule.——Mules are the progeny of a sire or father that is a domesticated African ass and a dam or mother that is a horse. The two parent animals belong to different species, and their progeny are called "hybrids," the technical term given to animals or plants that result from the crossing of members of different species. Sometimes hybrids give rise to a line of generations like themselves, but a few, like the mule, do not bear young.

Mules make extremely valuable draft animals where heavy loads have to be taken over slippery hills or up rough mountain sides. They are very "sure-footed." They appear to stand the rough treatment incident to work in the mountains much better than do more highly bred horses. Mules are not so liable to become ill from indifferent feeding, or to mind going long without food or water, while horses must be fed at least three times a day, and do better with four or five feedings.

Mules are supposed to be very quick-witted and tricky, besides being able and even anxious to use their heels to play against the bodies of their enemies, who may be any other creatures near at hand. There is very little doubt that mules live up to their reputation. For that reason they are less available for general use than horses are. But the men who manage mules are willing to match their wits against them, and are not averse to emphasizing their superiority with not a little mistreatment.

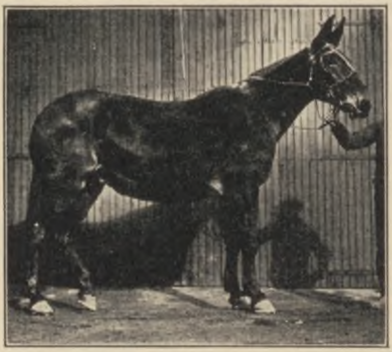


FIG. 94. MULE.
(Courtesy of American Museum of Natural History.)

The Ox.——The technical common name for cattle is oxen. The two names will be used here interchangeably.

There are no fossils of the direct ancestors of the ox in America, but fossil bones of the race are found in the Pliocene of Asia and in the Pleistocene of Europe. According to the authorities on the development of the ox, the long-horned ox, *Bos longifrons*, migrated westward in Europe in the domesticated state with Neolithic man. The bones of this species are found from the polished or new stone age down to historic times in such places as to lead to the conviction that this species is the origin of our domesticated type. But when descendants of the species first came to America they were divided into the many varieties that had developed under the control of the breeders.

As the direct result of accepting and isolating the mutations that appeared in herds of cattle, breeders in Europe have obtained such distinct varieties as those represented by the red, short-horned Durham, the red and white Hereford, both famous as beef cattle, and the Alderney, and the Jersey, both remarkable for their milk- and butter-producing qualities, and also the curious hornless, Polled Angus breed.

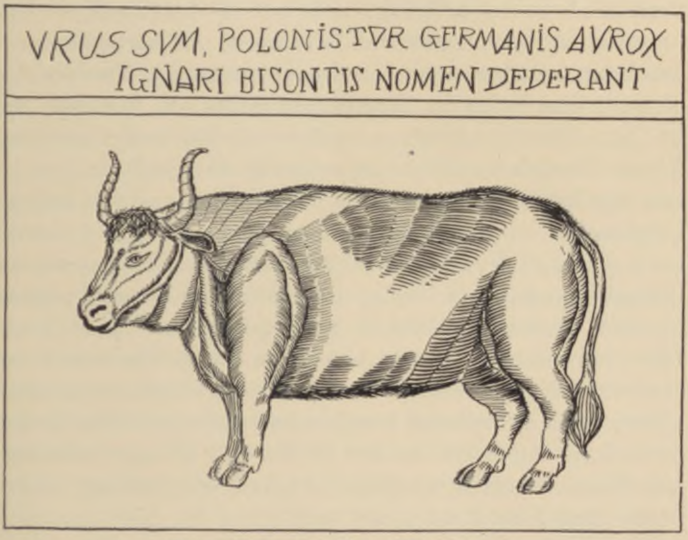


FIG. 95. ANCIENT LONG-HORNED OX.
(From Kobelt: *Die Verbreitung der Tierwelt.*)

The Polled Angus began its career as a striking mutation, an animal being born that did not later have horns. Experimental breeding showed that when either parent was hornless the offspring would also be hornless, no matter what might be the length of the horns of either parent. The characteristic of hornlessness is thus described as "dominant," and the horned condition as "recessive." For if the progeny of horned and hornless parents be bred together the average result of many experiments will be that one-fourth of the succeeding generation will have horns, showing that the character of having horns had not been eliminated but had merely receded into the background, so to speak; hence, the term recessive.

If the remaining three-fourths are bred for another generation experiments show that one-fourth on the average will produce hornless progeny, and so on continually. One fourth of each generation will have horns. If horned animals are bred together none but horned appear. Two-fourths of each generation in these experiments are hornless, but in them there is always a mixture of the two characters. These characters always separate in the next generation into one-fourth horned, one-fourth hornless, and two-fourths hornless but with mixed characters again. When a character is retained through an indefinite number of generations, the individuals possessing it are said to breed true in respect to that character; that is, to constitute a "pure line." Thus, horned cattle always constitute a pure line, but hornless cattle may be representatives of a pure line, or a mixture of two lines, a dominant hornless line and a recessive horned one. It is impossible to say in the case of any individual hornless ox whether it is pure or mixed, until an experiment in breeding from it is carried out.

This brief account of the way the character of hornlessness works out in the breeding of cattle is intended to introduce the student to an elementary understanding of the operation of Mendel's Law of Heredity. A more complete account will follow in a later section of this chapter, and also an explanation of the application of the law to inheritance in man. The fact that the Austrian monk, Gregor Mendel, first discovered the working of the law while carrying out experiments on the breeding of the common garden pea will give a suggestion of the wide range of life to which the law has been found to apply.

In concluding this section of the chapter the student perhaps does not need to be reminded of the vast economic importance of cattle to man. The beef and the leather of which enormous quantities are used make one of our greatest sources of wealth. Cattle are still raised on the plains of the great West, where in former times the unclaimed stretches of land formed the "range" over which cattle wandered and fed from "water hole to water hole," being "rounded up" every spring for the purpose of branding the calves. Branding the flank of a calf with a red-hot iron was the only satisfactory way of indicating the ownership of a "critter" (creature) after it reached the age of independence of its mother (at about one year or less). Every owner had his peculiar brand, consisting of a letter or a symbol formed out of iron and adjusted at the end of a rod of iron. For example, one mentioned in a fascinating story of the West written by Stewart Edward White was a capital "Y" lying on its side, thus, ≺. It was appropriately called the "Lazy Y" Brand, and so was everything connected with the ranch ownership of the great property of which the brand was the symbol.

In the fall the larger animals were rounded up and usually shipped to some of the middle western states to be fattened for the market. Nowadays the range-produced cattle are becoming fewer on account of the range land being taken up in numerous small tracts by home-builders. This fact makes the raising of cattle for the market a more expensive proceeding, and doubtless has much to do with the increase in the cost of meat.

Again, if you have ever watched a long milk train starting out late at night for a distant city, and have realized that many other similar trains are hurrying to cities all over the country, you can build up in the imagination the extent of the milk industry. The milk and the butter and the cheese are also sources of vast wealth, for the reason that they are among the most valuable sources of human energy when used as food.

The Sheep.——The sheep has no fossil remains in America, having made its way here only since the Pleistocene. Its ancestry dates back to the Miocene.

Sheep belong to the group of ruminants with the ox and the deer. They are given this name on account of the possession of four sections of the stomach, one of which is called the *rumen*. The process of chewing the food until it is partly ground up, swallowing it, and later "unswallowing" it as far as the mouth to be rechewed as the "cud" is characteristic of the sheep as it is of the ox. The number and arrangement of the teeth is exactly the same as it is in the ox, there being no upper incisors in either species. The skeleton is much the same in both.

FIG. 96. A VALUABLE WOOL PRODUCER.
(From Lydekker: *The Sheep and Its Cousins.*)

Sheep raising is one of the most productive industries we have in this country, and one in which a farmer or stock raiser may engage with a small capital. It should be added that it is also an industry in which the inexperienced may lose more quickly than in any other of the kind, for sheep are delicate animals, and also very stupid. They have little sense about running to shelter on the approach of a storm, and permit themselves to be driven away from safety and chilled to death in a cold rain that would not seriously affect cattle or horses. A sheep raiser to be successful must practically live with the animals, and must be ready on the earliest sign of a storm to go out and drive the herd to shelter.

The factors that make sheep raising profitable, supposing that losses from storms and from diseases have been kept down by extraordinary care, are the facts that each ewe or female on maturity will have usually two lambs, and that each sheep yields a valuable fleece each year. As a source of meat supply sheep and lambs bring good prices. In primitive sheep-raising districts young men frequently make records of shearing eighty or more sheep in a day.

In regions where a sheep range and a cattle range lie adjacent sheep may wander beyond their territory. If that happens the range is liable to be spoiled for cattle, for sheep feed so closely to the ground that cattle will starve if they depend on what the sheep leave.

The future of sheep raising in America is secure, although not nearly so many persons raise sheep as formerly did. The industry is carried on by men who control large herds, and the production of the wool is more carefully managed than it was at one time. There is no question that man is able to manufacture warmer clothing from wool than he can make from any other raw material. The more expensive furs cannot compare with woolen garments in serviceableness and cleanliness.

The Pig.——The ancestry of the true pigs may be traced back to the Miocene period in Europe and Asia. But none ever visited America until after its discovery by Columbus, and then they were brought over.

The ancestor of our pig is undoubtedly the wild boar of

Europe, an animal that even to-day roams the forests of Germany, and was once hunted by royalty and others, not because it is a dangerous animal (except when wounded) to be exterminated, but for the "sport" his pursuit afforded. Breeding has resulted in the production of varieties which reach maturity in two years, and often weigh several hundred pounds.

The production of meat by way of the pig is a remarkably quick way of getting a supply. It has been estimated that

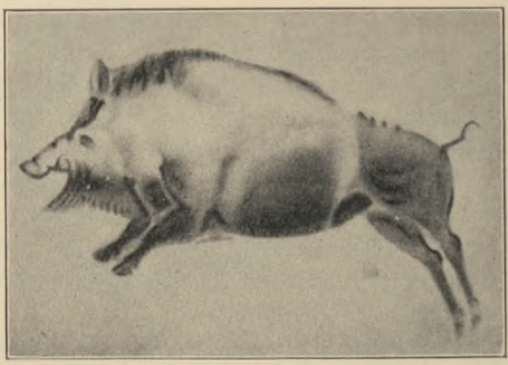


FIG. 97. WILD BOAR.

Cave-Man drawing. (Courtesy of American Museum of Natural History.)

within eighteen months a quantity of meat may be doubled by feeding pigs food that for the most part is the waste of the household. Although pigs may be fattened on garbage, it is certain that the quality of the pork may be improved by feeding corn or other grains. Pork is the flesh food which practically every farmer is able to produce for himself, and by "curing" keep a supply through the winter and until the fall, when a fresh supply is ready. However, pork is too fat for general use in summer weather, except as food for a man who is doing very hard work requiring a large supply of heat-energy, which pork readily supplies. But it is certainly not suitable for young children, except in the form of thin bacon.

The manners of pigs are proverbially bad, especially their table manners, which are characterized by gulping and the vulgar smacking of lips. These habits of pigs are objected to by all human beings, although imitated by some. Besides, pigs are not cleanly. In this particular, however, the European farmers frequently seem to assume that the pig is not untidy because it likes it, but probably because it cannot help it in its customary narrow quarters. Hence, they very generally keep the pig pens clean and the pigs supplied with straw. Some of them go so far as actually to scrub the pigs with a scrub brush, soap and water.

The Dog.——The ancestry of the dog is known to be extremely ancient, extending into the dim Eocene period, where it developed from a stock that produced the now extinct bear-dogs, the hyena-dogs, fox-dogs, and many others. More recently true types of dogs, foxes, hyenas, bears, and wolves developed from the complex stock. Some authorities believe that our many varieties of dog originated from wolves in different parts of the world. Others claim that the immediate wild ancestor of the dog is extinct. There seems to be considerable justification for the latter point of view, which was held by the late Professor Shaler, of Harvard University, an authority on dogs as well as a great lover of them. Two bits of evidence important in this connection are the facts that dogs have never been known to revert to the wild state, showing that their captivity must be very ancient, and wolves have never been domesticated.

There is good reason to believe that dogs were the first domesticated animals of man. At first, however, they served the function of a reserve food supply. But man must soon have made use of their racial capacity to hunt, run down and capture prey. Very likely the dogs had to be trained perpetually to "retrieve" or to return to the master the prey they had captured, for that quality needs to be emphasized in the training of dogs even to this day, except in certain remarkable cases where, as in the shepherd dog, retrieving sheep and returning them unharmed to the master has become ingrained in the breed.

Somewhere in the development of dogs from their wild ancestors they became the companions of man in a more intimate way than have any other species. Professor Shaler thinks man's first use of the dog was as a companion, but this seems hardly likely, since companionship comes usually after intimate acquaintance. At whatever time the tendency to friendliness and loyalty to a master developed as a mutation, certainly the selective breeding carried on has fixed the characters indelibly as a part of the emotional nature of dogs.

In the early history of the breeding of dogs, we may easily suppose that an important purpose must have been the use of the animals as aids in hunting. Besides loyalty and faithfulness the owners must have realized the need of a certain amount of intelligence in dogs. Mutations in this direction would be seized upon and emphasized in the breeding. Thus acts which at first would be original and unusual, by selective breeding would become fixed, if the character were of a dominant type. Inherited tendencies to act in a given way are called *instinctive*.

In the early days of the study of animal psychology it was customary to assert that the animals lower than man do not manifest intelligence, but acted always from instinct, that is, without understanding and without reason. We now realize that instinctive acts must have arisen as original experiences from mental mutations of as definite a character as the mutations of structure or of color of hair or skin. The real distinction between the mentality of an animal lower than man and man himself is more accurately made by calling the difference one of degree rather than one of kind. That is to say, the range of ability to think, to reason what should be done in a given situation of a new or unusual nature is much lower than it is in man. However, if we were entirely without prejudice we might be willing to grant the possibility that some dogs really think effectively under unusual circumstances, if we should see one tugging at the coat of his master and indicating by short excursions in a given direction that some unseen person is in danger. And if on reaching the bank of the river we observe a person standing there wringing his or her hands helplessly while looking at a friend struggling in the water, we might be forced to acknowledge considerable overlapping in the range of intelligence of four-legged and two-legged animals. But we must retain our loyalty to our own species (and also to our intelligence) to the extent of recognizing the fact that the height to which our thinking *may* attain is never approached by animals lower than man. We can be sure of this in spite of the fact that we understand little of the language of the lower animals, and we know it from the tangible results which our eyes can see.

FIG. 98. DUTCH DOG IN HARNESS.
These dogs help to distribute milk and other food in Belgium and Holland.
(© Press Illustrating Service, New York.)

Interesting as dogs are to most persons, and willing as we might be that the frequent loneliness of a man or a woman shall be lightened and cheered by at least one creature friendly to him or her, we cannot but resent the insult to our kind, and to dogs as well, that is implied in the nauseating custom of misguided persons who prefer to fondle a toy spaniel to holding a baby of their own. Dog dinners, dog birthday celebrations, and dog funerals conducted by grown men and women are unmistakable signs of degeneration,—of the persons and of the dogs.

The Cat.——The Oligocene period in North America saw the beginning of the great family to which our domestic cat belongs. The most ferocious and terrible of them, one with upper canine teeth eight inches long, migrated to Europe and became extinct in the Pleistocene period. Most of the existing species of the cat family are now living in Africa. From one of these the domestic cat arose. The wild ancestor is probably the Egyptian cat, which was domesticated in Egypt at least 1300 years before Christ.

Professor Mivart, of England, says, "The cat in Egypt was an object of religious worship, and the venerated inmate of certain temples. Pasht, the Goddess of cats, was represented in Egypt under the Roman Empire with a cat's head. Cats were embalmed and made into mummies on death. The cat was an emblem of the sun to the Egyptians. Its eyes were supposed to vary in appearance with the course of that luminary, and also to change with the moon; hence, it was also sacred to the moon."

In modern times there are two kinds of persons who have opinions about cats,—those who like them and those who do not. Professor Mivart, although writing a very technical treatise on the anatomy of cats, gives them an excellent character. He says cats display a high order of intelligence, meeting new problems with considerable skill. They are very emotional and very expressive of their feelings by sounds and by gestures as well. Some other persons claim that cats are extremely selfish, being absolutely without feeling except those of cruelty and a desire for a warm spot to comfort their lazy bodies. A few persons have such hatred of cats that they refuse to enter a room where one is suspected of being.

Without betraying a sympathy for either side of the controversy, perhaps we may recall a few facts about cats which will not arouse opposition. You may carry a cat away from its home in a basket without its being able to see where it is going, and it will return to its home, which may be many miles distant. Cats capture mice, rats, young rabbits, and also birds, the latter not from sheer cruelty, but because the act is in accordance with their instinct to capture to meet their need for something to eat. Cats and dogs are hereditary enemies. It has been suggested that the reason for this is the fact that both come from families of carnivorous or flesh-eating animals that lived in the same ancient environment, and found themselves in sharp competition with one another. We are reasonably sure they did compete for a common prize, for the fossil bones of wolves and other dog-like creatures and tigers have been found near the bones of elephants, and all were trapped together in great tarpools where California now lies. Doubtless, there are other cases of species that are hereditary foes for economic reasons, but we happen not to have them as domesticated animals.

The Chicken.——It is generally agreed that the ancestor of our common barnyard fowl is the wild *Gallus bankiva* of East India. The East Indian fowl is an existing species, and specimens of it may be seen at many zoölogical gardens. The domesticated game fowl, sometimes kept by chicken fanciers, and by traveling bands of gypsies as a means to gambling at cock-fighting, is thought to be the breed nearest to the wild ancestor.

FIG. 99. ORIGINAL JUNGLE FOWLS AND SOME DESCENDANTS.

The breeding of chickens has resulted in the production of striking differences from the little wild game fowl. Domestic fowls may be eight to ten times heavier than their ancestor, and generally lay far more eggs. The length and strength of the wings have not developed well; hence, chickens fly laboriously and with little success. The latter fact explains why chickens never go far from home. Although our neighbor's chickens may fly well enough to enter our gardens occasionally, we may be sure their "homing" instinct is sufficiently strong to lead them back where they belong, even if they do not remain there permanently.

Chicken-farming is a favorite branch of stock-raising with more persons who have not had previous experience in it than is any other branch. Although many fail at it, the apparent profits and the small capital necessary to make a start influence the inexperienced to keep on trying. The most general complaint heard from those who do not succeed at this industry is that they never thought chickens could eat so much. To use the common expression, "Chickens eat their heads off." It is necessary therefore to reduce the cost of the food supplied to them. This can be done most satisfactorily by the chicken farmer raising it himself, thus saving the profit that would go otherwise to one or two "middlemen" who grow rich out of the needs of others. It is a common saying with farmers generally that the way to make profit out of raising grain is to feed it to hogs or to other animals right on the farm. This is the same as saying that the way to make money in raising farm stock is to reduce to the minimum the number of business dealings involved in producing the animals and getting them to the consumers. It is an important incident that the same policy if pursued generally would reduce the cost of food to the consumers themselves, and that means to all of us.

Possible Additions to the Kinds of Domesticated Animals.——We have other birds than the chicken that have been brought to a state of domestication within comparatively recent times, the turkey, the duck, and the goose. This suggests a point made by Professor Shaler in his book, *Domesticated Animals.* He calls attention to the fact that certain of our wild species of animals are in danger of being exterminated through slaughter by man, and suggests

FIG. 100. THE AMERICAN BISON.
(Courtesy of American Museum of Natural History.)

that experiments be made in domesticating valuable wild species to save them from destruction. The American Bison, for example, might be one of these. It appears to be difficult to domesticate the members of this species, but hybrids with domestic cattle make good beef. Deer also might be domesticated on a larger scale than they are, and removed from the danger zone. The antelope referred to on page 126 could be domesticated without much doubt, but it does not breed in captivity.

Among the game birds, the ruffed grouse or "red ruff" of literary fame might be domesticated, along with the several species of its near relatives now fast disappearing. The movement of the Audubon societies relative to protecting the song birds is now on a sound basis. Nearly all intelligent persons know the economic reasons for saving the song birds (see p. 117).

Mendelian Inheritance in Man.——Professor Edwin G. Conklin, in his book, *Heredity and Environment in the Development of Man*, calls attention to the fact that the study of inheritance in man must always be less satisfactory than it is in the cases of many lower animals. This, he says, is because we must obtain our data by observation and by the tedious collection of statistics alone, whereas Professor Jennings, of Johns Hopkins University, can in two months carry an experimental lot of *Paramecia* (see p. 6) through as many generations as there have been of human beings in all the Christian era, which is about fifty-seven, counting thirty-three years as a generation. Besides, the number of children in a human family is so few that it is difficult to determine what the hereditary possibilities are. However, Professors Davenport and Plate have published data covering about sixty human traits which seem to be inherited according to the Mendelian principle.

Curly hair is dominant over straight hair, in the white race as well as in hybrids of black and white races. Dark hair is dominant over light to red hair. This means that if either parent has curly hair or dark hair, all the children will have hair of the same nature. But it also means that on the average one-fourth of the grandchildren of curly and straight haired persons will have straight hair, although both parents will have curly hair. Similarly, one-fourth of the grandchildren of dark and light haired persons will be light haired although both parents have dark hair. If the straight haired children and the light haired children severally marry persons with the same kind of hair, the recessive straight and light hair appear in the children for as many generations as the line remains pure; that is, so long as no marriages with curly or dark haired persons take place.

A dark skin is dominant over a light skin, and a skin of normal color, light or dark, is dominant over the character of albinism. As you may know, once in awhile a child with white hair and pink eyes, like those of the white rabbit, will be born into a family where the parents both have skin and eyes apparently of the normal appearance. This means that both parents have in their bodies the character of albinism as a recessive character. The children received albinism as their share of the algebraic formula given in Chapter XXXIX. Of the remaining children of such marriages one-third on the average (one-fourth of the entire number) are of normal color and always have children of the normal color, and two-thirds (two fourths of the entire number) will appear to be normal but in reality are mixed dominant and recessive with reference to the character of albinism. But it is impossible to tell which are pure and which are mixed until their children are born. When born, their children separate into the same classes as the preceding generation of mixed lines.

A nervous temperament is dominant over a phlegmatic temperament. The character of average intellectual capacity is dominant over the character of very great intellectual capacity and also over the character of very small intellectual capacity. Thus if a person of average intellectual capacity had married into the family of Jonathan Edwards (p. 177) that would have tended to establish a branch of the family that would be permanently average in intellect (one-fourth of the descendants), double the number who themselves would be average but capable of having one-fourth of their children of great intellectual capacity (see Table, p. 205, and finally, one-fourth who might reëstab-

TABLE OF INHERITED QUALITIES

Mendelian Inheritance in Man

Normal Characters

Dominant	*Recessive*
Hair	
Curly	Straight
Dark	Light to red
Eye Color	
Brown	Blue
Skin Color	
Dark	Light
Normal Pigmentation	Albinism (absence of pigment)
Countenance	
Hapsburg Type (thick lower lip and prominent chin)	Normal
German Type	Jewish Type
Temperament	
Nervous	Phlegmatic
Intellectual Capacity	
Average	Very great
Average	Very small

Pathological Characters

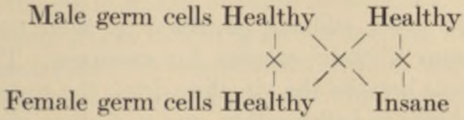
Nervous System	
Normal Condition	Hereditary Epilepsy
	Heredity Feeble-mindedness
	Hereditary Insanity
	Hereditary Alcoholism
	Hereditary Criminality
	Hereditary Hysteria
	St. Vitus' Dance
Ears	
Normal	Deaf-mutism
Eyes	
Hereditary Cataract	Normal
Pigmentary Degeneration	Normal

lish after the second generation a line of persons of great intellect.

There are many abnormal characters which operate in inheritance according to the Mendelian principle. These characters are easily followed because of their unusual nature. For example, there are persons who lack one joint in each finger and toe. This character of short-fingeredness is dominant over the normal hand. Webbed fingers will tend to obliterate the normal separateness of fingers, and persons with six fingers and six toes tend to increase the proportions of persons in a given community who have the abnormal number. Such a community has actually been discovered.

Various hereditary diseases of the nervous system have been found to be recessive with respect to the character. Among these are epilepsy, feeble-mindedness, insanity, alcoholism, criminality, hysteria, and St. Vitus' Dance. It is the knowledge of the way Mendel's Law operates in the cases of these diseases that gives to individuals and to states the basis for any course of action they may decide to take. Mental heredity has always been considered the most elusive, as well as the most important to be considered, although certain hereditary diseases of the eyes like cataract become important in that they are transmitted as dominant characters.

The nervous abnormalities, though recessive, involve the race in untold but avoidable miseries. A conscientious person who finds himself or herself in love with a person in whose family there is a strain of insanity will face the situation calmly, and calculate the chances from marriage. Such a person will see after studying the data contained in the Table that a young man or woman may be mentally normal to all appearances and still carry germ cells in which reside the recessive character of insanity, provided of course, one of the parents has been afflicted with hereditary insanity. Insanity that results from mental stress in a single generation is not inherited. The mathematical chances with reference to the children of parents of whom one has hereditary insanity, not showing, are different from those cases in which both parents are descended from strains bearing insanity. According to the rule as worked out by Mendel and others none of the children in the former case would be insane. But the fact that the insane strain is still present is shown by the formula:



The possib!e combinations would give two healthy children and two healthy (insane) children. That is to say, in a large number of such cases all the children would apparently be healthy, but one-half of them would bear the strain of insanity in them. If children of such parentage always married into families free from the diseased strain, insanity would never make its appearance there. But if one bearing the recessive strain of insanity should marry a person who also bore the insane character in recessive form, one-fourth of their children on the average would surely be insane, and one-half would bear the insane strain in recessive form. Only one-fourth would be free from the dread catastrophe.

If you consider these matters thoughtfully when you are young you will be surer of the happiness of adult life that is due you.

CHAPTER XVII

THE ENVIRONMENT OF PLANTS AND ANIMALS

Man and other animals go about in their environment drawing from it their supplies for existence. Those more familiar to us breathe the air, they drink the water, they remain near home in bad weather, and go farther afield in good weather. The common activities of animals are related to the problems of securing food and avoiding enemies.

Plants appear to have habits contrary to those of animals. This appearance is due to the stationary position of the large well-known plants. A more complete comparison of plants and animals will appear in later chapters than is necessary in a preliminary discussion. The more obvious facts can be given here.

Plants and animals are invariably associated; that is to say, neither plants nor animals exist alone. Sometimes we are able to discover some helpful relation between the two, but more often a great many kinds of animals live in a given environment in company with a great many kinds of plants, and in relations that are vague and seemingly unimportant. This appearance of vagueness of relation is in part due to the fact that many species of plants and animals actually do occupy little "corners of existence," so to speak, having slight concern with other creatures. In large part the familiar species of plants and animals distribute their dependence among a multitude of incidents in nature. But any of us may come into contact with definite examples of dependencies or interrelations.

Let us first realize that all living things breathe. One of the essential facts in the process of breathing is that air is drawn into the body of the plant or animal, and the oxygen retained; the other essential fact is that an approximately equal quantity of carbon-dioxide is sent out from the body through the breathing organs. Whether we are discussing plants or animals, the facts are the same. Thus, all organisms breathe. The ocean of air, therefore, is an essential factor in the environment of every living thing.

Now, many plants exhibit a special relation to air. These are the green plants. Green plants contain in their leaves and other young surface parts a granular substance called *chlorophyll*, which is from the Greek for "leaf-color." Through the agency of chlorophyll the leaf, or other green organ, has the power of combining carbon-dioxide drawn from the air with water from the soil, and producing a carbohydrate (starch or sugar), a simple form of food. In this process of food building, characteristic of no organisms but green plants, there is an excess of oxygen. This oxygen is sent out into the air. Oxygen is thus kept abundant in the air, providing for renewed quantities for breathing.

The noting of green plants as a group suggests plants that are not green. There are such plants and they are sometimes called *non-green* plants or fungi (sing. *fungus*). Examples of non-green plants are mushrooms, molds, yeast, and bacteria. None of these have chlorophyll, and hence have no capacity to create food. On the contrary, they break down the food compounds which they use, causing such disintegrations of food as are characteristic of animals.

The non-green plants are dependent for the food they use on living plants or animals, or on the dead food produced by plants or directly traceable to animals. If the non-green plants obtain their food by consuming juices from other plants or from animals, they are called *parasites* (Lat. *parasitus*, a person who obtains his living by the work of another). Examples are all the disease bacteria and many plant diseases such as wheat rust, leaf blights, etc. If the non-green plants live in the decayed or dead tissue of plants or animals they are called *saprophytes* (Greek, for "rotten plant"). Examples of this type are the mushrooms, that exist on the partially decayed vegetation in the soil, or molds, or yeast.

It is important to note that the green plants reach out to the air, the water and the soil, and construct living material from what is not alive. On the other hand, animals and the non-green plants, whether they subsist upon the tissue of animals or of plants, tend to consume, break down chemically, and to disintegrate the organic substances built up by green plants. One group of bacteria plays a very important *rôle* in entering and causing the decay and disintegration of all plants and animals at death. When disintegration is complete, the gases, the water and the minerals in solution are on their way to being restored to inorganic nature. Through this great cycle the elements are in constant process of change, and a certain balance in nature is maintained.

Thus, the interrelations of organisms, although seemingly vague and lost in a maze of countless incidents exhibit dependence that is undeniable. If we realize that green plants are the only organisms that have the power to create organic food from inorganic materials, the carbon-dioxide of the air, the water and the soluble minerals in the soil, we then see that green plants must have been the pioneers in organic existence upon the earth. As such they doubtless started as small and inconspicuous things, and through the process of evolution became different from one another, and at the same time increased in complication of structure.

Once we begin to seek examples of dependencies in nature we find them in multitudes, and they begin to assume importance in the scheme of nature. One of the most obvious examples is that of the relations between insects and flowers. On p. 41 the activities of the honey-bee are described, and on p. 55, those of the butterflies. A great variety of insects visit flowers for the purpose of securing food in the form of nectar, a sweet sap formed by flowers.

In the process of evolution both insects and flowers have become adapted to one another in form and structure. In some species this mutual adaptation has extended to the point where flowers, as among certain orchids, cannot "set seed" unless the flowers are visited by a certain species of insect.

The parts of a typical flower are shown in Fig. 101. The two *essential* organs are called the *stamens* and the *pistil.*

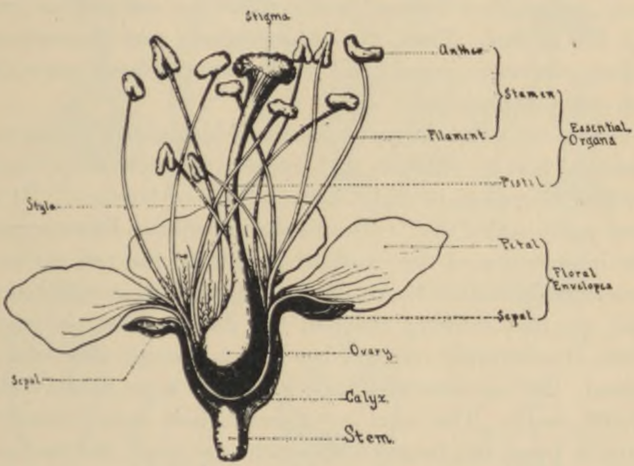


FIG. 101. DIAGRAM OF A FLOWER.
(Courtesy of the American Museum of Natural History.)

The *anther* of the stamen contains a yellow or orange powder called *pollen.* When this pollen falls upon the *stigma* or top of the pistil it completes a process called *pollination,* and starts the process of *fertilization* or seed production.

There are two common ways in which pollen is carried from stamens which produce it to pistils (on other flowers of the same species) which receive it. The wind carries the pollen in many species. Insects carry the pollen in many more. Wind-pollinated flowers are open, inconspicuously colored, and without odor. Insect-pollinated flowers are sometimes open, but always conspicuously colored, with odor, and yielding *nectar*. Often the form of the tube of the flower, or the position of the stamens, are adapted to the form or habits of movement of a few species of insects, and often to only one species of insect. Orchids are among the most highly specialized flowers in form. The insects themselves are similarly modified in form of body, covering of body, or length or form of mouth-parts that are used in reaching the nectar. Thus, the interrelations and dependencies existing between insects and the flowers of plants are numerous and far-reaching.

One of the most dramatic stories of biological dependencies was told first by Darwin, and interestingly retold by Prof. J. Arthur Thomson in the "The Outline of Science." It has been aptly called the "cats and clover" story. Darwin tested the importance of the visits of insects to the red clover by covering a hundred heads of that plant with muslin bags so that air and sunlight reached the flowers, but no insects. From the hundred covered heads not a single seed was obtained. But one hundred uncovered red clover heads yielded 27,000 seeds. The uncovered heads had been visited by bumble bees, the tongues of which can reach the nectar at the bottom of the slender flower tubes. The backs of these insects are covered with a thick growth of bristly hair in which pollen grains could be entangled.

Now, bumble bees live in nests in the ground in the fields of clover, where the young grubs of the bees are preyed upon by field mice. The more field mice that prey upon the nests of bumble bees, the fewer bumble bees come to maturity, and, in consequence, the smaller the clover crop.

In districts where cats are plentiful, as near towns and villages, the fewer field mice there will be, and the more abundant the supply of bumble bees. Finally, under these conditions there will be a better crop of clover.

The more clover there is, the more food there will be for cattle, and, indeed, the richer the soil will be, for clover improves the soil by carrying with it certain soil bacteria which combine nitrogen with other elements creating nitrates in the soil. Darwin also called attention to the probability that with a large number of kindly old ladies in a village there

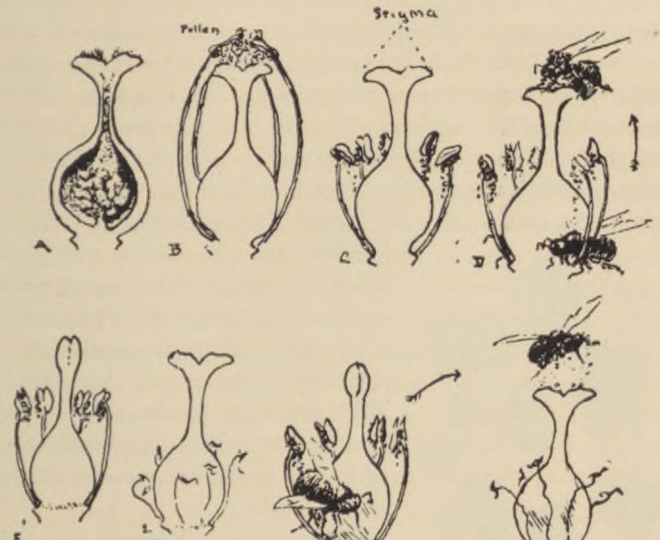


FIG. 102. POLLINATION OF FLOWERS BY INSECTS.

A, B, Self-pollination possible; *C, D,* self-pollination impossible, except by the agency of insects; *E, F, G, H,* self-pollination impossible because stamens and stigma ripen at different times; insects receive pollen from ripe stamens and visit flower with stigma ready to receive pollen. (Courtesy of American Museum of Natural History.)

would be a correspondingly large number of cats. This again would favor the clover.

It is obvious that the environment of plants and animals, though serene and vague in appearance, is full of intense activity and meaning.

CHAPTER XVIII

GREEN PLANTS

Pleurococcus.——There ought to be a good common name for the plant which makes up the green patches on the shaded surfaces of trees, fences and rocks. The common name is green slime. It is not a good name, for these green plants are not slimy. The presence of green slime on the north side of trees, which is usually the shaded or less illuminated surface, has given rise to the suggestion that probably the Indians used this fact in stormy weather to find their way. They might have done so. Although the Pleurococcus as a green plant requires light, it apparently prefers less than the full light and heat of the sun. It may also find useful the larger amount of moisture probably present on the shaded surfaces.

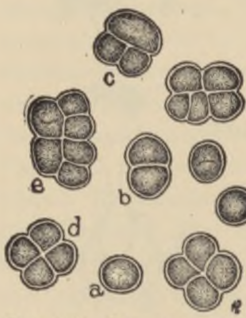


FIG. 103. PLEUROCOCCUS.
(From Gager: *Fundamentals of Botany;* P. Blakiston's Son & Co., Philadelphia.)

Pleurococcus vulgaris is a one-cell plant of microscopic size. But as shown in Fig. 103 the single cell may be associated with another cell, and sometimes with three or more additional cells. This grouping of cells results from the multiplication of cells by the process of *fission* or division and a subsequent clinging together, thus giving the appearance of a many-cell plant.

The same parts of a cell are found in Pleurococcus as in the Amœba or Paramœcium (Chapter II). There are the cell wall, the cytoplasm and the nucleus. In addition, there is the material which especially characterizes green plants, the chlorophyll. In Pleurococcus the chlorophyll is present as a single body which nearly fills the whole cell.

Pleurococcus is an interesting type of the simplest possible form of a living thing. It is just as much a plant as an oak tree is, for it lives as a complete being. It absorbs water including minerals in solution and carbon-dioxide. It makes its own food, digests it, uses it for energy and for the making of protoplasm, and it disposes of its own waste.

When one of these one-cell plants grows to its full size, it begins to divide into two, half of each organ of the cell passing into each smaller cell. Immediately each small cell begins to grow. When the full size characteristic of the cell is attained, division takes place again. Thus, the process of reproduction by division is in reality connected with the process of growth. When a one-cell organism reaches its full size after taking in food material for growth, its surface is not capable of taking in enough material to supply the need of a larger volume of protoplasm. Reproduction in the plant then results in the creation of two cells each of which is taking in all the food material needed, and growing on it. Reproduction also provides for the continuance of the kind or species.

Spirogyra.——Another green plant not so common as Pleurococcus is Spirogyra (from the Greek, meaning "spiral rings"). In the warm months of the year it is found in pools of fresh water fed by springs. It appears as slimy mats of light green threads a few inches below the surface, clinging to submerged twigs and the roots or branches of grasses. Sometimes, especially on sunny days, the whole mat is apparently lifted to the surface of the water by great bubbles of gas. We have reason to believe that these bubbles are the oxygen which the spirogyra gives off as waste incident to the process of the rapid manufacture of carbohydrate (starch and sugar) from carbon-dioxide and water. The strong sunlight increases the activity of this process of *photosynthesis* (Greek for putting together by light).

A few threads of Spirogyra may be placed in a drop of water on a glass slide, covered with a thin piece of glass and

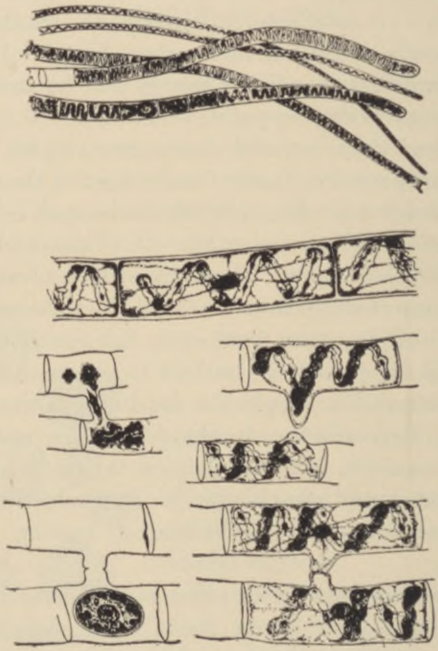


FIG. 104. SPIROGYRA.

Above, several filaments, low magnification; *below*, much enlarged study of filaments. Adjacent filaments in conjugation. (Courtesy of American Museum of Natural History.)

prepared for examination. The compound microscope shows clear-walled threads composed of a series of cylindrical cells attached end to end. Each cell contains within it symmetrically arranged spiral bands of green extending the length of the cells. There are one, two or more of these spiral bands of chlorophyll in each cell, depending on the species. Here and there in the chlorophyll bands are starch-forming bodies, called *pyrenoids*.

At the center of each cell is a nucleus with radiating strands of cytoplasm extending to the cell walls. The space within the cells not occupied by chlorophyll bands, nucleus and cytoplasm is a clear area containing cell sap. This cell sap is composed of water, sugar in solution, mineral substances brought in with the water and probably some wastes.

Like Pleurococcus, Spirogyra absorbs carbon-dioxide and water. Both these materials are abundant and easily secured by this plant. The carbon-dioxide, always present in air, is available to Spirogyra through the air which is mixed with the water. But a great deal of carbon-dioxide is being formed all the time in the decay of plant and animal substance in pond water. The chlorophyll in the presence of sunlight combines the carbon-dioxide and water into a carbohydrate, probably first as sugar. Later the sugar is changed to starch by the pyrenoids. The oxygen which comes off as a waste is left over from the process of photosynthesis as in Pleurococcus.

The plant continues its process of food manufacture, creating oils and finally protein. Out of protein the plant creates its own protoplasm. Protoplasm added to protoplasm results in growth.

When the cells attain their full size they divide by forming a wall across the middle of the cylinder. The nucleus, the chlorophyll bands and cytoplasm divide, and half goes into either cell. The growth of the cell is in length only, which thus increases the length of the thread. The thread separates into parts of variable length, and each part constitutes a *colony*. Sometimes a single cell separates from all others, and then is the entire plant, since it is able to carry on all the processes of living by itself.

Spirogyra is an important plant type on account of the fact that it demonstrates the beginning of the sexual process of reproduction. For a long time after Spirogyra became known to botanists there seemed to be no difference between the two threads of the plant as they were observed to take part in this process of reproduction. But now it is known that there are enough differences to justify designating one the receiving or female plant, and the other the supplying or male plant.

In the process of conjugation the two threads adjacent to one another begin to form at opposite points extensions in the cell walls. They extend toward one another until they touch, and a passageway forms. This is called the *conjugation-tube.* The contents of the opposite cells begin to condense and round up. The contents of the male or supplying cells then flow through the conjugation-tube and unite with the contents of the female or receiving cells. The united cell contents thus form a single body with fused cytoplasm and nucleus. The chlorophyll bands of the male cell disappear, and on further development the chlorophyll band of the female cell becomes the chlorophyll of the new plant. This new plant exists for some time in a resting stage. When formed it sinks to the bottom and remains there perhaps from Autumn till Spring, when it germinates by bursting the inclosing wall. The fused cell contents elongate, reproduce by division repeatedly until a new thread is formed.

The Rockweed.——A plant very well named because of its well-nigh sole possession of sea-worn rock promontories between high and low tides is the brown rockweed (see Fig.10) of the North Atlantic Coast, for example. The scientific name of a well-known species is *Fucus vesiculosus.*

Rockweeds maintain their hold on the rocks by producing from the base of the flattened stem a series of short clinging branches that inclose a large pebble or insert themselves into crevices in the rock mass. These root-like organs are called "hold-fasts." They are not true roots. But they are strong enough to keep the little plant in position as long as the rock holds.

Rockweeds are less than one foot in length. One cannot speak of the height of this plant, since it is not able to stand alone. There are few wood-fibers in the tissue, and nothing to hold it up. Hence, as the waves dash against the rocks the flat branches are swept up the rocks, and as the waves

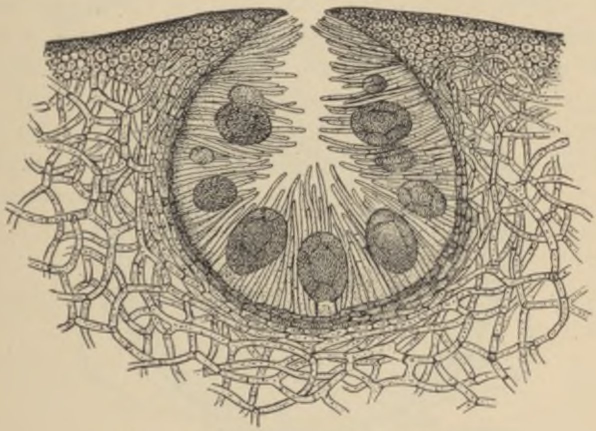


FIG. 105. CONCEPTACLE OF ROCKWEED.
Several egg-cases borne on stalks containing eight egg-cells. (From Kerner & Oliver: *The Natural History of Plants;* Henry Holt and Company.)

fall back the rockweeds sag in masses to their length and lie prone upon the rocks. Numerous bladder-like vesicles or cavities in the branches help support the plants in the water.

The branches of the rockweed are swollen at the tips into numerous pit-like organs. These cavities become flask-shaped beneath the surface and contain the reproductive organs. In some species of rockweed the male and female reproductive cells are produced in the same cavity or *conceptacle*, while in other species the male and female cells are formed in conceptacles of different plants, or even on different branches of the same plants.

The advance in the specialization of the reproductive cells in the rockweed over the same cells in Spirogyra is considerable. In the rockweed the microscopic female reproductive cells or egg-cells are contained in a case borne on a short

FIG. 106. EGG-CELL AND SPERM-CELLS OF ROCKWEED. (From Kerner & Oliver: *The Natural History of Plants;* Henry Holt and Company.)

stalk. There are eight of these egg-cells. When they are mature they burst from the egg-case, and escape from the opening of the conceptacle and float about in the water.

The male or sperm-cells are formed in cases on branched stalks from the wall of the conceptacles. When the sperm-cells are mature they escape from the conceptacles to the water. The sperms are extremely small in comparison with the eggs. By virtue of two thread-like lashes the sperms under the influence of the chemical attraction of the eggs for the sperms make their way to the eggs, and swim about them in large numbers. At length one of the sperm cells penetrates the wall of the egg-cell. The sperm migrates through the egg cytoplasm until it comes into contact with the egg-nucleus, when fusion or the union of the two is completed. This is called the process of fertilization, a general process in all but the lowest plants and animals. The fertilized eggs of the rockweed when they reach favorable places start to grow at once and develop into young rockweeds.

Although the rockweed is brown, the color only masks the chlorophyll which is abundant throughout the plant. Through the activity of the chlorophyll in the presence of sunlight rockweed carries on photosynthesis just as do fresh-water green plants.

CHAPTER XIX

NON-GREEN PLANTS

Bacteria.——Everyone knows about bacteria under the name of "germs." But germs is not a good name, since it is also applied to an essential organ in seeds.

A jar of rotting hay, such as was described in Chapter II in connection with the life-history of the Slipper-Animalcule, shows countless millions of extremely minute clear, rod-shaped particles, occurring singly or in chains. These are the bacteria that cause decay. A tiny drop of water from this source placed on a glass slide and covered with a thin bit of cover glass, if examined under the high power of the compound microscope, will be found to contain swarms of bacteria. No one ever saw a Bacterium except with the aid of such a microscope. They are the smallest organisms known.

Each of the minute bodies is a cell, a complete organism. They move in a rambling, quivering fashion by means of numerous thread-like extensions of the cell protoplasm. The vibrating threads serve to give the bacteria very slight independence, however, since they are carried by currents in liquids, by air to some extent, and are attracted or repelled by chemical or physical conditions in their environment.

All bacteria are without chlorophyll. This makes it impossible for them to manufacture their food. Thus, they occupy the same chemical position in nature that animals do. They break up food compounds; they do not build. The food compounds existing in bacteria are only transferred from living or dead organisms.

As stated in Chapter XVII, the non-green plants are either parasites or saprophytes. The difference is easily noted in bacteria. Bacteria that live in the bodies of living plants or animals are parasites. Examples are the disease bacteria of typhoid fever, tuberculosis, etc. Bacteria that live upon dead organic matter are saprophytes. Examples are the bacteria that live in dead or decaying organic matter of all kinds, vegetables, meat, fruits, etc.

Bacteria are unable to take in particles of food. Beside

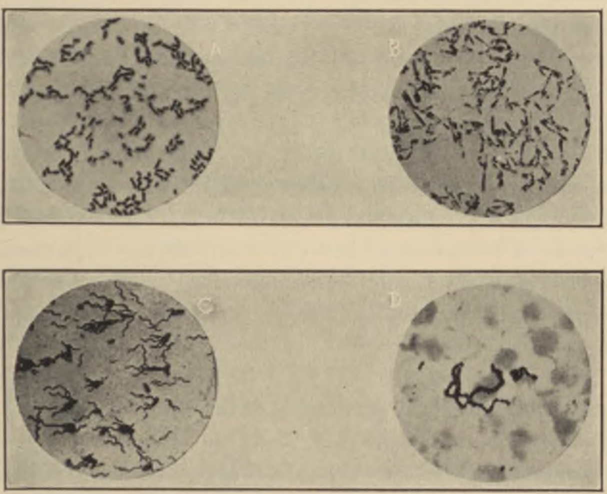


FIG. 107. TYPES OF DISEASE BACTERIA.

A, Pneumonia; *B*, Diphtheria; *C*, Typhoid Fever; *D*, Blood-poisoning. (Courtesy of American Museum of Natural History.)

the difficulty of finding space within their bodies for even the smallest observable particles, bacteria have no mouths. Furthermore, the cell wall is not flexible or permeable to foreign particles, as is the case with Amœba (Chapter II). Therefore, bacteria must dissolve their food outside their own bodies. This is done by the secretion of a chemical compound with a digestive function. It is one of a class of similar compounds found in all organisms that are called *enzymes.* Under the action of an enzyme the solid organic matter in a mixture in the presence of water gradually becomes liquified. The bacteria absorb the digested product, transform it into protoplasm of its own, or oxidize it to produce energy for growth, for activity, or for reproduction.

Reproduction in bacteria consists in the crosswise division of the cell. Some kinds of bacteria have been observed dividing about every half-hour. At that rate, it has been estimated that if nothing interferes one cell would give rise in ten hours to 1,048,576 cells. In twenty-four hours the number of bacteria produced would be well-nigh incalculably great. Thus the fact that bacteria fill all the nooks and crannies of nature is accounted for. The reasons that bacteria are prevented from overrunning and exterminating everything else are numerous. No living thing can exist without food. The moment bacteria, or in fact any organism, becomes so abundant that its customary food is relatively scarce, a natural check is applied to the increase in numbers of the species. There are other factors that tend to hinder the increase of bacteria. Heat, cold, dryness, and the prevalence of microscopic animal enemies make terrific inroads on their number. In the bodies of the living bacterial hosts, which means possibly all organisms above the one-cell forms, there are chemical and tissue conditions that hinder still more the rapid increase in the number of bacteria.

Sometimes the other forces in nature threaten to become too strong for aggregations of bacteria. Then it is that these tiny beings have recourse to a capacity to cease all functional activity for a short or a long time. In many species, when it threatens to become too dry for them, for example, the contents of the cells condense and becomes inclosed in a new, thicker cell wall. This resting stage is called a *spore*. In this condition it may lie attached to other matter, such as dried grass, until the grass may be subjected to immersion in water as in the hay culture described in Chapter II.

Thereupon, the bacteria will absorb the thick spore cases and resume business in the accustomed fashion. Possibly the only condition in which bacteria are carried far in the air is in this dry resting stage. Most of the species or kinds of disease bacteria, however, do not form spores, a fact which we may well appreciate in view of the very great difficulty we have already in fighting the ravages of communicable diseases.

On account of the fact that the word bacteria, or its common equivalent "germs," is known best in connection with diseases, these organisms have a bad name. But by far the greater number of species of bacteria are useful directly or indirectly to man, and in fact to all organic nature. The knowledge existing to-day about bacteria has brought about immense changes not only in the science of medicine, but also in such industries as relate to the production and care of food, in maintaining the fertility of soil, and in disposing of the wastes of municipalities, and of getting rid of all dead organic matter. The understanding of all that may happen through the agency of bacteria would be equivalent to having a pretty good grip on the comprehension of nature itself.

Something is said of the bacteria of certain diseases in Chapters XXXIX and XL. Those bacteria which cause decay in dead organisms are useful to all nature in causing the chemical break-up and the consequent return to earth, water and air of elements and compounds that have served their purposes in bodies the lives of which have closed. Our imagination can picture the condition of the surface of the earth if organisms that die fail to decay. It can also enable us to realize the fact that the elements and compounds in the earth, water and the air that pass into and become part of living things must be replenished. There is no other source of supply than the organisms which have taken them away.

Naturally, many of the bacteria that cause decay or putrefaction are found in the soil. But associated with them are other soil bacteria which have the opposite effect on surrounding substances. While the decaying bacteria tear down essential chemical compounds, another type, called *nitrifying bacteria*, change some of the products of decay called *ammonia compounds* into *nitrates* by causing the combination of ammonia and *nitrogen*. On the addition of more oxygen the nitrites become nitrates, which may be absorbed by the roots of plants. Nitrogen, as we know, makes up four-fifths of the air, the remainder being mostly oxygen. Since air permeates the soil, nitrogen is there too. Free nitrogen cannot be used by plants. The significance in agriculture and in nature generally of the presence of nitrifying bacteria in the soil is apparent when we realize that nitrogen is an essential element in protoplasm.

Fig. 108. Roots of Clover with Tubercles of Nitrogen-Fixing Bacteria. (Courtesy of Brooklyn Botanical Garden.)

Certain of the nitrifying bacteria have been discovered in small knots or swellings on the roots of clover, peas, beans, alfalfa and related plants. These bacteria are not parasitic on these larger plants, but are rather partners in a very important business. In poor soil the clover or alfalfa without the coöperation of the bacteria would make rather small growth, but with the bacteria, which are sometimes introduced in cultures, or even occur naturally in most places, the growth is very great. It is known that the nitrogen-fixing bacteria after they have taken up and combined the nitrogen, die in great numbers and give up the nitrates to the host plant which combines them in its own tissues. When the stubble of the crop is plowed under the soil is thereby enriched. Even before the life-history of these nitrogen-fixing bacteria was known, farmers had long alternated clover crops with other crops in order to restore soils to their normal fertility.

In Chapter XXVI are recorded other important facts about useful bacteria, such as those in milk.

Yeast.—Yeast plants are larger than bacteria and a little more highly organized. They are composed of one cell to

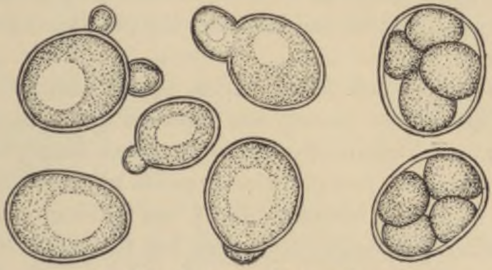


Fig. 109. Group of Yeast Plants.
At left, active budding cells; *at right,* cell contents changed to spores. (Drawn by Maud H. Purdy.)

which may be found attached one or more still smaller cells in the process of being separated from the parent cell. The cells are egg-shaped, surrounded by a wall. The nucleus is clearly seen in specimens that are prepared by killing and staining. In active specimens a large clear *vacuole* is visible. This vacuole contains water and various substances, possibly wastes in solution.

Yeast plants have in several respects the same life-history that bacteria have. This is due to the fact that chlorophyll is lacking. There is no mouth or place where food may enter, except by passing into the cell in solution. Enzymes digest external food and prepare it for absorption.

The most characteristic activity of yeast is the process of fermentation. This may be observed by stirring a piece of yeast cake (cooked potato and yeast) in a mixture of molasses and water. In a short time bubbles begin to rise. These have been found to be composed of carbon-dioxide. One of the enzymes produced by the cells acts on glucose sugar, dividing it up into carbon-dioxide and alcohol. Yeast keeps on growing in molasses for a considerable time. It causes fermentation, and at the same time absorbs some of the sugar which it uses as a source of energy by oxidation. The molasses contains also some minerals in solution and some protein. On these the yeast thrives and increases the number of individual plants.

To the plant itself fermentation is probably useful as a source of energy for growth and reproduction. In the place of oxygen, which ordinarily makes possible a supply of energy through oxidation, fermentation appears to give this energy. Man has employed fermentation in the making of brew and in producing fermented beverages for thousands of years.

In the making of bread, yeast obtained usually from the prepared yeast cakes is mixed with dough. The yeast produces an enzyme which transforms starch in the dough to sugar. Sugar is then split up chemically into carbon-dioxide and alcohol. The yeast uses some of the sugar to develop energy, but it feeds on the protein in the bread.

The carbon-dioxide in rising to escape carries along the sticky, glutinous dough, creating spaces in large numbers here and there. When the bread is placed in the oven the heat still further expands the gas and enlarges the cavities. At length the carbon-dioxide and the alcohol as well are driven off by the heat.

All fermented beverages are produced by particular species of yeast plants growing in the mixtures from which the beverage is obtained. The yeasts that produce the varieties of wines are called "wild" yeasts because they live on the soil of vineyards and blow in the dust to the skins of the grapes. Cider is fermented into vinegar by a wild yeast that grows on the soil under apple trees.

Yeasts are reproduced by a type of division. But instead of equal division, a bud forms at one end of a full-grown cell. The nucleus divides equally. The bud formation may go on

Fig. 110. Bread Mold.
At left, old plant; *at right,* young plant developed from a branch of old. (Drawn by Maud H. Purdy.)

until there are several cells clinging together in various stages of development.

Under conditions of extreme dryness or other unfavorable circumstances, the contents of a cell will divide into four cells with thick walls around each. This is the resting stage comparable to the resting stage of bacteria. As in bacteria it is a protection against extermination.

Pasteur's great scientific work was on bacteria and yeasts. Accounts are given of this work in Chapter XXXIX.

Bread Mold.——Bacteria, yeasts and molds and other non-green plants are often classed together as *Fungi.* They are also often found living together where food is stored at ordinary temperatures. Uncover a jar of jelly that has not been sealed well, or examine the bottom of a barrel of apples that has not been well culled, and you will observe masses of green and gray molds and a slimy substance resulting from the action of bacteria. There will also be noticeable the sour odor that comes from the action of yeasts.

When bread is left in a moist place for several days a special type of mold begins to appear on the surface. This is likely to be the species known as *Rhizopus nigricans*. As the mold spreads by lateral branches over the loaf, vertical stalks appear over the root-like structures that extend into the bread. On the tops of these vertical stalks, actually very short, appear minute black specks. These black specks are the cases which contain the hundreds of one-cell spores, the non-sexual reproductive bodies. When the spores are ripe, the spore-cases burst and the spores are scattered, and begin new plants on the same piece of bread, or lie in the container ready to begin active growth when favorable conditions exist.

Sexual reproduction in this mold is similar to that of the Spirogyra. Adjacent branches of separate plants extend short branches toward one another. When the short branches touch, cells are cut off the tips of either branch, and the contents of both cells unite after the separating walls are dissolved. The cell resulting from the fusion of the two cells is called a *zygote*. It enlarges and becomes surrounded by a thick wall. In that condition it may become a resting cell for a long time. At length under favorable conditions the zygote bursts and a small sprout emerges. This sprout grows upward as a stalk, on the top of which is formed a spore-case containing many spores. In this way the sexual reproduction of the bread mold actually brings about a large increase in the number of plants.

Ordinarily the effect of the growth of molds on foods is destructive. Foods that are attacked by molds are in general rendered unpalatable, even if the mold is apparently removed.

But Rocquefort cheese is ripened in part by an internal greenish mold which gives the cheese its characteristic *tang* or flavor. Camembert cheese also is usually covered with mold. The combined effect of the mold and the bacteria within the cheese give it a flavor appreciated by many.

The Wheat Rust.——A parasitic fungus disease that does a great deal of damage to wheat crops is the Wheat Rust. It consists of small red patches scattered over the blades of the wheat plant. Their presence in large numbers tends to prevent the plants from reaching maturity and producing a normal yield.

The wheat rust is an example of a plant parasite that requires two "hosts" to complete its life cycle. In the early spring spores of the parasite infect the leaves of barberry, and in the young stems. Thread-like branches of the rust grow generally between the cells of the barberry. But short branches penetrate the cells and live on the food and protoplasm of the host. Later there are formed on the under surface of the barberry leaves small "cluster cups" which contain what are called *spring spores*. These spores result from the division of a *zygote* by the union of two branch cells in the bottom of the cluster cup.

By this time the wheat plant is large enough to offer space for catching the spring spores as they are blown from the barberry. The spore germinates on the leaf of the wheat plant and sends a fine sprout through a *stoma* or air-pore of the leaf. After this numerous branches are formed and the second stage of the life-history is entered upon.

In a little while the fungus has established itself in the wheat plant. It then begins to grow to the surface where *summer spores* are formed. These spores are spread to other plants and before long an entire field of wheat may be infected. Toward the end of the growing season *winter spores* are formed in the same clusters that have formed summer spores. The winter spores consist each of two cells borne on a minute slender stalk.

The winter spores are inclosed in thick walls capable of protecting the minute bits of protoplasm contained in them from drying. These spores remain on the ground or on the stubble until spring returns. Each cell of the winter spore then germinates and produces a little plant of four cells. From this plant a special type of spore is produced. It is called a *sporidium*. These *sporidia* are carried in some way to the leaf, stem or flower of a barberry where they are liable to germinate, thus making the cycle of their life-history complete.

The barberry is usually a host of this parasite. But wheat rust is common even where no barberries have been known to exist. Wherever rust has been found it has done great damage. Eradication of the disease by direct methods has not proved successful. The most hopeful method of saving the wheat crop in some sections of the country seems to be the cultivating of hybrid or crossed varieties of wheat. A *rust-resistant* variety brought from the Mediterranean countries is being crossed with varieties in this country to produce a variety that is rust proof, and has other desirable qualities.

Mushrooms.——The best known fungus is the mushroom. This is because some species of mushrooms are edible, and some are poisonous. The poisonous ones are often called toadstools. Every summer the newspapers contain stories of whole families being poisoned, often fatally, from eating poisonous mushrooms. There is no positive way of distinguishing an edible variety from a poisonous one. The only safe practice to pursue, especially when one is collecting mushrooms in the woods, is to take only the varieties absolutely known to be safe. If one becomes expert he may gradually extend his collections to those which other experienced persons have found to be good. Anyway, no matter how palatable some mushrooms are, none is very valuable as a substantial article of food.

The best known mushroom is the field mushroom, *Agaricus* (*Psalliota*) *campestris*. This is edible. It may be collected in the open fields. But it is cultivated in dark rich beds of soil and decaying organic matter maintained in underground "root houses" or in barns. Another edible mushroom that grows in the decaying leaf-mold about the bases of trees is

FIG. 111. FIELD MUSHROOM.
(Photograph by Dr. Wm. A. Murrill.)

the "shaggy-mane" mushroom. The name "inky-cap" is also given to this and two allied species. Young puff-balls are also edible.

The visible portion of a mushroom consists of a stalk bearing an umbrella-shaped cap. Under the cap are a great number of radially placed thin plates or "gills." At the top of the narrow spaces between these gills are situated the *spores* or the reproductive cells. These are borne four in a group on stalks that emerge from the mass of tangled threads or strands of which the whole mushroom is composed. When the spores are ripe they fall beyond the lower margins of the protecting gills, where they are likely to be caught on currents of air and carried to other places where they may germinate. No indication of a sexual method of reproduction has been discovered.

Certain species closely related to the mushrooms grow on living trees, as well as on rotting logs. One of these is the "bracket fungus." In its method of extending from the

FIG. 112. BRACKET FUNGUS.
(Photograph by Dr. Wm. A. Murrill.)

trunk of a tree, it resembles a shelf. The flat portion of the shelf, however, is beneath. This under surface is covered with minute holes in the upper ends of which the spores are produced.

The substance of the bracket fungus is added to in plates beneath year by year. The root-like base extends into the bark and growing tissue of the tree, and in time will destroy the tree.

CHAPTER XX

MOSSES AND FERNS

A Moss.——Mosses are always small plants. Some species live in swampy places. Among these is Sphagnum, a moss that is sometimes collected, dried and used as packing material by nursery men and florists. This species extends from the temperate zone far to the North in the Arctic region, where it serves as food for reindeer. Other mosses live on thin gravelly soil in the woods, on rocks and on bark where a small quantity of soil has collected. Thus, they are obliged to survive periods of considerable dryness.

Mosses are true green plants. They contain chlorophyll, and are able to create their own food, drawing water and minerals in solution from the soil, and obtaining carbon-dioxide from the air. Many organisms are called moss that are not moss at all. Among these incorrectly so called are Pleurococcus described in Chapter XVIII and many species of the gray-green lichens that grow on rocks and fences. Lichens are in reality two plants living in a partnership relation, a one-cell alga and a many-cell fungus.

One of the best known mosses is the hair-cap moss, *Polytrichum commune*. This species is from two to three inches high. This moss, as well as others, exhibits two distinguishable forms. One is the form which in this species gives the basis for the name hair-cap, the other is without the fringed cap at the top of a slender stalk that extends beyond the leaves, and shows instead a shallow, flaring top at the end of the slender cluster of leaves. The hair-cap form bears at the top a capsule containing many spores. This is called the female plant for a reason that will appear presently. The other form is the male plant. The top of the male plant resembles a tiny flower in shape and appearance. At the center are slender spindle-shaped organs called *antheridia.* These antheridia produce *antherozoids* or *sperm-cells.* Before the female plant produces its stalk and cap it has a top similar to that of the male plant. But instead of producing antheridia, it has at the center of the "flower" a group of flask-shaped organs called *archegonia.* In the bottom of each archegonium is an egg cell.

FIG. 113. LIFE-HISTORY OF A MOSS.

Male and female plants at left, flowers at top; *top middle,* section showing three archegonia; *bottom middle,* section showing three antheridia; adjacent at right, archegonium and (below) antheridium with escaping sperm-cells; at *right,* asexual stage. (Courtesy of American Museum of Natural History.)

The archegonia and the antheridia complete their development at a time when free water is available about them. At such a time the sperm-cells escape from the antheridia and make their way by means of vibratile or waving lashes to the archegonia. They pass down the neck of an archegonium.

The first sperm to reach the egg-cell begins to fuse or unite with it. The remaining sperm-cells die.

The union of the sperm-cell and the egg-cell is the same process of sexual reproduction we discussed in connection with Spirogyra, the bread mold, and the rockweed. In the moss, however, the two sex cells are more highly specialized.

One of the archegonia and its contents begin to manifest signs of activity. All other archegonia in the same plant die whether their egg-cells are fertilized or not. This chief egg-cell divides into numerous cells most of which gradually transforms into a spore case with spores. A stalk begins to form beneath and the top part of the archegonium is torn from the branch portion to be carried upward as a cap on top the spore case.

When the spores are ripe they are thrown out. They eventually germinate, and if the situation is favorable a very fine thread of a few cells is formed, called the *protonema* (meaning *first thread*). From this protonema a small moss plant begins to grow. From that time it is merely a continuance of development until the two male and female plants are produced. Thus, it is that one may begin anywhere and by tracing the changes in a moss plant come back to the same point. In other words, the life-history of moss is a cycle, invariably the same for each species. Furthermore, there is an *alternation* of *generations* or a change from a *sexual generation* to a *non-sexual* or *asexual generation*, and from asexual to sexual. The sexual generation in the moss begins with the germination or sprouting of the spore. It includes the protonema, the formation of male and female plants and the fertilization of the egg-cell in the archegonium, and ends with the resulting *zygote* or fertilized cell. This fertilized cell constitutes the beginning of the *embryo*, as well as the beginning of the asexual generation. In the moss the asexual generation is relatively short and simple. As already described it consists of the dividing of the embryo and its development into the spore-case, the spores and the supporting stalk.

A Fern.——Ferns are among the most beautiful of our native plants. In the woods they seek the moist, shady spaces, and give to pleasure-hunters in nature some of their most gratifying experiences. Who has not seen a massive cinnamon fern with its enormous spreading *fronds* or leaves surrounding several sturdy shafts of brown spore-bearing stalks? Then there are the masses of rock-ferns. *Polypodium*, skirting the margins of a cliff, or the dainty maidenhair ferns clinging to the moss-covered dripping sides of a shaded crag. Some of these species and others are capable of being adapted to house confinement and cultivation. Some like the Boston fern, *Nephrolepis*, grow well, but occupy a great deal of space. The maidenhair is often used for dinner table decoration, but is difficult to rear.

FIG. 114. CINNAMON FERN.
(Courtesy of Brooklyn Botanical Garden.)

The botanist has a double satisfaction in his knowledge of ferns. If he is artistic he will appreciate their beauty. If he is scientific he will appreciate the clear manifestation of life phenomena in the wonderful series of changes in form in the life history of ferns.

Many species of ferns bear on the under surface of the fronds black or brown regularly arranged dots smaller than a pin head. These are called *sori* (sing. *sorus*). The covering of the sorus conceals a large number of *sporangia* or spore-cases borne on slender stalks. Within the sporangia are numerous spores. Estimates have been made of the number of spores a single plant may produce. In one species the estimate is 50 millions. When the sorus covering breaks the sporangia pop open, and throw the spores considerable distances from the parent plant. The spores do not all germinate, of course, on account of the lack of space for so great a

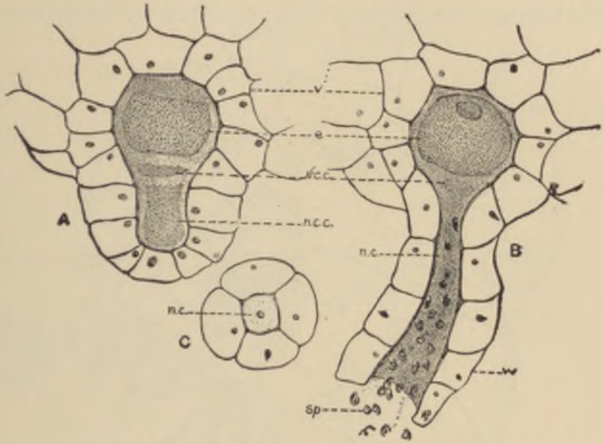


FIG. 115. ARCHEGONIA OF A FERN.

A, young archegonium; *B*, mature stage; *C*, top view and canal. (From Gager: *Fundamentals of Botany;* P. Blakiston's Son and Co., Philadelphia.)

number of plants adjacent to the parent plants, and also on account of some spores falling in unfavorable localities.

The first result of the bursting of a spore wall is the extension of a minute rhizoid or root-like organ to the soil. Then a few cells form the *protonema* or first thread, comparable to the protonema in mosses. But the fern protonema adds more cells and grows into a delicate flat plant, a fraction of an inch across, usually with a heart-shaped outline. These heart-shaped plants lie flat against the ground, but are seldom seen in nature. They may be seen, however, in a greenhouse where they attach themselves by a small tuft of roots to flower pots and to moist frames. Thus, with the flat green heart-shaped leaf exposed to the light and the rootlets growing into a few tiny particles of soil, this small plant is able to maintain itself while it performs its important function. This stage of the fern is called the *prothallus* (meaning, *first plant*). The prothallus is a sexual organism, for on the

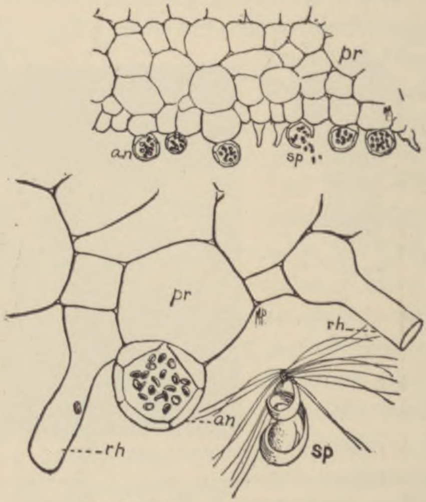


FIG. 116. FERN PROTHALLUS.

Above, cross-section showing antheridia and archegonia; *below*, enlarged antheridium and (*sp*) sperm-cell; *rh*, rhizoids, root-like organs. (From Gager: *Fundamentals of Botany;* P. Blakiston's Son & Co., Philadelphia.)

under surface near the middle there is a set of *archegonia* containing egg-cells, and near by among the rhizoids (meaning, *root-like organs*) there are several *antheridia*, containing, *antherozoids* or *sperm-cells*.

When the prothallus has reached its complete development, it is ready for rainy weather. In the presence of free water the terminal cells of the archegonia and the antheridia swell and break. The *neck-canal* of the archegonium is thus open to the entrance of sperms that have been swimming through the water to the opening of the neck-canal.

Many sperms enter from the same prothallus or from others. But the first sperm to reach the egg-cell in the bottom of the archegonium unites with it, and thus accomplishes the process of fertilization. This completes the sexual genera-

FIG. 117. DEVELOPMENT OF ASEXUAL GENERATION OF FERN FROM PROTHALLUS. 1, prothallus without asexual generation; 2, 3, 4, 5, prothalli with asexual generation developing. (From Gager: *Fundamentals of Botany;* P. Blakiston's Son and Co., Philadelphia.)

tion which began with the germination of the spore. The asexual generation begins with the fertilized egg. This is called the zygote or sometimes the *oösperm*, which name indicates a structure composed of the egg and sperm. It is also the embryo. The embryo now begins to divide in the bottom of the archegonium that has got the start of the other archegonia on the prothallus. After many cells in the embryo have formed by the process of dividing, the cells begin to group themselves into a root, a stem, a leaf and a "foot." The foot is the organ which establishes a connection between the embryo and the prothallus. The importance of this root is that it enables the young embryo to draw food from the prothallus until such time as the new root system, the stem and the leaves of the asexual generation can begin to create its own food, and take care of itself.

The asexual generation begins with the fertilized egg and ends with the spore that has been produced under the frond.

In the era of the world's history, many million years ago when the vegetation lived that subsequently formed the great mass of our coal, ferns were the highest type of plant in existence. There were many species, some of them growing as large trees.

CHAPTER XXI

THE INDIAN CORN

The Indian corn plant is the first in importance among food plants in the United States. The census of 1900 showed that one-third of all the land under cultivation in the United States was planted to corn. We produce over three billion bushels of corn annually. But relatively few people in the great cities seem to eat corn bread. However, in country districts and especially in the South corn bread is popular. By far the largest quantity of corn is used to fatten pigs and cattle. In fact, there have been times, especially in years of a heavy yield of corn when it did not pay the farmers to sell corn at the low prices prevailing. Corn raising was profitable then when the food thus created could be transformed into pork or beef. At any price for corn it is more advantageous thus to transform the corn food into animal food.

Although three-quarters of the total quantity of corn produced in the world each year is produced in the United States, the grain is grown in all the temperate regions on all continents both north and south of the Equator. The early explorers found the American Indians raising some of the same varieties of Indian corn known to-day. Like the tobacco plant, which is a native plant in America, Indian corn was early exported to Europe for experimental growth.

The ancestral species of all varieties of Indian corn is thought to have existed in Mexico, since the closest known relative of Indian corn grows there now. Indian corn is supposed to have developed from this relative, possibly thousands of years ago.

Under the care and intelligent selection of varieties by the white settlers Indian corn increased in importance as a food for man. The experienced farmers and the agricultural experimenters of later years still further improved the species, which is known to scientists as *Zea mays*. We now have over five hundred varieties of this species classed under the common terms, pop corns, flint corns, Dent corns, soft corns and sweet corns.

FIG. 118. EAR OF CORN SHOWING COB. (Photograph, U. S. Dept. of Agriculture.)

The flint, and the few varieties of soft corn are called "field" corn. All of these produce corn meal and hominy, or are used as food for animals. Under improved cultivation and the proper selection of seed for planting, the chief varieties produce fine large "ears" of corn with numerous grains set in rows. A good ear is shown in Fig. 118.

One, two or three ears of corn grow on a single stalk. Fig. 119 shows one ear with the husk and "silk" partly removed. The plants grow from seeds planted in rows about 3 feet 4 inches apart, and separated from 12 to 20 inches in the rows. The height of corn plants may be as great as ten feet, but better yields may be expected of shorter plants.

Throughout the country the yield of corn is about 28 bushels of dry, shelled grains per acre. But in nearly every section of the United States more than 100 bushels per acre have been produced. Under especially favorable conditions good land has yielded 200 bushels of dry, shelled corn per acre.

The best results have been obtained by boys who belonged to corn clubs. The increase in yield obtained by intensive cultivation of small plots of ground has helped to set high the standard of corn production for the whole country. Scientific experimenters working at state and national experiment stations have also helped to show the general farmer how to make his land yield more abundantly.

Certain factors are taken into consideration always when increased yields in corn are being sought. Among these factors are,

1. The selection of the most perfect seed ears.
2. Preparing the seed for planting by sorting for perfect grains and for germinating capacity.
3. The selection and preparation of fertile, deeply plowed soil.
4. Liberal supply of soil water and well-decomposed manure.
5. Protection against crows and cutworms.

Scientific farming is gradually becoming general owing to the farmers' bulletins that are issued by the U. S. Department of Agriculture. The successors of the old time farmers who used to express contempt for the

FIG. 119. CORNSTALK WITH EARS. (U. S. Dept. Ag.)

"college fellows" who gave advice about crops are now sending their boys to college. And because the colleges are keeping more and more in touch with real farm life, their contributions to the success of organized food production have been very great.

ROOTS

The Indian corn plant is a member of the grass family. Although the plant is annual, the stem is strong enough to bear the weight of the one to several ears of corn, as well as to withstand the pressure of a strong wind against the broad leaves and the speading tassel at the top. Apparently as a preventive against the accident of a corn plant being uprooted a few circles of prop-roots or brace-roots grow out from low joints of the stem, and sink into the soil. Very early in the development of the root system from the seed the lowermost joints in the young stem give rise to numerous finely branched roots which together with the first or primary root constitute the extensive root system.

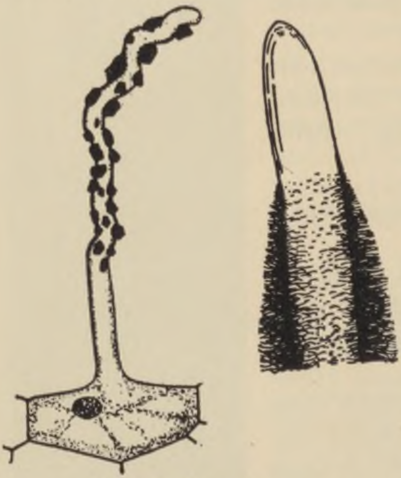


FIG. 120. ROOT-HAIRS.

At right, root-hairs on corn rootlet, root-cap at end; *left,* single root-hair of wheat shown as part of a cell, soil particles clinging. (Courtesy of American Museum of Natural History.)

Throughout the five months of life of the plant the root system is carrying upward great quantities of soil-water in which there is dissolved such soluble minerals as are characteristic of the soil. Near the tips of the finest root divisions the surface is covered with a fine white velvet-like mat of *root-hairs.* These root-hairs consist of single cells, with very thin walls, within which is protoplasm and a cell-nucleus. It is only through these root-hairs that soil-water may enter the roots at all.

THE STEM

The stem of the corn plant extends as a single stalk from the roots to the tassel with only the short stems of the ears as branches. The stem is round except for a flat or shallow-grooved vertical region above each leaf. As the leaves change position, so these grooved regions appear first on one side of the stem and then on another.

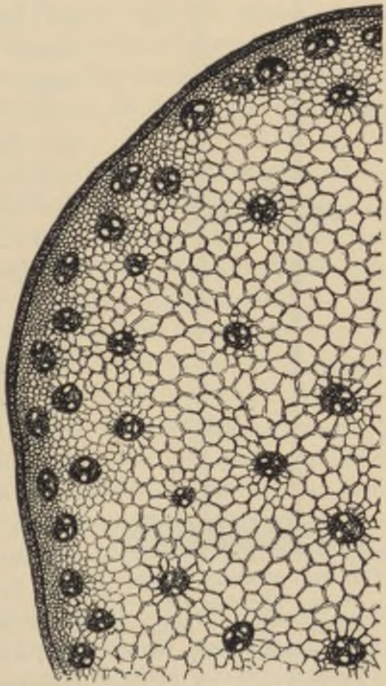


Fig. 121. Cross-Section of Corn Stem.
Showing external "rind," thin wall pith cells, and dense fibrovascular bundles.

A cross section of a young stem shows the arrangement of cells as they appear in older stems. The mass of the interior tissue, or groups of similar cells, is *pith.* The surface of the well grown stem is covered with a tough *rind* which adds greatly to the strength of the stem. The microscope shows the pith to be made up of numerous thin walled, loosely packed cells. Scattered here and there within the pith are what are called fibro-vascular bundles. These bundles consist of numerous slender wood and bast fibers and a few tubes (*vasculæ*) extending lengthwise of the stem.

The water and dissolved mineral substances absorbed by the root hairs are carried up the roots to the base of the stem. There the incoming water or *sap* passes up the stem and out the leaves by way of the wood fibers and such ducts or tubes as are included in the wood tissue. On the return journey the sap comes down the bast fibers and tubes.

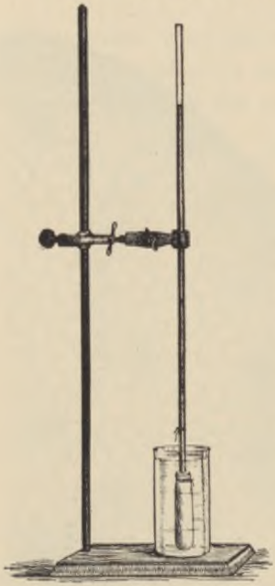


FIG. 122. OSMOSIS EXPERIMENT. Showing sac containing sugar solution; water penetrating membrane rises in tube against force of gravity. (Drawn by Maud H. Purdy.)

The statement has been made that the water and minerals in solution or the soil-water enters the root-hairs and passes up to the leaves. We all know this must take place, but perhaps it may not occur to us to inquire how it is done. It is, indeed, remarkable that water is carried upward in a tall tree apparently with no effort, when it would be impossible for the most powerful fire engines to force water directly to the upper stories of our very high buildings. The explanation we are seeking may be prepared for by studying the behavior of solutions.

If we take a tube, and tie closely over the open end a slender sac of softened parchment or animal membrane like a section of an intestine, oiling the crevices to make the connections watertight, we have an apparatus that will represent a plant cell. Into the small end of the tube we pour a dense solution of sugar, filling up the sac and a portion of the tube. The tube is then adjusted in a tumbler of water and clamped in position.

In a few hours the solution has risen in the tube, and over night it may rise twelve inches or more. To understand this you may recall having noticed that a lump of sugar, a pinch of salt, or a spoonful of medicine in a glass of water will distribute through the water in a short time. This distribution, or *diffusion*, as it is called, keeps up until the whole solution is equally dense. The reason diffusion continues until completed is that the *molecules* (smallest particles) of water and the molecules of substance being dissolved have a strong attraction for one another.

In our experiment the dense solution of sugar and the water of the tumbler containing no sugar are separated by a membrane. But observation has shown that water may pass through the membrane, although the membrane does not leak. If we taste the water of the tumbler we find that a little sugar has passed through the membrane, but not much. The explanation of this condition is that even when separated sugar-water and water will continue to attract one another and seek to mingle. The water is able to pass through the membrane spaces, because the water molecules are small. The sugar molecules are larger, and have difficulty in getting through. Thus comes the high level of water in the tube. Let us apply this principle to the cells of the plant.

The cells of plants contain sugar, chiefly glucose. Soil water contains no sugar. The membrane of every one of the millions of root hairs are permeable (may be penetrated) to the soil-water. Thus soil-water comes into the root-hairs, but no sugar passes out. In each set of cells with which the incoming water comes in contact there is less water than can be used in a solution of sugar. And the reason there is always less water is because it is being given off constantly through the air-pores of the leaves. Thus, from cell to cell, from root to stem, from stem to branch, and from branch to leaf, the procession of countless molecules of water marches upward.

THE LEAVES AND THEIR WORK

The leaves of the corn plant join the stem at joints singly. The leaf clasps about the stem in sheath fashion. Leaves are long and slender, and the midrib and veins run parallel lengthwise of the stem. The midrib and veins are composed of fibrovascular bundles and are directly connected with these structures in the stem.

Photosynthesis.—One of the most important functions of the leaf is the creation of food. What happens is exactly what happens in all green plants. Carbon-dioxide from the air and water from the soil are the raw food materials which meet in the leaves and are combined in the process of *photosynthesis* (putting together by light). The thinness of leaves permits light to penetrate all their tissues, and to stimulate the protoplasm and chlorophyll (leaf-color) to complete the steps necessary to carbohydrate formation. Incidental to the process of photosynthesis, oxygen is present in excess, and thus is considered a waste.

As already stated on p. 217, the first product of photosynthesis is a form of sugar. Under certain conditions this sugar is changed to starch. In daylight the carbohydrate is formed rapidly. A leaf cut from a plant toward the close of day, and subjected to chemical treatment to remove the chlorophyll, will, on the application of a food test, show large quantities of starch. But in the night all this starch is acted upon by an *enzyme* (digestive chemical in plants) and changed to sugar again. There are two reasons why the action of the enzyme is necessary; first, it is necessary to remove all starch to give space for more, secondly, the molecules of starch will not pass through a cell wall. The molecules of sugar will.

Sugar is the form in which food is carried about the plant to serve as material for oxidation, and as the basis for the more elaborate protein compound.

Transpiration.——An active plant absorbs through the root hairs a great quantity of soil-water. The soluble mineral portion of this water is used in part by plants in the formation of protein. But it requires a large quantity of water to dissolve a small quantity of mineral compounds. Thus, when the minerals in solution are used up by the plant cells, the water comes to the leaves free of all dissolved substances. Some of it is employed in photosynthesis, but the greater portion is no longer needed, and is waste. It passes out through the air-pores (*stomata*, Greek for little mouths) in the form of vapor. This process of sending out excess water is called *transpiration*.

Respiration.——Confusion is likely to arise in our minds with regard to respiration or breathing in plants. This is because of the emphasis naturally placed on the fact that the leaves absorb through the air-pores or stomata a large quantity of carbon-dioxide for photosynthesis. As a matter of fact, plants and animals are forced to breathe for exactly the same reason. Both require free oxygen to combine with food thus yielding the energy necessary to carry on the work of the organism. The chief form of energy characteristic of plants is the chemical energy necessary to food formation and growth.

Although the air-pores take in oxygen along with the carbon-dioxide, the plant employs in the process of respiration or breathing some oxygen that is released in the process of photosynthesis. In fact, the probability is that wherever oxygen occurs free in the plant there it is used to release energy by combining with carbon or with hydrogen in its own food compounds. We understand respiration to mean

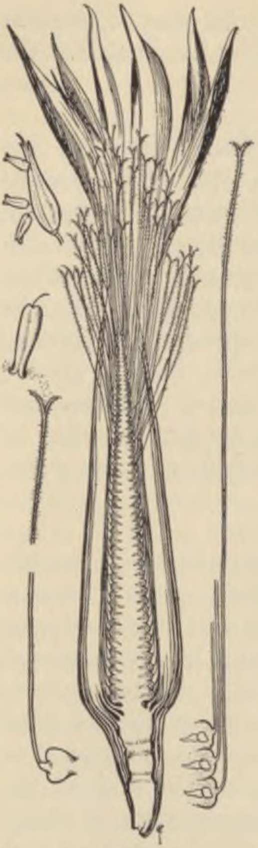


FIG. 123. PISTILLATE AND STAMINATE FLOWERS OF INDIAN CORN. Young ear showing styles or silk extending from pistillate flowers to tip of husk; *at left*, pollen dusting on tip of stigma. (Drawn by Maud H. Purdy.)

the taking in or securing of oxygen and the formation and setting free of carbon-dioxide. The beginning and end of this process is what is especially considered respiration in man. Wherever and however the same events occur, the process is called respiration.

In July the flowers of the corn plant begin to develop. They first appear at the top of the plant. These are called the *staminate* flowers, because they contain the pollen-bearing stamens only. The cluster is called the *tassel*. A single flower (Fig. 123) contains three stamens surrounded by a number of dry, husk-like *bracts*.

When the tassel is well formed, one may discern extending upward from the angle between the stem and a leaf a small tuft of delicate silk from a budding ear of corn. The ear, when its form becomes fully apparent, is made up of a central core called a *cob*, on which are set in rows running longitudinally numerous *pistillate* flowers. These flowers consist of two minute scale-like bracts, an *ovary* containing the *germ* of the seed, and a long, silken *style*. Surrounding the ear are *husks* which consist of enormous bracts extending from the base of the ears beyond the tips of the ear.

In the latter part of July, usually, the staminate and the pistillate flowers are mature. The pollen of the stamens then breaks from its covering, and being light and dust-like, is caught up and blown away by the wind. Vast quantities of pollen are carried across a corn field, much of it falling on the ground between the rows, or beyond the field altogether. When pollen falls upon the end of the silken styles of an ear of corn, whether from the same plant or from a distant one, pollen grain forms a fine tube still more slender than the style. This pollen tube grows down the length of the style to the *ovule* in the ovary itself. There the tube penetrates an opening in the ovule.

Then from the pollen grain still attached to the top or *stigma* of the style there passes down the tube a cell called the *sperm-nucleus.* This cell finally comes to rest adjacent to an egg-nucleus in the ovule. The sperm-nucleus and the egg-nucleus unite to form what corresponds to the *zygote* of the lower forms described in Chapters XIX, XX. The zygote gives rise to the embryo.

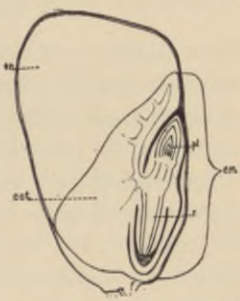


FIG. 124. LONGITUDINAL SECTION OF CORN GRAIN. *En,* endosperm; *cot,* cotyledon; *pl,* plumule; *r,* radicle or root; *em,* embryo. (Drawn by Maud H. Purdy.)

The embryo is the essential part of the young plant which is contained in all seeds. The parts of the embryo in the corn grain are the *plumule* from which may be traced stem and the leaves and certain of the roots. From the *radicle* comes the *primary root.* The remainder of the embryo is the *seed leaf.*

Packed about the embryo, but not inclosing it, is the horny and starchy *endosperm.* The endosperm is the food material of the young plant, a fact clearly shown by the gradual absorption of that part of the grain when the corn seedling is developing.

There are four kinds of food substances in the corn grain available to the germinating plant or to man who makes his levy upon nature after having stimulated nature to develop the bountiful supply from small beginnings. These four food substances are, first, starch, obvious in the chalk-like masses in the grain. There is sugar in the endosperm and in the embryo especially during germination. There is *fat* or *oil* mainly in the embryo, and *protein* throughout the grain.

THE PRODUCTS OF CORN

Corn Meal.——Until near the time of the Civil War it was common merely to grind up the grains of corn between the old-fashioned mill stones, to bolt or sift the meal by hand, and then to prepare it for the "hoe" cake, johnny cake, "hasty pudding," or Boston brown bread. It is now the custom to kiln-dry the corn, remove the outer skin and also the embryo, leaving only the endosperm. Then the meal is bolted or sifted through great cylinders of fine silk cloth. Drying the grains and removing the embryo with its contained oil improves the keeping qualities of the meal.

Samp and Hominy.——Samp and hominy are prepared as corn meal is. The outer skin is removed by softening and the embryo is taken out. But the endosperm is broken into large pieces. In samp the pieces are very large, and in hominy the pieces are not larger than a pin head. But in some sections of the country the name samp is applied to the small pieces and hominy to the large pieces.

The old-fashioned way to prepare hominy was to soak the grains in lye obtained from water and wood ashes. The lye softened the grains and loosened the skin of the grain. By stirring the grains the skins were removed. And by soaking the grains in clean water afterward the lye was removed from the grains. The grains were then soft, and after cooking by boiling were very palatable. A popular Southern food combination used to be "hog and hominy," and is still in country districts.

As cereals, samp and hominy require long cooking, but when thoroughly cooked are excellent for anyone.

Corn Starch.——A grain of corn broken into a few large pieces shows near the center a region of chalk-like whiteness. This is nearly pure starch. It can be separated from the remainder of the grain by certain processes. It is then called corn starch. Corn starch is used a great deal for thickening sauces, and as the basis of puddings.

Glucose.——Reference has been made before in this chapter to the fact that starch may be changed to sugar in the plant. The sugar to which starch is changed is glucose. This change may be induced artificially for commercial purposes by boiling corn starch with hydrochloric acid, and refining and evaporating the material produced.

Glucose products, both liquid and solid, are now used with success in making candy. Glucose hardens and crystallizes as easily as cane sugar. It is quite possible that another fact receives some consideration by candy manufacturers. And that is the fact that glucose is less sweet than cane sugar is. As every one knows it is not possible to consume as much home-made candy, which is customarily made of cane sugar, as one can eat of "store" candy. Besides, glucose is cheaper than cane sugar is.

Corn Oil.——We have already noted the fact that the embryo of the corn grain is removed before the grain is ground up for corn meal. However, the embryo is not wasted. It is used as a food in fattening live stock, pigs especially. It is also used in increasing quantities every year to produce salad oils and cooking oil. There are trade names for the products, and the oil products give complete satisfaction, besides being less expensive than olive oil. They are more digestible than lard.

CHAPTER XXII

THE BEAN

In the states of New York, Michigan, California, Wisconsin, Maine and Florida, the growing of beans in field and garden has become one of the best paying enterprises a farmer or gardener may engage in. In fact, beans have displaced wheat in some areas, owing to decreasing fertility of the soil for wheat, as well as to the better economic return from the production of beans.

Beans are valuable as food, being especially rich in *protein* (Chapter XXVIII). In countries where meat is expensive, beans are eaten in great quantities by those who cannot afford to buy meat often, and by many who can. In every language one may find the word for "bean," which fact indicates the wide use of the plant throughout the world.

Aside from the fact of producing a valuable food in the seeds and green pods of the plant, beans belong to a family of plants that performs an extraordinarily valuable biological service. This service consists of renovating or rejuvenating the soil through the activity of nitrogen-fixing or nitrifying bacteria. It was related in Chapter XIX how the bacteria grow in small knots or *tubercles* on the roots of beans, peas, alfalfa, clover and other members of the pulse or pea family, and cause free nitrogen of the air lying between particles of soil to combine with free oxygen in the soil. While the field and garden beans are not so active in the production of nitrogen compounds as are the important forage plants, such as soy beans and cowpeas, nevertheless they do combine nitrogen and oxygen to such an extent that the land is improved. This makes the growth of beans a doubly valuable soil product.

In Chapter XXIX you will find green beans mentioned among the green vegetables that supply iron, an important need of our blood. Of late years green beans have been available all year round. The Southern states, especially Florida, in the winter time grow and ship vast quantities of green beans, as well as other fresh green vegetables, to the Northern markets. The cost is two and three times what it is in the Northern summer time, but the body's need must be supplied.

THE WHOLE PLANT

There are two types of bean plants, one that grows as a low bush-like annual plant, the other that climbs a slender support by twining the stem about it. Thus, they are called bush beans and pole beans. The well-known Lima beans are usually pole beans. Some of the common kidney beans are bush beans and some are pole beans. On account of the great richness and palatableness of Lima beans they are grown in large quantities, but other beans grown are mostly bush beans, on account of the greater ease with which bush beans are cultivated and harvested.

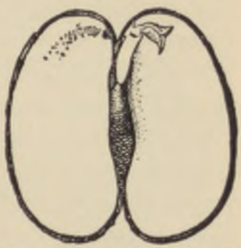


FIG. 125. BEAN SEED OPENED. Interior of seed-leaves exposed; plumule above, and rod-shape radicle. (Drawn by Maud H. Purdy.)

Like other green plants bean plants create their own food from the water and minerals obtained in solution from the soil and from the carbon-dioxide in the air. They grow rapidly, and even in soil of ordinary fertility will produce edible pods of green beans in six weeks from the time of planting. A professional gardener may thus have a garden in New Jersey, another in Virginia or in the Carolinas, and another in Florida, and he may move from one to another, keeping busy all the year round. Some gardeners actually do this.

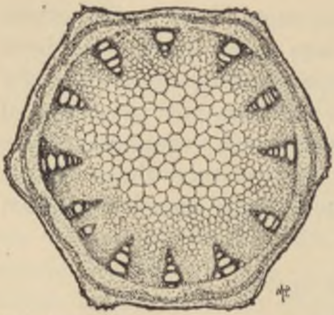


Fig. 126. Cross-Section of Stem of Bean Seedling. Pyramid-shaped fibrovascular bundles forming at cambium layer; pith cells at middle; bark outside f. v. bundles. (Drawn by Maud H. Purdy.)

GERMINATION

The life history of the bean may be said to begin with the germination of the seed. This takes place in the soil a few days after the planting of the seeds one and one-half to two inches deep. A cluster of roots soon forms from the free tip of the *radicle* in the seed. The roots give attachment to the soil. Covering the surface of the roots is the thick mat of root hairs. These root-hairs as in corn are thin-walled cells capable of absorbing water with minerals in solution.

The remainder of the radicle begins to grow longer, thicker and stronger. The result is that the thick seed-leaves, their covering and the *plumule* are pushed above the surface of the ground. In a little while the seed-leaves spread and the plumule opens out, grows larger, takes on the green color of leaves, and becomes established as the first pair of permanent leaves of the plant. The seed-leaves at first are swollen beyond their normal size in the seed by having taken in water, but soon shrinking is evident in the wrinkles that appear on the surface. Eventually, the seed-leaves dry and fall off as withered remnants, having given up their rich nourishment to the young plant. Seeds of all the seed-bearing plants contain food

Fig. 127. Demonstration of Path of Sap Circulation. (Courtesy of American Museum of Natural History.)

that the "mother-plant" produced and stored there. Out of this food the young plant makes roots, stem and leaves sufficient in number and size to enable the young plant to take care of itself. This provision for a new generation reminds us of what is noticeable in the eggs of animals. The germ of the animal in the egg is very small. The remainder of the egg is food for the new creature, and is all used before the hatching takes place.

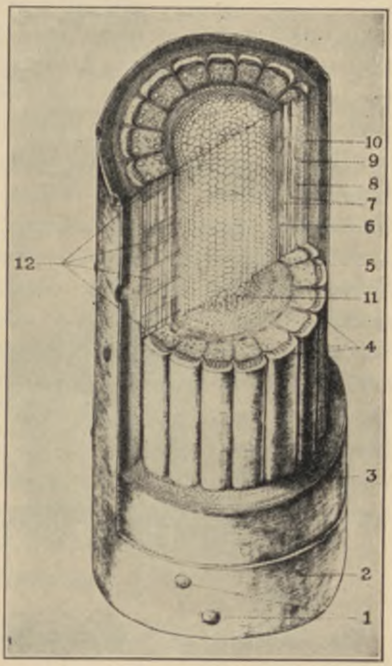


Fig. 128. Cross-Section Diagram of Typical Dicotyledonous Stem.

1, lenticels (breathing pores); 2, outer bark; 3, inner bark; 4, fibrovascular bundles; 5, medullary rays; 6, 7, wood ducts; 8, wood fibers; 9, sieve tubes; 10, bast fibers; 11, pith cells; 12, medullary plates. (Courtesy of American Museum of Natural History.)

THE STEM

The stem of the bean, like the stem of all plants, serves the function of holding the leaves up to the light and air and of serving as the pathway by which water and minerals are carried up and dissolved food is brought down from the leaves. In the corn plant we discovered a type of stem structure and arrangement of tissue that is characteristic of all flowering plants that have one leaf or *cotyledon* in their seeds. The corn plant represents the *monocotyledons* (plants with one seed-leaf). The bean, as you know, has two seed-leaves. It is, therefore, a *dicotyledon.* Most of our flowering plants are dicotyledons.

The arrangement of the tissues in the stem of any dicotyledonous plant is the same as it is in the bean stem; and the manner of growth is the same. A tissue is a group of cells similar in structure and in function. Beginning at the surface, the order of tissues in the bean stem are the epidermis, the cortex or corky layer, the bast fibers, cambium (the region where growing occurs), wood fibers, pith. These tissues lie in rings one within another, except that the pith occupies all the central region of the stem. At an early stage in the growth of the stem there are present small masses of wood fibers, cambium, and bast fibers. These are called *fibrovascular bundles.* When more wood is added it is formed in the inside of the ring of cambium. When bast or cortex is added it is formed on the outside of the cambium. All the water passes up the stem in the wood tissue. All the liquid food created in the leaves and carried downward for use by the plant is carried in the cortex or bark region.

THE LEAVES

The leaves of the bean plant are compound leaves of three leaflets each. The compound leaves occur in pairs alternating by pairs up the stem. The fibrovascular bundles of the stem extend through the leaves. Their presence is visible as the midrib and veins.

Characteristic tissues of the leaf are the upper and lower epidermis and a layer of narrow cells set on end (called palisade cells). There are loosely connected rounded green cells, and air-pores, connecting the interior spaces with the outside air. Here, as in the leaf of corn and in other green leaves, the chlorophyll-bearing leaves produce the carbohydrate.

THE FLOWER

The flowers of the bean plant develop from clusters of buds. The parts of the flower from the margin to the center are, the *calyx*, the *corolla*, the *stamens*, and the *pistil*. The calyx is made up of fine leaf-like *sepals*. This set of organs remains on the flower stalk while the fruit is developing. The corolla is made up of five *petals*. The petals are of three shapes. A large petal is expanded into a "standard" or "banner." At its base, and cupped toward the standard on

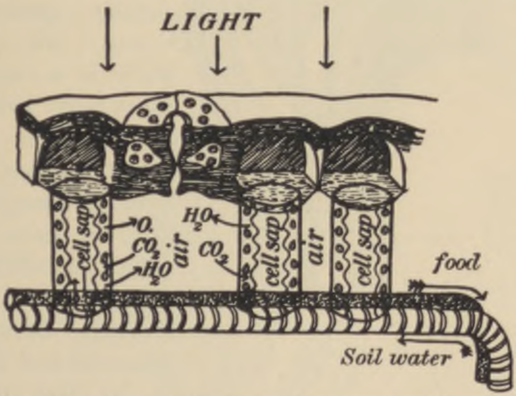


FIG. 129. DIAGRAM SHOWING DIRECTION OF FLOW OF LIQUIDS AND GASES IN PHOTOSYNTHESIS.

(Courtesy of American Museum of Natural History.)

the opposite side of the stamens and pistil, are two petals joined together at their margins to resemble the keel of a boat. This keel incloses and conceals the stamens and pistil. At either side of the keel, but in the circle of parts of the corolla, are two petals resembling "wings." There are five sepals and five petals.

The stamens are ten in number. Nine of the stamens are joined by their stalks or filaments the greater part of their length, forming a sheath or trough in which is inclosed the most of the long flattened boomerang-shaped pistil. The tenth stamen is free to its base, but lies in the narrow crevice formed by the edges of the trough. The basal portion of the pistil is the flattened *ovary*, containing four to ten *ovules* which later develop into seeds. Above the ovary is the *style*, bent over toward the standard at nearly right angles. Near the top on the inner side is the *stigma*. The stigma is rough and is covered with a slightly gummy substance. All over the pistil is a covering of short plant hairs.

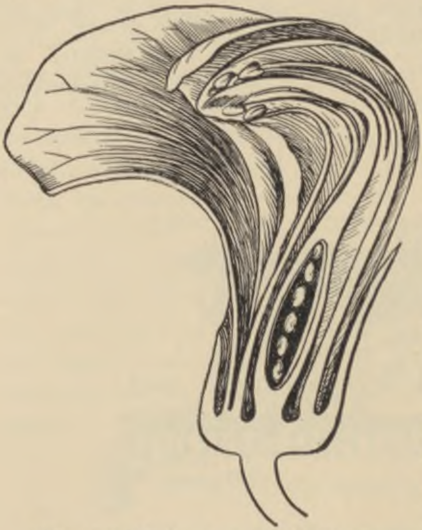


FIG. 130. FLOWER OF BEAN PLANT. Section through middle of flower showing calyx, corolla, stamens, and ovary. (Drawn by Maud H. Purdy.)

The flower precedes the formation of the fruit or bean pod. In fact, we have already noted the similarity in shape and internal structure between the bean pod and the pistil. It is clear that the meaning of the flower is as a producer of the fruit. But in a sense all the organs contribute their part to the creation of the fruit.

In Chapter XVII reference was made to the importance of the relation between the flowers of plants and certain species of insects. So general are the manifestations of adaptations of the form and color of the parts of flowers to the activities of insects that we may be sure that any flower with a conspicuous corolla is visited by insects. Bumble bees visit bean blossoms as well as many other species. When a bee alights upon the wing of a bean blossom the trough of stamens spreads slightly from the single stamen. The proboscis or "tongue" of the bee is then thrust into the trough between the ovary and the stamens where nectar has been formed. The tongue and the bristle-covered head and back of the bee comes into contact with the pollen of the stamens, and is entangled there. The next flower visited by the bee is likely to receive on its stigma a few grains of pollen from an en-

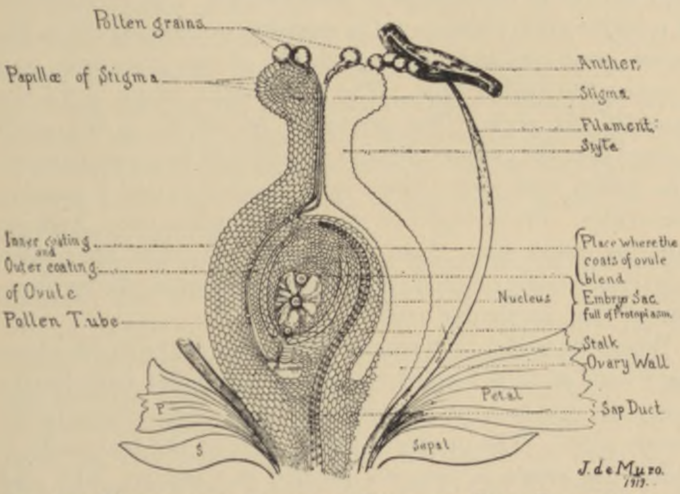


FIG. 131. DIAGRAMMATIC SECTION OF FLOWER TO SHOW FERTILIZATION. (Courtesy of American Museum of Natural History.)

tirely different bean blossom. The process by which pollen is transferred from the stamens to the pistil of the same species of plant is called *pollination.*

It is very probable that pollination in many bean blossoms occurs without transfer of pollen out of the blossom. That is to say, self-pollination takes place. But this is not easy, since the stigma of the pistil is beyond the reach of the anthers where the pollen is produced. Better seeds and hence better plants are produced when *cross-pollination* occurs, that is, the transfer of pollen from one flower to the stigma of another flower. When one or more grains of pollen are deposited on a stigma that is ready to receive them, the process of pollination is said to be complete. The process of *fertilization* or the production of seed then begins.

Pollen grains are inclosed in heavy walls with thin places, germ-pores, through which the contents of the pollen grain may emerge in the process of germination. The germination of a pollen grain consists in the *vegetative* or growing *cell* in the pollen grain pushing out through one of the *germ-pores*, and forming the pollen tube. The pollen tube grows down the canal of the style. The *generative cell* of the pollen grain follows into the pollen tube and divides into two *male gametes*. The pollen tube grows down into the ovary until it reaches the ovules. There might be many more pollen tubes growing into the ovary than there are *ovules*, but when one pollen tube reaches one ovule no more can take part in the fertilization of that particular ovule.

When the pollen tube reaches the center of the ovule where the *female plant* is located the end of the pollen tube breaks open, and one male gamete unites with the egg-nucleus in the female plant. The product of this union of the two nuclei is called the *zygote*, a term we learned in Chapters XIX and XX. The zygote by division forms the embryo. By special grouping of cells the several organs of the embryo are formed.

Food material is formed in the endosperm of the seed, and within two weeks after pollination the bean pods are large enough to serve as food. A few weeks more and the seeds are fully developed, dried and ready to start the growth of bean plants for the next season.

CHAPTER XXIII

THE FORESTS

In fairy tales and in romantic literature forests stand for untraveled regions of mystery where wood nymphs flit through the dark shadows sometimes protecting a human wanderer, but oftener leading him into trouble. Mythical wolves with gleaming eyes, as well as substantial ones with hungry stomachs and sharp teeth, roam the forests in the bed-time stories of our childhood. As we grow older we love to read of robbers sallying forth from the depths of the forest to rob the rich and give to the poor.

Not only in story, but even in actual life in the present century, the forest has its charm for nearly everybody. Young people especially like to run, and loiter, through the woods, hunting early flowers in the spring, eating berries in the summer time, and gathering nuts in the autumn. Most of the older people like some of this too. There are others from the city who worry about the polish on their shoes. But to the men and women who live in and by means of the forests there may be a subconscious feeling of freedom in the life, but there is more of hard work and matter-of-fact concern about whether the forest will make them a living. There is the day-to-day labor of protecting the forest, of selecting for the cutting of trees for lumber for the house fires, of brush burning, and of resetting young trees. Thus, the forests are sources of pleasure and of livelihood.

When the early settlers of the country endeavored to establish their farms, they cleared the land of trees. They built houses of logs, because logs were cheap. Besides there were few or no saw-mills available. The river bottoms were the first lands to be cleared, because travel was along the rivers. Forests were regarded as obstacles to be overcome, and not at all as sources of wealth. The wastefulness of our countrymen in dealing with the forests did not seem wasteful until lumber began to be scarce in certain regions, and until some of the effects of stripping trees from the higher lands away from the rivers became apparent.

In so great a problem as that of conserving our natural

Fig. 132. Wasteful Methods in Lumbering.
(Keystone View Company, New York.)

resources in forests, we should not ascribe altogether to previous wastefulness the existing great cost of building materials. In the seventeenth century there were very few people here. In the twentieth century we now have over one hundred millions of human beings in our country. If the needs of our present population were of the same character as those of our predecessors three hundred years ago, there might be no scarcity even now. But within the last one hundred years we have developed an immense industrial system. The multitude of uses for wood is so great as to be beyond the ordinary powers of computation and description. A few details will be useful to suggest to your understanding the immense field of the industrial uses of wood. Factories produce elaborate and numerous farm implements, as against a few simple kinds one hundred years ago. The whole system of transportation is almost a new thing within one

FIG. 133. TRANSPORTATION OF LOGS TO THE SAWMILL.
(Courtesy of American Museum of Natural History.)

hundred years. Wood goes into the building of fleets of giant steamships, trains of cars, railroad ties, stations, and also the numerous groups of municipal and suburban transportation systems, and the trucks of private companies.

The cities of homes and the thousands upon thousands of square miles of commercial houses consume enormous quantities of lumber. The factories themselves in their own structures comprise an infinitely great quantity. Then nearly every family takes at least one newspaper, and this is made of wood fiber. Great stretches of forest go into the

Fig. 134. Evergreens and Hardwoods in Adirondacks.
Heavy stand of trees sustained by dense mat of decaying vegetation holding water supply. (Courtesy of The New York State College of Forestry, at Syracuse.)

manufacture of paper. Furniture in the houses and numerous articles of use there are also made of wood.

Our industrial age has changed luxuries into actual needs and has developed new needs not dreamed of by our forefathers. One hundred years ago one small house was enough for a family. Now some families have several, and all of them expensive and very large, besides the hotels and clubs which our greater activities make useful. Luxurious appointments and the need of traveling have their effect in increasing transportation by rail and by automobile. The richer the nation becomes the more things we need or think we need for work,

Fig. 135. Forest too Heavily Cut.

Will lead to wearing down of soil. (Courtesy of The New York State College of Forestry, at Syracuse.)

for leisure and for play. Is it any wonder that the forests have been devastated?

There are two phases in the problem of restoring our forests. One is to make the growth of trees throughout the country at least equal to the quantity used each year and if possible to regain something of what has been consumed in the industrial age. The other phase is to so place the new forests of trees that they will hold the water of the hills and mountains, conserving it in a steady flow for the water supply of cities, for irrigation and for hydro-electric power. The solution of both phases of the problem can be approached at the same time.

It was not until 1875 that the United States began to consider this problem officially. We then began the policy of setting aside certain tracts of forest lands in the domain as permanent forest reservations. In the prairie regions of the middle West not yet claimed by settlers there were at regular intervals quarter-sections of land (160 acres) set aside as "timber quarters" to be planted to timber by a settler before he could receive a deed to his "claim." By far the more effective government provision was in reserving virgin forests.

The setting aside of forest reserves began under the administration of President Harrison, and continued through the second administration of President Cleveland, and the administration of President McKinley. But in the administration of President Roosevelt the movement for forest conservation became a national enthusiasm. Many of the states entered the movement and established their own forest reserves. Municipalities took up the cause of forest conservation, for example, the City of New York which planted young trees around its great reservoirs one hundred miles from the city itself. President Roosevelt's great love of nature and thorough knowledge of its forces contributed much to the effectiveness of the campaign of education for forest conservation. Among other things he did was to request the publication in the National Geographic Magazine of a series of photographs of the mountains of China. These mountains had been stripped of their trees, and the sides were gullied deep with the unchecked torrents of rains. China had robbed itself of its wealth of forests, and had made it possible not only for its wealth of fruitful soil to be washed away, but also to lose its rains in floods that devastated property and caused immense loss in human lives. The misfortune of China was an object lesson.

The principle of forest conservation is not to prevent the cutting of trees, but rather to make the forest produce efficiently, just as we expect a field to produce corn or wheat efficiently. Federal and state forests are leased to individuals and companies. Forest rangers and inspectors employed by the government watch for fires and also to see that the law is not violated. The different species of trees attain their

Fig. 136. California Redwood.
(Keystone View Company, New York.)

maximum growth or their most productive growth, some in thirty years, and some in fifty years. Others require one hundred years to mature. The giant redwoods now standing are known from comparison with those already cut to be not less than two thousand years of age. The age of a tree is ascertained by the number of *annual rings* shown in a cross section. Trees that have done their best should be cut. Otherwise they die and become a commercial loss. Under the most careful management, for every mature tree cut and turned into useful products a young tree is planted in its place. Or at least the natural tendency of trees to scatter their seeds over unoccupied territory is encouraged. Natural reforestation, however, is checked in regions where the government permits companies to pasture sheep and cattle.

No matter how successful the federal and state governments might be in making their forest reserves produce efficiently, our needs would still fail to be met. It has been estimated that to-day we are cutting three times as much timber as we are renewing by growth. Even at that, we obtain great quantities of wood from Canada which is still immensely rich in forests. Our hope will come through the extension of education about forest growing to those who have in charge the great tracts of unused lands or lands that are unproductive of ordinary crops.

It is known that land that will not produce any of the ordinary cereal crops will produce trees. Most farms have parts which are unprofitable to cultivate in ordinary crops, and constitute a waste in the economy of the farm. Agricultural colleges, schools of forestry and the government itself are trying to make it clear to farmers that what are called "wood lots" on a farm not only improve the land, but even yield a considerable profit. If the movement to establish wood lots of several acres on every farm gains headway under the stimulus of scientific agriculture, the chances are good that for a considerable time trees will be made to yield more efficiently than is possible under the non-personal, governmental control of the enormous tracts in the forest reserves.

We are likely to think that forests produce only lumber. At one time that was all they did produce. But our industrial age has worked out many other uses. The wasted tops of trees as well as the logs of the soft woods, such as spruce, poplar and larch, are used in the manufacture of paper. The yellow pine of the Southern states produces enormous quantities of turpentine and rosin. The waste material of saw mills, instead of being thrown into the river as formerly, is now subjected to great heat under pressure in distilling

FIG. 137. ROAD THROUGH ASPENS.

Showing branches seeking maximum of light. (Courtesy of American Museum of Natural History.)

tanks and made to yield large quantities of wood-alcohol, turpentine, formaldehyde, tar, creosote and other less well known products. We may secure all these substances, and still have a residue of charcoal. The science of industrial chemistry may discover other ways to produce wood products useful to man.

Forests are producing richly even under the care being given them. We know, however, that the product of forest trees will be increased still more when we begin to give the same care to forest trees that is commonly given to fruit trees. Trees must have adequate light or they will die. With sufficient light to set in motion the process of photosynthesis in the leaves the tree will grow the more rapidly and yield a greater quantity of wood. If the light admitted to a forest is too great, grass will begin to grow on the forest floor, and the mineral substances needed by the trees will be wasted in growing grass. If grass is grown, there is a temptation to the farmer to allow cattle and sheep to graze in the forest. If this is done, considerable loss is liable to occur, for the grazing and browsing destroy seedling trees and injure other young trees. It requires good judgment to decide whether to be content with less profit on the trees, or a possible gain in the weight of the live stock.

Fig. 138. Forest Observer's Tower. (Courtesy of Wisconsin Conservation Commission.)

High winds, and the ravages of insects, especially tent caterpillars and other insects that attack the plant laboratories, the leaves, cause a loss that cannot be easily determined, but is nevertheless real. Bracket fungi and many bacterial diseases attack trees through wounds they have received. The loss from this source is also considerable. But the losses by fire are the greatest of all, and they can be estimated. It is represented not only in the actual loss of the existing stand of trees, but also in the possible cumulative return of all the years intervening between the fire and the time when complete restoration of the forest can be attained. Even to-day with all the protection we try to give the forests, the destruction of trees by fire in some years exceeds the entire years' cutting.

So important is this matter of protection against fire that

GOING FISHING?

THE FINEST TROUT STREAMS AND LAKES, THE BEST HUNTING GROUNDS AND THE MOST BEAUTIFUL CAMPING PLACES IN AMERICA ARE TO BE FOUND IN WISCONSIN

PRESERVE THE FISHING AND HUNTING IN THE NORTH WOODS BY HELPING US PREVENT FOREST FIRES

LIGHTED MATCHES, CIGARS AND CIGARETTES ARE DANGEROUS. PUT OUT YOUR CAMP FIRES BEFORE LEAVING

KEEP THE FORESTS GREEN **DON'T BUILD BONFIRES**

Wisconsin Conservation Commission

Fig. 139. How One State Advertises the Desirability of Protecting Forests. (Courtesy of Wisconsin Conservation Commission.)

high towers are built on mountain or hill tops for observers. The towers are connected by telephone with the district station. Airplanes are now being used for scouting purposes to supplement the slower process of scouting on horseback.

In the summer of 1908 the author had the odd experience of being in the midst of a serious forest fire in the vicinity of the Tuolumne Redwood Forest in California without realizing at first the menacing character of what appeared to be a small smouldering fire at one side of the mountain road. But soon forest rangers were seen rushing along the road on their horses seeking news about the condition of the fire at some distant point. And suddenly a large pine tree burst into flame in a place where to all appearances there had been no fire at all. Nearby was a ranch house and barns that the rangers said would surely be consumed in a few hours.

The dangerous feature of the fire was the fact that it was mostly underground. Sometimes for several feet beneath the surface a forest fire "mulls" within the mass of semi-decayed pine needles and other decaying or dead vegetation, here and there following a root or air space underground. The tremendous heat released in the slow burning will set a green tree on fire and consume it. A forest fire cannot be extinguished by ordinary means. It must be headed off by burning fire guards in spaces where control can be organized. Or the fire must be "hemmed in" by a roadway, or by a stream. The particular fire observed was threatening the national redwood forest. In the middle of August the fire was several miles from the forest of prize redwoods, like one shown in Fig. 136. The fire did not reach the redwoods, but the rangers were busy six weeks before they were able to completely head it off, and force the fire to burn itself out.

CHAPTER XXIV

PLANT BREEDING

Plant breeding consists of a more or less systematic effort to improve existing varieties of plants and to develop new varieties. Everyone of the cultivated useful plants we have to-day has been developed to its present productiveness by long continued attention to the principles of plant breeding. Among familiar food plants which show the most striking changes from primitive uncultivated ancestors are the apple, the potato and the Indian corn.

For hundreds of years these and many other plants useful to man have been brought out from wild nature into a state of cultivation, and have been improved in numerous ways. But the principles employed by plant breeders for a long time were little understood. Not until the beginning of the present century, when scientific plant breeders came to understand principles of heredity that had been discovered by Gregor Mendel, an Austrian monk (Chapters XVI, XXXIX) did plant breeding as a truly scientific undertaking attain a high state of efficiency. If by patient practical efforts made by fruit growers, gardeners, farmers, and experiment stations we have the vast supplies of plant food and plant products for clothing available at the present time. Our imagination may picture still greater stores of food and clothing when scientific principles are thoroughly worked out and applied. And when the principles of plant breeding are applied to new varieties still reposing untried in wild nature, we may see the development of large additional stores for the future.

Some of our useful cultivated plants may be traced back beyond their recorded history. The white potato came from a species of the genus *Solanum*, a native of Chile. Members of the same genus are the egg-plant, the nightshade and the tomato. The primitive ancestor of the numerous varieties of white potatoes was a plant that had small tubers (a type of underground stem) growing from branches at the base of the erect stem. By some chance unknown to us to-day, this species came under cultivation. The tubers developed as the food storage portion of the plant, and by selection of the specimens that showed desired qualities, the several varieties were created.

Fig. 140. White Potato Plant.
Part of top not showing. (Courtesy of American Museum of Natural History.)

The specialization of the potato has become so great that the seeds are not able to reproduce the species, although many seeds are produced from the well-known white flowers. Reproduction is brought about by planting pieces of potato tuber that bear an "eye" or bud surrounded by bud scales. A new plant develops from the bud.

There are thought to be three European wild species that gave rise to all the varieties of apples, both European and American. The primitive apple may be demonstrated even to-day in actual experience. This is often done accidentally by the growth of apple trees from seeds. The apple seed probably never reproduces the variety of apple from which the seed comes. These "seedling" apple trees generally produce small, extremely sour and unpalatable fruits, and the trees themselves are small.

When more trees of a desired variety are to be created another method of propagation is resorted to. In principle it is the same as creating new potato plants by planting a piece of a tuber. A twig of Baldwin apple, for example, is cut from a parent tree. By various devices this twig may be cut and trimmed to fit the prepared stump of a vigorous young tree that has grown from a seed. The two are bound with gummed tape and fixed in wax to ensure the two parts growing together, and becoming in effect one tree. The new tree is nourished through the roots of a seedling tree, but the fruit borne will be the variety of the top or budding portion. This

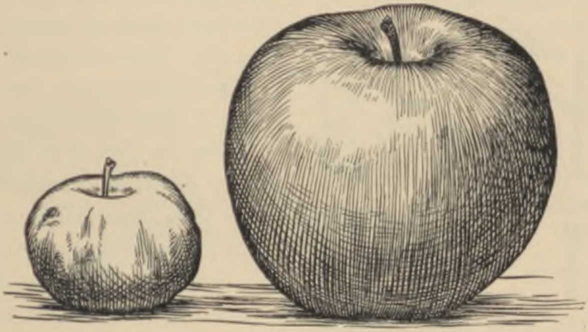


FIG. 141. SEEDLING APPLE AND BALDWIN APPLE.
Showing a common difference in size between seedling apples and grafted varieties. (Drawn by Maud H. Purdy.)

method of propagation of apple trees is called *grafting*. It is employed in many species of edible fruit trees, or roses and other species of cultivated plants.

Plants in many instances are capable of forming new generations without the aid of reproduction by flowers and seeds. Very often a twig may be cut and planted, and a new plant with roots soon established. Well-known examples of this kind are geraniums and willows. The hardwood trees, like oaks, easily regrow stems and leaves from a stump, even in cases where the original tree is quite large and old. However, oak twigs will not produce new trees if planted. Almost any weed will reproduce a complete plant from a portion of a root.

This capacity needs to be possessed by plants that become weeds, on account of the top portion being destroyed so often. Leaves sometimes reproduce the whole plant, as in the begonias. A great number of plants by possessing underground stems, like the tubers, the *bulbs* of onions or lilies, and the *root-stocks* of horse radish, not only start new generations, but also start them quickly by the aid of large quantities of stored food. All of these portions of plants are useful in reproduction in maintaining a measure of stability in the varieties desired when once they have been secured.

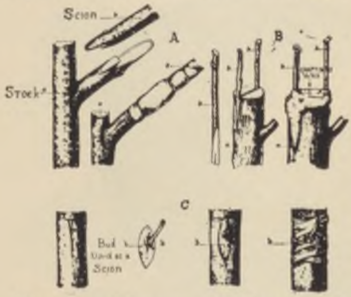


Fig. 142. Methods of Grafting. (Courtesy of American Museum of Natural History.)

Plants, however, are not stable. Variability or the capacity to change is a basic fact in nature. Plants especially are manifesting this capacity in the shapes, sizes and detailed structure of the leaves of a tree, in the markings and colors of flowers, in the size and numbers of seeds in fruits, and it is thought even in the miscroscopic and ultra-microscopic organization of the germs of seeds. Variation is the usual phenomenon in growth and reproduction.

There are many points in connection with the influences in nature that tend to stimulate and modify variations. Some of these points we may easily notice. For example, plants vary in relation to the source of light that reaches them. They vary according to the soil in which they grow, according to the cultivation they receive, and according to the number and kind of other plants growing near them. The determination of what many variations will be lies, in the judgment of some scientists, within the germ of the seed itself.

Another occasion for variation in plants is observed in their need of adapting themselves to different conditions of all sorts. Some of these conditions may be quite unusual, such as a considerable change of climate with differences in soil and amount of water. The capacity of the plant to adapt itself to the new conditions may be demonstrated in the appearance of plants that look quite different from those inhabiting the customary place.

Experimentation has shown that sexual reproduction in plants brings into existence a flood of variations. These variations are doubtless induced by combinations of the

FIG. 143. BEGONIA LEAF WITH ROOTS.
Roots growing from cut areas. (Drawn by Maud H. Purdy.)

characteristics of the male and female cells taking part in the process. This variety of result is the more likely to happen if the uniting cells originate in entirely different plants of the same species.

Those who experiment in producing new varieties of plants know the foregoing facts. They take advantage of the facts and are constantly on the lookout for new variations in the direction they desire development to take. Although the variability of plants is the factor on which the experimenter works, yet it is what the experimenter *thinks* he is striving for that really commands the situation. What he thinks, of course, is limited by the probable ultimate capacity of the species of plant to become.

It would be incorrect to say that all the plant breeder has to do is to think out what he desires, and then to proceed to manipulate the adaptable plant, and finally accomplish the end sought. Plants occasionally vary in large and conspicuous ways. Variations sometimes appear of so striking a character as to look like a new species. In fact, the observations of the Dutch botanist, DeVries, on the variations in the evening primrose indicate clearly that new species arise often by way of large, rather than by small differences from

Fig. 144. Mountain Pine in the Tyrol.

Showing effect of high altitude on growth of vegetation. (Kerner & Oliver: *The Natural History of Plants;* Henry Holt and Company.)

the regular form or *type* of the species. These sudden appearances of large variations called *sports*, easily serve as the basis of further progress in the creation of varieties. They would also tend to modify what an experimenter might *think* as the end sought. One of these sudden and unexpected variations became the "wealthy" apple. Once the wealthy apple appeared, the problem would be to retain it as an established variety. In the case of a new variety of apple this is not so difficult an undertaking as it might be if it were necessary to depend on sexual reproduction for new generations. Grafts continue the variety. But there is a strong tendency for sports to hold more or less firmly to the new character, once it has appeared, even where sexual reproduction is the method of propagation employed.

Nevertheless, variation is so common a factor in plant life that nothing can be left to chance in plant breeding. The experimenter may desire to hold firmly to an attained variety. In that case he must eliminate all variations that tend to dissipate and scatter the qualities he has strived to establish.

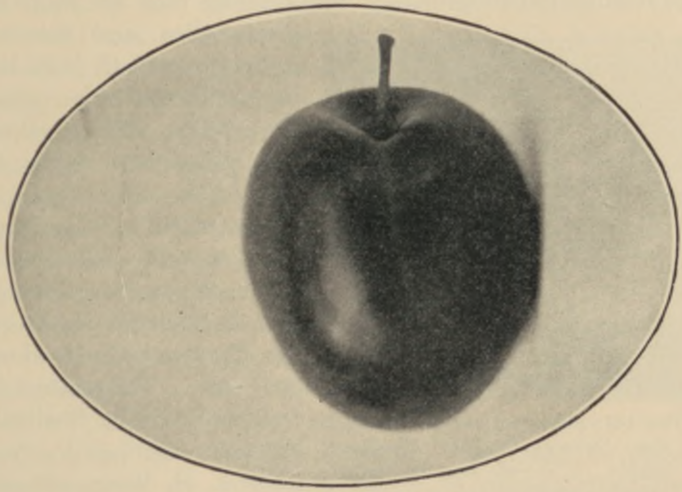


FIG. 145. PLUMCOT FRUIT.
(From Harwood: *New Creations of Plant Life;* The Macmillan Company.)

It may be that he is hoping for certain improvements on what he has already attained. If that is true, he must be on the watch for characters that point in the desired direction, and he must eliminate by destruction or separation the plants that are varying in unprofitable directions. It is said that Mr. Luther Burbank, the well-known California experimenter, possesses phenomenal skill in detecting the undesired variations early in the life of the individual plants, and saves much time by getting rid of them at once.

The name of Burbank is connected with a number of new varieties of plants created by applying certain principles. One principle he applies is *hybridization*. This is the crossing of species. This principle has often been used, because it releases a great number of variations some of which may be valuable. Burbank's most famous experiment in this line was in the production of the plumcot, a hybrid of the plum and the apricot. The method employed in hybridization is to remove the stamens of a flower before they are ready to yield pollen, and then to protect the pistil from being pollinated by covering the branch with a paper bag. When the stigma of the pistil is ready to receive pollen, pollen is taken from the flower of a plant with which crossing is desired, and the pollen is dusted on the stigma, and covered up once more. The method of work followed by Burbank has been described by Professor L. H. Bailey of Cornell University, who himself is a successful experimenter with plants. In "Plant Breeding" Professor Bailey writes of Burbank: "He cultivates with personal care, multiplies the stock to the limit of his capacities, scrutinizes every variation, hybridizes indiscriminately, saves the seeds of the forms that most appeal to him, sows again, hybridizes and selects again, uproots by the hundreds and thousands, extracts the delights from every new experience, and now and then saves out a form that he thinks to be worth introducing to the public." The quotation will serve to give the student an idea of

Fig. 146. Branch of Spineless Cactus. Showing the effect of reserve supply of stored food in cactus. (Photographed on shed in garden of Luther Burbank.)

the method of work of most other experimenters in this line.

There are three objects in the minds of plant breeders that are of wide application. The first of these is the improvement of existing types of plants; the second is the creation of new varieties; the third is the breeding for what are called "unit characters" that have each in itself a particular value. The first two have been discussed. The third object has had its best consideration under the stimulus of the scientific work of Gregor Mendel (Chapters XVI, XXXIX). Mendel's experiments showed that characters are inherited singly, or as units, their presence or absence in a generation not being influenced by the presence or absence of any other character. For example, a head of wheat could be short and bearded or long and bearded, or short and smooth, or long and smooth. The unit character of resistance to rust, or of resistance to drought would follow the same rule. However, by means of hybridization between varieties new varieties of wheat or other plants can be produced that are adapted to particular regions. In this direction important progress is being made.

Thus, plant breeding has its purely technical basis, as well as its social and economic bearing. There may be plant breeders who are interested chiefly in manipulating the plastic organization of the plant. But the response scientific students may expect from the people is based on their success in making scientific work in plants contribute to the welfare of mankind.

CHAPTER XXV

THE FARM, A COMPREHENSIVE BIOLOGICAL UNIT

The indication that the farm is a biological unit is to be found in the story of pioneer life in America. It was a biological unit for man at that time. It still is a fundamental grouping of biological factors in the life of mankind. By the term biological unit we understand a group of organisms, plants and animals, living in nature entirely or in part in such relation that the life of one kind contributes to the life of other kinds.

On the pioneer farm the family was surrounded by primitive nature. The forest produced lumber or logs and shingles for the house, the barns and other structures. From certain species of trees the primitive farmer also obtained dye-stuff, as from the inner bark of the yellow oak, tanning agencies for the preparation of leather, as from the hemlock bark, medicines, as from the root bark of the sassafras tree and from numerous annual plants. From the ashes of all trees he obtained the lye by which animal fat was made into soap. From the bark of hemp, rope was made; from the bark of the flax plant linen was made. Whether the wood of the farm was burned or whether it rotted, the mineral compounds in it in time became a portion of the soil again, thereby maintaining the resources of the soil.

Within the forests numerous species of animals lived. In some instances these animals served as food for man. Of these there were rabbits, squirrels, grouse. Other animals lived upon the animals and plants in nature, and sometimes on the organisms which man was engaged in protecting for his own use and profit. These preying animals were foxes, wild cats, bears.

The forest harbors many other species of animals and also species of plants. The living together of all these species create numerous biological situations of interdependence. For example, the birds live under the protection of the trees and the underbrush. The shadows and the material of the forest help to conceal them. In the branches and in protected places the birds lay their eggs, and bring up their young.

In the forest also are to be found at least a portion of the

Fig. 147. The First Clearing in Plymouth Colony. From Drawing showing Governor Bradford's House. (© Keystone View Company, New York.)

food on which the birds live. Insects live on the forest vegetation, and are preyed upon by the birds. Certain species of birds sally forth to the adjacent fields, preying upon insects which otherwise would prey upon the farm vegetation, the gardens, the field crops, the fruit trees and their fruit.

When the first farms were carved out of the wilderness the cultivated patches frequently produced scantily, because ground that produces trees is often too poor for farm crops. Besides, there are numerous stumps which made cultivation tedious work. The plowing and the cultivation of the farm crops stirred up and covered over the mass of partly decayed leaves and other débris which were spread over the forest floor. When this became thoroughly transformed into mineral compounds, and when the farm crop remains themselves were rotted, the soil was more adaptable to the successful growth of crops. The powdered earth also served as a retaining blanket for the moisture below. Excessive organic débris tends to the formation of excessive quantities of humus

FIG. 148. IMPROVED FARM.

Showing variety of productive vegetation. (Keystone View Company, New York.)

acids. These are counteracted by the lime thrown upon the soil. Thus "sweetening" takes place, and more successful cropping.

After many years of farming in the clearing grounds, the forests gradually disappeared, the change being accompanied frequently by considerable waste of organic wealth. Then the richness of the soil sometimes began to fail. The crops that the land produces were often carried far from the land, as when hay was sold in the city, or when corn, wheat and rye were carried to market. And also when corn and hay were fed to the farm animals, the inorganic riches of the soil were in part transformed into organic tissue in the animal, and in part were cast out from their bodies as indigestible material.

The soil then had to be restored to its former condition. This was done by means of spreading various kinds of fertilizer on the soil, and subsequently plowing it in. The maintenance of the mineral compounds in the soil is done sometimes at considerable cost, but the results usually justify the expenditure.

Whatever the source of the fertilizer, the chemical compounds formed in it are what the soil lacks, or has lost. In a sense, therefore, what has been carried away from the soil through the crops sold or eaten up by domesticated animals, is now returned to it. Such fertilizers as barn manure, and some forms of commercial fertilizers made from the wastes of *abattoirs* (places where food animals are prepared for the market) make the biological return to the original soil source.

It is an interesting fact that a farm which is organized to yield the most satisfactory income is one on which the food produced is consumed there by the farm animals. The test of this is observed when a farm product, such as corn, is so cheap that it does not pay to raise it if it is to be sold and carried away. But if the corn is fed to hogs, on the farm, there is a profit made on the corn when the hogs are sold in the market. Likewise, when hay or rye are raised, it is more profitable to have horses, cattle and chickens (Chapter XVI) on the farm eat what can be eaten by them.

There is another charge against the cost of living eliminated, if in the process of making the farm create food for animals to consume, there are enough varieties of plants produced to maintain the varieties of food required by man himself. In primitive days this was nearly possible even in temperate regions. The chief reason it is not possible to-day for the farm in temperate regions to produce what a family requires in food is because our needs, fundamental and those that develop by the extension of our likes, have increased enormously. Then, too, farming itself has become specialized in some regions so greatly that the biologically balanced farm is not as common as it was once. We now have potato farms, wheat farms, strawberry farms or general garden vegetable farms, and only enough animals to care for the heavy work, and even the horses are often replaced by the gasoline tractor.

Fig. 149. Dispersal of Dandelion Fruits. (Courtesy of American Museum of Natural History.)

One of the conspicuous factors in the life relations on a farm is the dispersal of fruits and seeds. All the cultivated varieties have seeds that require the hand of man to distribute. The seeds of trees are dispersed by the wind or by animals, pines and maples by the wind and the heavy nuts by squirrels chiefly. The plants which are known as weeds attain a large measure of their success by the fact that their seeds are dispersed widely by the wind and by sticking to the hair of farm animals.

But no matter how satisfactorily the biological balance is maintained on a farm, there is more food produced than can be consumed there. This food finds its way to the market. Its function is to feed animals and human beings. There is no other reason for producing food. If the farmer who produces this food for a use so important is not fairly compensated for his work of creating the food, it may be because some other groups of persons are trying to secure great reward for performing some minor service, or for no service at all. There are those who live honestly by carrying food from

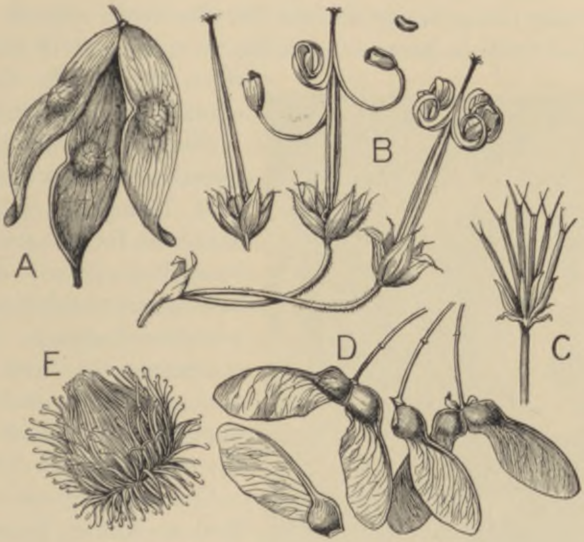


FIG. 150. DISPERSAL OF SEEDS AND FRUITS.

A, ailanthus; *B*, wild geranium; *C*, bidens; *D*, maple; *E*, burdock. (From Kerner & Oliver: *The Natural History of Plants;* Henry Holt and Company.)

the farm to the consumer and distributing it. But there are many others who exist as economic "parasites" on the sustenance created by those who actually work; that is to say, there are numerous food brokers and speculators in the necessities of life.

One effect of the existence of numerous groups who try to make a profit on the product of the farmer's labor is to force him to accept less for the fruit of that labor. The outcome of all this with the resulting high cost to the consumer is to stop the flood of plenty at its source. An intelligent farmer will cease producing food which it does not pay to create. He will try his hand at making special kinds of food the price of which seems to be more satisfactory. In any event the quantity of food for the lower animals and ourselves tends to decrease, and the price tends to be higher, when the supply should actually be unlimited.

FIG. 151. GRINDING WHEAT IN THE GREAT MINNEAPOLIS MILLS.

The broken particles of wheat are ground fourteen times before the process of grinding is completed. Diagram shows steel rollers at work. (Keystone View Company, New York).

The farm is without question the most important biological unit in existence, for reasons that have been given. It is also an extremely important social agency. This is because the farm creates, transforms and renders available, food for the race of human beings.

Consider wheat. A field in Kansas is sowed to wheat in the fall of the year, or in the spring. In June, or July, the crop is ready for cutting. The harvester or binder reaps it. In either case the wheat is soon threshed, and the bushels of grain are stored in the farm granary or taken to the railroad for shipment, or stored in an elevator storage house, or shipped abroad. In time the wheat reaches the great milling center of Minneapolis, Minn., or European mills, where the various grades of flour are made. Transportation systems carry the flour all over the world.

On account of the universal need for bread, the creation of food through the sowing and the growth of wheat is among the most important social activities known. Perhaps if boys on the farm realized how necessary the functions of the farm are to the very existence of millions of men, women and children they might come to be inspired by the thought of their opportunities. There would seem to be no greater source of inspiration than the consciousness of creating something that all the rest of mankind needs. Thus, it is possible for the farm to be the medium through which a boy or a girl may be educated.

Once in a while we marvel that some of our leading citizens spent their early life on the farm, and, incidentally, had little opportunity to attend school or college. Perhaps many of us have accepted without question the notion that education consists in occupying a seat in school more or less steadily for eight to sixteen years, and then entering upon adult life with the limited capital in experience thus acquired.

Life upon the farm offers a well rounded series of experiences. There is a theory of education that emphasizes the training of the senses. The farm affords experience material, and offers demands for the use of every one of the sense organs, especially the eyes, the ears, and the organs of touch. There is a theory of learning which stresses the discipline of the hands together with the correlation of these parts with the brain, and the reaction of the great muscles and the body as a whole to the factors in the environment. The farm offers a multitude of experiences in this field. It is conceivable that a farm boy or girl may go through life more or less ineffective and helpless. But at least the opportunity to master the environment is available, and the stimulus to gain control of its elements exists in the necessity to live under conditions that are sometimes hard indeed. Yet in spite of all these opportunities boys and girls have left the farms in large numbers, as soon as they were able to look after themselves. This has been a social problem of great concern to the country. As we see, it is also a clearly biological problem.

The creation of food and the organization of productive relations on a farm cannot well be carried on by those who are content to stay on the farm while, as often happens, the more intelligent, independent and aggressive boys and girls go to the city "to seek their fortunes." There is need of the highest intelligence among those who create food, clothing and shelter for mankind and thus make it possible for human beings to enjoy life, and work toward a higher civilization. There have been many "back to the farm" enterprises organized, but the problem is not yet solved.

The farm cannot compete with the city in the variety of entertainment available. Hence, it will not help to try to outdo the city in this direction. Boys' corn clubs have been organized, and wonderful results have been obtained by the members of these clubs in producing quantities of corn several times greater than those obtained in general farming. This enterprise has interested a great many boys. But it has also served to intensify the burden which constitutes the chief objection to farm life. This objection is hard, grinding work.

Even the very men who, after attaining eminence in public life in the city, look back with enthusiastic recollection to their boyhood on the farm, actually left the farm because they could not endure the thought of wearing their lives out struggling as their fathers had done. The recollection of the gruelling work, like other unhappy experiences, had been softened by time. The really inherent features of native charm had stayed in their recollection at their true value.

In the city, in commerce and in industry, the eight-hour day is accepted as proper and right by most employers. The farmer rises at five o'clock in the morning, and immediately begins work at making fires, feeding the live stock, milking, and in going over machinery in preparation for the day's work. After breakfast he starts on the regular farm work of plowing, sowing, cultivating, or other of the numerous activities of the farm. In the city at the same time of day the machinist is barely on his way to work, while the pro-

FIG. 152. FARMER BOY BRINGING IN WOOD BY LANTERN LIGHT.
(© Keystone View Company, New York.)

fessional man is sitting down to breakfast, or just getting up.

About noon, with a glance at the sun, the farmer "turns out" for dinner. And the horses have their dinner. At one o'clock he is at work again, continuing till sundown, or about seven-thirty or eight o'clock. The horses are fed, and "bedded" for the night. After supper, or before supper, the other farm animals are fed, the cows are milked, wood is cut and carried in, and everything put in shape for the night,—everything but the farmer himself—for he has not had time to rest, or to read the newspaper. Books he never sees, except their backs in the unused bookcases. Altogether he has worked,—have you ever counted it up and wondered how he stood it?—he has worked from twelve to fourteen hours. And yet we all know farmers who are still hard at work at seventy years of age. There must be something about farm life that keeps them up. There is, but why do they deprive themselves of all the joy of living? says the intelligent boy who has made up his mind to "clear out" for the city.

After all, perhaps the farmers may work out the problem themselves. As a group of workers they can quit going without the happiness of life whenever they give thought to the reasons why they are obliged to work so hard, and get so little for it.

CHAPTER XXVI

OUR RESOURCES IN FOOD

Grain Products.—The important grain products in this country are barley, buckwheat, corn, oats, rice, rye and wheat. Altogether they represent about one-half of the entire value of all our farm products. Of these grains corn is the most important in point of economic return, and barley is the least important.

Barley is grown mostly in the North Central States and in California. As "pearled barley" it is used in soups. Barley flour is dissolved and used as a food for babies in illness. Another use for barley is as a source of fermentable sugar. This is obtained by causing barley to sprout, in which condition an enzyme present in the grains changes starch to sugar. The fermenting sugar is called malt. Malt is modified to form various medicinal compounds, and in brewing certain alcoholic liquors. Barley grains are about the size of wheat grains.

Buckwheat seeds are also about the size of wheat grains, but are three-angled in form. The blossoms are much frequented by honeybees. Fifteen to twenty million bushels are raised yearly, not a great quantity, but as a winter food buckwheat cakes are much prized.

Indian Corn has been called King Corn because of its preëminence as a food, not altogether for man, but mainly for cattle and hogs. Corn is the most important single crop raised in the United States. As stated in Chapter XXI the chief value in corn lies in the fact that the grains are easily transformed into marketable pork and beef by way of the hogs and the cattle that eat the grain. Just as one will find

Fig. 153.
Stool of Buckwheat.

Fig. 154.
Stool of Rice.

(Drawn by Maud H. Purdy.)

the iron and coal industries occupying the same territory for reasons of industrial convenience and economy, so the distribution of hogs and corn are almost identical, especially in regions where they exist in the greatest numbers. This is in Nebraska, Iowa, Illinois, Indiana and Ohio. From 85 to 90 per cent of the corn crop is fed on the farms.

The quantity of oats raised in the United States is about

FIG. 155. FIELD OF RICE IN TEXAS.
(© Keystone View Company, New York.)

one-third the quantity of corn raised. It is a favorite food for horses whether in America or Europe. In America, at least, oatmeal is perhaps the most commonly used breakfast food. Incidentally, it contains all the nutrients (chemical classes of foods) present in other cereals, with a high percentage of oil. It is an interesting fact that we eat far more oatmeal in the winter time than we do in summer time. The body hunger adapts itself to using this cereal mostly in winter partly to use the oil as an added source of heat energy.

Rice is being cultivated in considerable quantities in the

FIG. 156. STOOL OF OATS. FIG. 157. STOOL OF WHEAT.
(Drawn by Maud H. Purdy.)

states of Louisiana and Texas. Perhaps about twenty-five million bushels are produced in the United States. Rice is sold in two forms. One is the white "polished" rice that most persons are accustomed to seeing; the other is the brown or unpolished rice. The white rice in India, China and Japan, where it forms an important portion of the food of everyone, is now believed to be responsible for the prevalence of a disease called *beriberi* (see p. 348). The polishing of rice removes some important mineral and other compounds that are saved in the brown or natural rice. Moreover, the brown rice is thought by many to be more palatable anyway. Even so, the quantity of brown rice eaten is very small, so firmly fixed are some of our habits of selecting foods.

About thirty million bushels of rye are produced in the United States yearly. This is about one-twentieth the quantity of wheat produced. About one-third of the rye produced is used to manufacture rye flour. The remainder is used as food for domestic animals. Rye bread is excellent, quite as good in every way as the best wheat bread. Probably the brownish color causes many persons to shun it. Children generally like rye bread, especially when the meaningless caraway seeds are not included.

Wheat is the most important grain we have for bread-making purposes. It stands second to corn in the quantity produced, being nearly one billion bushels yearly, but stands first in the quantity actually sold and shipped away from the farms where it is grown. North Dakota, South Dakota, Nebraska, Kansas and Minnesota are the most important wheat-producing states.

FIG. 158. LONGITUDINAL SECTION OF WHEAT GRAIN. *en*, endosperm; *cot*, cotyledon; *pl*, plumule; *r*, radicle; *em*, embyro. (Drawn by Maud H. Purdy.)

There is a great deal of discussion about the relative value of the different kinds of wheat bread. This is partly due to the fact that the white appearance of flour suggests that only starch is present. As a matter of fact, protein (the muscle, and other tissue-forming class of food compound) is distributed throughout the mass of the wheat, although largest in quantity in the *aleurone* layer, just beneath the bran layer.

The old fashioned method of grinding the wheat between the rapidly turning millstones made possible a classification of the product into white flour, "middlings" and bran. The white flour did contain less protein and less mineral substances than the middlings. The middlings were considered inferior. This was sold for much less than was the white flour. The three classes of product were separated by the cylindrical sieve or "bolt" of silk of differing mesh.

With the introduction of the system of crushing the wheat by rollers, and the duplication of numerous systems of rollers for crushing and "granulating" the hard *aleurone* layer, it was possible to produce a flour, called "patent" flour, which gave the desired whiteness, and at the same time prevented the great waste incident to the manufacture of the old-fashioned "middlings." Patent flour is bolted, and the bran separated from the remainder.

Graham flour, unbolted, and entire wheat flour, bolted,

FIG. 159. REAPING OATS.
(Keystone View Company, New York.)

owe their color to the presence of the particles of bran. To produce Graham flour and entire wheat flour is really less costly than to make patent flour, but owing possibly to the smaller demand and to the cost of advertising it, the bread from these two kinds of flour is more expensive than is white bread of good quality. As a matter of fact, however, the dark breads have a higher protein content as well as mineral content than are found in white bread. But experiments on the digestibility of breads show a much higher percentage for the white breads than for the dark breads. The lower percentage of digestibility of the dark breads is probably due to the fact that the bran is digested with difficulty, or not at all. The meaning of all this is that there is little to choose between the white bread and the dark breads. Some persons like dark breads because of their effect on keeping the large intestine in active condition. But there are those who do not require this stimulus; others are affected unfavorably by it.

FIG. 160. THRESHING WHEAT.
(Press Illustrating Service, New York.)

Vegetables.——The term "vegetable" is a general one, and is not technically accurate. Under it are included seeds, such as beans and peas, fruits, such as tomatoes, leaves, like spinach, stems like asparagus, buds, like cabbage, bulbs, like onions, roots like carrots and sweet potatoes, and tubers, like white potatoes.

The quantity of these plant products is unknown, as also is the money value, but both are very great. The consumption of vegetables is undoubtedly increasing rapidly on account of the understanding the people are gaining of the need

Fig. 161. Some Descendants of Brassica, the Wild Cliff Cabbage.

A, wild cliff cabbage; *B*, broccoli; *C*, kale; *D*, kohlrabi; *E*, brussels sprouts; *F*, common cabbage; *G*, cauliflower. (From Gager: *Fundamentals of Botany;* P. Blakiston's Son & Co., Philadelphia.)

of vegetables in their bills of fare. New kinds of vegetables are created by experimenters in plant breeding. A good example of this is the near family kinship known to exist between kohlrabi, cauliflower, cabbage and Brussels sprouts, all having originated from an uncultivated plant somewhat resembling the cauliflower (Fig. 161).

Another factor that will operate to increase the production and marketing of vegetables is the considerable profit the business insures. With the development of cold storage systems, and also with the extension of the alternation of cropping periods in the South and in the North, the enterprise of supplying vegetables will become very important.

Beans and peas are grown in enormous quantities as green vegetables in the whole pods, and as dried seeds. We produce of the two annually about twenty-five million bushels as dried seeds. Both are also canned extensively.

White potatoes give an enormous yield in this country. Perhaps five hundred million bushels are now produced each year. The yield is steadily increasing. Potatoes are so important a food serving as a companion food for meat, that it may well be wondered how our ancestors got along without them before their discovery in America. The chief ingredient in the white potato is starch. Protein and fat and mineral products are present in very small quantities.

Sweet potatoes are grown in relatively small quantities, being chiefly a product of the Southern States. They are similar to the white potato in composition except for having about eight per cent of sugar.

Other vegetables are produced in undeterminable quantities. The quantities available for the table depend on the season, and also on the price, curious as the latter point may appear. After all we must remember that the reason we may have green vegetables when we want them is that some one finds it profitable to supply them. We pay for what is delivered, and at what is called the market price. If by any chance the market price is very low, it does not mean that we shall be able to order freely for some time. The price may be so low that it does not profit the distributers to handle the product. Vegetables have been allowed to rot, or have actually been thrown into the sea to create a shortage, a condition that will cause the price to rise again. If the vegetables can be put into cold storage, the effect on the price

FIG. 162. SWEET POTATO PLANT.
(Drawn by Maud H. Purdy.)

will be the same. But whatever is done, the decision depends on relative costs, and whether it pays. The two groups of persons who are liable to suffer from these phenomena of the market business are the producer who may be obliged to give hard service and lay out money, getting little or nothing in return, and the "ultimate consumer," the person who pays for the vegetables for his family.

The business of food distribution is characterized by having a large number of "middle men," some of whom perform very little service, taking meanwhile a little profit, passing the vegetables along for the next man in the line of "profiteers."

Fruits and Nuts.—This subheading is somewhat misleading because nuts are practically all fruits. The fruits here indicated or implied are soft fruits.

Every state in the Union contributes to the enormous total yield in value of fruits and nuts. North Dakota, Wyoming and Nevada yield the least, California the most.

FIG. 163. EVERBEARING STRAWBERRY PLANT.
(Keystone View Company, New York.)

But New York, Michigan, Pennsylvania and Florida also yield tremendously.

The classes of fruits recognized in the markets are small fruits, orchard fruits, grapes, citrus fruits, nuts, with peanuts in a separate class. The value and the yield of all these plant products are steadily increasing. Their value has now reached the total of hundreds of millions of dollars. Strawberries represent about three-fourths of the total value of all the small fruits, followed in order of value by raspberries, blackberries, currants, gooseberries and cranberries.

Orchard fruits are five times more valuable in the amount yielded than are the small fruits. The apple, of course, is by far the most important orchard fruit. About two hundred million bushels of apples are produced in the United States annually.

Of the citrus fruits oranges are the most important in value. About twenty-five million boxes are produced yearly. Lemons come next in quantity. Grape fruit is being grown in increasingly larger quantity every year. But the cost is still

Fig. 164. Lemons Going to Waste.
Permitted to rot in California because their sale in East would not pay for freight charges. (© Keystone View Company, New York.)

too great per fruit for families of moderate income. Indeed, the fruit itself is too large except for formal dinners.

In the fruit-growing industry a portion of the problem of production and distribution has been worked out. The California Fruit-growers Exchange is a federation of co-operative associations of fruit-growers. These associations build packing-houses in which the fruit is brought together, graded, packed, and marked for shipment. The charge for this work is based on the number of crates each grower sends.

The fruit trees are pruned and fumigated, and valuable information relative to the growth of fruit and to markets is supplied at the cost of the service.

At one time about $1,000,000 worth of oranges and lemons were lost yearly by decay on the way from California to the Eastern markets. This has been eliminated by the introduction of scientific methods of picking, handling and "precooling" the fruit. Precooling consists in cooling the fruit at 30° F. before shipping, loading in refrigerator cars, and shipping with a supply of ice to carry them to any part of the country.

FIG. 165. CUTTING CANE IN CUBA.
(Keystone View Company, New York.)

Sugars.——There are several chemical compounds that go by the name of sugar. The principal one is called *cane sugar*, because it has come to be identified with cane as its chief source. It is also found in commercially valuable amounts in the sugar beet. In small quantities cane sugar or *sucrose* is found in the fruits and stem juices of many plants mixed with glucose or fructose (fruit sugar).

Cane is a plant that has been known to civilization from the earliest time of recorded history. In our territory it is grown in some of the Southern states, in Porto Rico, Hawaii, and in the Philippine Island. Cuba, however, is the country that produces the largest amount of sugar.

Cane is produced by planting in furrows the tops of the stalks of the preceding year's plants. Young plants sprout from these and grow one or two years before the stalks are ready to cut. When the crop is ready the stalks are cut close to the ground, stripped of the leaves and the green tops cut off.

The sugar cane is hauled to the factory where it is passed through sets of corrugated crushers and rolls to crush free the juice of the stalks. From 11 to 16 per cent is waste fiber, used to burn and help operate the factory.

The processes of evaporating the juice, crystallizing the sugar, refining or removing the molasses, filtering, evaporating again, crystallizing again, are all involved with many intricate steps and minute attention to chemical and physical details.

About three million tons of sugar are brought into the United States annually. Nearly all of it is refined here. We are able to produce only about one million tons in this country.

Fats and Oils.——Fats and oils are from both plant and animal sources. Butter comes from milk, oleomargarine and lard from meat fats, corn oil from the germ of the corn grain, olive oil from the olive fruit, cocoanut oil from the cocoanut, cottonseed oil from the seeds of the cotton plant. Of all these sources of fat, butter is not only the best known, but it is also by far the best for all purposes.

Over one and one-half billion pounds of butter are made in this country in one year. Until about the time of the Civil War butter making was entirely a household industry. Now nearly one-half the butter made in the United States is made at creameries. Dairy farmers may prefer to specialize in furnishing cream for creameries instead of making the butter themselves, or instead of shipping the milk to the headquarters of the great milk distributing companies. Whether one or the other is done may depend on the situation of the farm. Farmers may use a cream separator for separating the cream from the remainder of the milk, and send the cream to the creamery.

On a large scale butter is made by means of "combined churns" which churn the cream, gather the butter, wash it, salt it and "work" out the whey without exposing the butter to the touch of hands or to contact from flies.

Butter keeps better in earthern jars, but on account of the great weight of such jars, tubs of spruce are commonly used except when butter is molded into "prints." The tub butter is just as good, and costs retail about 5 per cent less.

Butter contains on the average about 84 per cent of fat, 12 per cent of water, over one per cent of curd, and about 2 per cent of salt and ash (minerals from the milk). Besides, it contains what is called a *vitamin* (see p. 350) an important substance not found in artificial butter.

Oleomargarine is a name applied to a butter substitute that is made by churning beef fat with milk or cream to a butter-like emulsion. Legislation compels merchants to state the exact nature of butter substitutes, as well as to sell the butter color separate from the substitute. The amount of oleomargarine sold is only about 2 per cent of the total value of the butter sold. When the superiority of butter is fully understood even less than 2 per cent may be expected as the sale of this substitute. Other butter substitutes are cottonseed oil, cocoanut fat and peanut oil.

Olive oil is not used in the United States so extensively as it is in certain European countries. We produce nearly a half million gallons, and import five million gallons yearly. The chief use of olive oil is as a dressing for salad.

An important cooking fat is lard, the fat of hogs. We manufacture and export tremendous quantities of it. There are many substitutes for lard. These are mixtures of beef fat and cottonseed oil. Commercial forms of cottonseed oil are

FIG. 166. OLIVE TREES IN CALIFORNIA.
(Keystone View Company, New York.)

hardened to resemble lard. Corn oil is a liquid fat that is becoming very popular as a cooking fat.

Meats.——The industry of meat packing is the greatest single manufacturing industry carried on in the United States. It exceeds by many millions of dollars annually the industries of foundry and machine shop products, and the lumber industry. And this estimate takes no account of the meat prepared for the market by local butchers or on farms.

The center of the pork-packing industry is at Chicago, a fact that in part is determined by the nearness of the great corn fields of the middle West. At the same time it is the center for the distribution of most other meat products.

Beef, pork and mutton are prepared at the establishments in Chicago, Kansas City, Omaha and other places with a high degree of efficiency and swiftness. The spoiling of meat is largely prevented by an elaborate system of chilling in cold storage rooms a few minutes after the animal is killed. When meat is to be kept a considerable time or sent a long distance it is thoroughly frozen. For example, we import frozen mutton from New Zealand, and export frozen beef to distant parts of the world.

The federal meat inspection law of 1906 provides for the inspection of all packing houses, and all animals before and after slaughter. Carcasses that are found to be unfit for food are condemned. As condemned meat the carcasses may be transformed into fertilizer.

Meats are the great sources of protein and fat. Meat food is prepared in every conceivable form as fresh meat, canned meat and dried meat. Meats are the most expensive forms in which the compounds occur anywhere, but a little meat appears to be necessary as a portion of human food.

The net cost of lean meat is highest in the cuts that command the highest price per pound. The cheaper cuts supply lean meat at one-half or less than one-half the cost of the expensive cuts. In reality the cheaper meat is as good as the more expensive kind.

Milk.——Attention has been called by scientific authorities to the fact that milk is the one article of diet the sole function of which in nature is to serve as food. For the great class of mammals milk is the food which the mother animal provides for its young. Man is the only species which levies on other species for this food for his own use. We should note the fact, however, that through man's attention to the selection of favorable variations in cattle there exist varieties of cattle to-day that produce far more milk than their own young require.

It has been estimated that on the average each person in the United States consumes from one-half pint to one-third of a quart of milk a day. This may amount to as much as 35,000,000 quarts a day for the entire country. At ten cents a quart, the daily bill for milk would be $3,500,000.00. Yet few are thoughtless enough to want to reduce that bill. The value of milk lies in its completeness as a food product. It contains a high percentage of water, but fat, protein and milk sugar are present in about equal percentages. In addition, there is the *vitamin* compound described on p. 350, without which the young of animals would never grow, no matter how much milk they might consume.

Fig. 167. Mechanical Milker at Work. (Keystone View Company, New York.)

A good milch cow will yield two gallons of milk per day for eight months of the year. Many high-grade cows produce six to eight gallons a day. By proper selection of varieties and by care and good feeding, the yield of milk is maintained.

Under the best conditions cows are inspected for signs of disease. Stables are kept clean, and free from sources of possible contamination. All utensils employed in connection with handling the milk are kept clean by steam or boiling water.

Milking is now done by mechanical milkers. These hasten the period necessary for milking and reduce the chances of the contamination of the milk. When they are not used the need of the personal cleanliness of the men in charge is greater. Municipal inspection of the conditions under which milk is produced reaches out to the great dairy farms, and does effective work in protecting the lives of those in the city who consume the milk.

The inspection of milk extends to *lactometer* tests, as well as temperature tests, by which adulterations may be detected and indications of the presence of large quantities of bacteria ascertained.

Eggs.——On account of the fact that most of the interior of the eggs of birds is a rich food substance set aside as nourishment for the young, it is natural for other species to find in eggs nourishment suitable for themselves. For that reason the eggs of birds are much preyed upon.

It has been estimated that nine-tenths of all the farms in the United States keep chickens. The Eastern half of the country is bountifully supplied; the Western half more scantily supplied.

In the months of March, April, May and June eggs are shipped in the largest quantities. In these months large quantities of eggs are placed in cold storage, to be sold later when the prices are higher. But when they are sold it is at a price several cents a dozen less than the current price for fresh eggs.

Eggs are graded for the market according to freshness, size and color. Freshness is determined by "candling." This is a term derived from the old fashioned practice of holding an egg up against the light of a candle. The test is more effectively made by placing the egg in an aperture beneath which is an electric light bulb. A fresh egg shows a small air space at the round end. An old egg shows the air space much enlarged. If there are "spots" or fungus growths, these are also shown by the candling test.

When eggs are cheap some persons immerse large quantities in jars containing water glass (sodium silicate). The chemical seals the pores of the eggshells, and thus prevents the entrance of bacteria or the spores of fungi. These eggs cannot be boiled, however, without breaking, on account of the closed volume of air within the egg. Besides, it is some

FIG. 168. FRESH EGGS AND STALE EGGS.

1, 2, 3, quite fresh; 4, 5, 6, showing gradual shrinking of egg contents, leaving air space above; 7 to 12, interior molds growing in egg contents; 8, a broken egg, with mold growing beyond shell. (Keystone View Company, New York.)

trouble to prepare the solution and to store away the eggs. Most persons content themselves with paying the higher price asked for fresh eggs.

CHAPTER XXVII

OUR RESOURCES IN CLOTHING

The first great need of human beings is for food. The second is for clothing. There are four chief sources of the materials that go into the creation of articles of protection and comfort for our bodies. These are cotton, linen, silk and wool. Articles made of fur are also in use, even more than linen is, at least in the United States, but fur is now a luxury, and unnecessary, as indicated in Chapter XIII. True, our primitive ancestors did use skins of fur for garments as do the people of the far North to-day, because they could and can get nothing else. It may be granted that fur garments are useful for anyone who is subjected to such low degrees of temperature as are characteristic of the polar region.

It is interesting to note the fact that just as skins were used by the people who could get that kind of clothing better than any other, the same is true of the primitive use of the fibers of plants, of the hair of some animals, and of the thread-like product of others. The production and use of all four of the common materials from which articles of clothing are made to-day had their origin in those sections of the world where the plants and animals yielding the raw substances were easily available. The portions of the world in which this occurred were on the continent of Asia and in the warm and temperate regions of that continent. Cotton, linen, silk and wool have been traced as materials for clothing into remote antiquity.

The Egyptians used all these materials as did other national groups of human beings in central and eastern Asia. But where the manufacture of each began we can no more say with certainty than we can say where civilization itself began. However, central Asia was in all probability the "cradle of the human race." Within the same region there would naturally be the longest period of human experience. In the presence of the plants and animals that yielded the raw materials for clothing through that long experience there would tend to be developed first the primitive notion that fibers and hairs could be arranged in the form of primitive weaving. By the slow process of "trial and error" through thousands of years, we have reached a stage of development where the production of articles of human wear and comfort are carried on in gigantic industries. The conduct of these industries in this country gives employment to hundreds of thousands of men and women and involves the use of many billions of dollars of capital. In fact, the annual product of the mills themselves yearly is worth billions of dollars.

COTTON

Cotton is made from the plant hairs or fibers that surround the seeds in the pod or fruit of the plant. Although most of the cotton fibers are over an inch in length, sometimes nearly two inches, fibers can be spun into yarn even when the fibers are no more than three-fourths of an inch in length.

The cotton plant is widely distributed throughout the world north and south of the Equator to the 35th degree of latitude. Cotton grows in all our southern states except Kentucky. The production of cotton is the chief agricultural interest of these states.

In the United States the cotton plant, *Gossypium hirsutum* is an annual plant. The seeds are planted from March to May. The plants grow to a height of four to six feet. The flower has five large whitish or yellowish petals. The blossom is open but one day. The petals then fall off. The base of the pistil gradually enlarges into a three-celled or five-celled pod. When the pod has grown to the size of about one inch in diameter, and has ripened, it bursts open and discloses the large mass of cotton fibers surrounding in mat-like masses the several seeds. The pod is called the "boll." The boll matures from August first to late November, depending on the latitude.

As soon as the bolls are open the cotton must be picked. The men, women and children who pick the cotton work long hours to gather the crop to prevent waste. Picking the

FIG. 169. COTTON FIELD.
(Keystone View Company, New York.)

mass of cotton out of the open boll and leaving the husks of the bolls behind, an average adult picker can gather 200 to 250 pounds of seed cotton in a day. The pickers toss the handfuls of cotton into a bag which is slung over the shoulder. When the bags are full the contents are collected by wagons and taken to the cotton gin.

The school histories tell of the great importance of the invention of the cotton gin, and give the name of the inventor and the date, Eli Whitney, 1793. Whitney was a Northern man, a teacher in a cotton district in the south. He had noticed the slow, tedious process by which the cotton fibers were pulled away from the seeds. His cotton gin consisted of a cylinder or drum on the surface of which were hooks or teeth. The drum was made to rotate against a grate. The seed cotton was caught up by the teeth and came into contact with the grate. The cotton fibers were pulled away from the seeds, and the fibers later in the turn of the drum were removed by an automatic brush. Before Whitney's time a man could separate the seeds from only one pound of cotton a day. The latest improvement of the cotton gin can clean four thousand pounds a day. No wonder the invention

FIG. 170. COTTON FIBERS ON THE SEED. (Drawn by Maud H. Purdy.)

FIG. 171. MODERN COTTON GIN. (Keystone View Company, New York.)

of the cotton gin was recognized as one of the most important inventions of modern times. An expensive fiber was made the cheapest of all fibers for clothing.

When the cotton is ginned it is packed under hydraulic power and bound with jute bagging and with steel bands for shipping. Such a mass is called a *bale*. There are about 500 lbs. in a bale of cotton in the United States. Each cotton-producing country has its own way of baling cotton. Ours is said to be the worst, because it is the most wasteful.

We ship baled cotton to our Northern cotton mills in the states of Massachusetts, Rhode Island and Pennsylvania. We ship also to Great Britain and to other European countries. Great Britain owns nearly half the entire cotton manufacturing mills in the world. For this reason it is not surprising that we import from Great Britain large quantities of cotton cloth and cotton yarn, undoubtedly some of it made from the raw cotton we had sent to Great Britain.

The manufacture of cotton cloth is of itself a tremendous industry. The mere names of the machines employed in the work make a long list. The processes of manufacture are bewildering in their complexity. As in all modern industry, the tendency is for the workers to be doing small tasks in the factory that would employ thousands of men and women.

LINEN

If some process had been discovered by which linen could be produced at a cost nearly as low as we produce cotton, linen would be much more commonly used as an article of wear than it is to-day in this country. But at one time linen was more common than it is to-day. We used to have sheets, pillow cases, towels and handkerchiefs made of linen. Men's suits and "dusters" and women's dresses made of linen were common. To-day linen is very little worn in this country as clothing. But it still holds supremacy as table linen, and in laces. Curiously enough the Russian peasants still wear linen underwear for winter use.

The relative cheapness of cotton goods, together with the numerous processes that have been discovered for making cotton goods look attractive, have doubtless had some influence in causing the consumers to cease wanting linen. Those who wanted and could purchase more expensive raiment than that made of cotton were probably attracted to the numerous and new processes by which silk is made beautiful for garments. No doubt that also the processes by which wool was turned into very delicate materials served as factors in the evolution of dress by which linen has experienced practical elimination in the "struggle for existence." The tariff on importations of linen has also affected the situation. We still have our linen closets in the houses, but there are usually cotton sheets, cotton pillow cases and cotton towels on the shelves. However, France, Germany, Belgium and especially Great Britain continue the manufacture of linen for a great many uses. The entire annual output of linen fabrics for the world is over one billion pounds.

Linen is made from the fibers of the bark of the flax plant, *Linum usitatissimum*. The flax plant is annual, and grows from twenty to forty inches high. The small flowers range from yellowish to bright blue in color. The seeds are small, brown and flat. The chief product of flax plants in this country now is the seeds. The seeds are ground and the oil is pressed out. This is the familiar *linseed oil* used in paints.

In the preparation of the flax plant for the manufacture of linen the plant is pulled up by the roots to prevent the escape of certain plant juices necessary to the satisfactory ripening of the fibers. Later the roots are cut off and the tops removed. In Belgium where the best linen is made, floats are prepared and large quantities of flax stems are laid out and covered with weights so as to sink the flax several inches beneath the surface of the water. In that position bacteria attack the soft tissues in the bark of the flax causing decay. The bast fibers from which linen is manufactured are loosened, and later can be freed entirely from other tissue. This process is called *retting*.

The stems are then removed from the water, dried and passed through numerous processes of separation and carding or arranging in parallel rows for spinning. The weaving, finishing, bleaching and dressing of the linen require elaborate machinery and highly skilled workers.

WOOL

In all the world there are about 700,000,000 sheep. In the United States there are about 40,000,000. The United

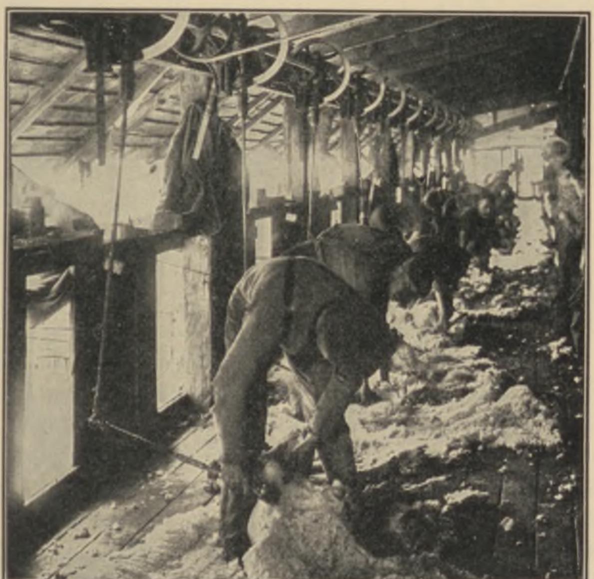


Fig. 172. Sheep Shearing Scene.
Mechanical shearers at work.
(Keystone View Company, New York.)

States stands second to the United Kingdom in the amount of wool consumed in manufacture. This country produces about two-thirds of the amount of wool it consumes in manufacture.

It is well known that sheep require a great deal of care to yield the most satisfactory results. The slightest neglect of the welfare of the sheep gives rise to one or another defect in the wool fibers themselves.

The great wool-producing states of the Union are in the far West. These are Idaho, Wyoming, Montana, Utah, Nevada, Washington and Oregon. Each of these states contains over 4,000,000 sheep. There are occasional sheep ranches where as many as 100,000 sheep are owned by one company, or even by one man. With so many, it is impossible to give detailed care and large numbers of sheep are lost in the winter storms, or the wool is injured by extremes of weather conditions, or lack of proper feeding.

Sheep are brought to the shearing pens at the beginning of the warm season. The shearing is carried on by using the hand shears, or machine shears. A sheep is thrown on its haunches and held between the legs of the shearer. These animals are docile and stupid creatures. They will remain still in that position, their legs hanging helplessly out in front while the operator trims the mat of wool in a single piece from their backs, sides and legs. The entire cutting is called the *fleece*. After the wool is removed, the sheep is thrown into a vat of antiseptic solution to destroy parasites and disease. The fleeces are packed into a long bag and prepared for shipping to the market. Boston, New York and Philadelphia are the chief markets for the sale of raw wool.

When the wool comes to the mills, the bags are opened, and the sorting begins. This selection of fleeces of varying grades is carried on under conditions of some danger to the workers, because of occasional contact with "wool sorters' disease," or *anthrax*. Sheep are filthy animals, and the fleeces require extensive cleaning. Dirt must be removed, grease must be eliminated, burrs must be separated from the fleeces.

When the cleaning is finished, the wool must be carded or laid in parallel lines for spinning. The weaving of wool into cloth has been developed into an art. The number of combinations possible by the selection of yarn, by the assembling of shades after dyeing and by the character of the weave itself are apparently unlimited. And after the cloth is woven

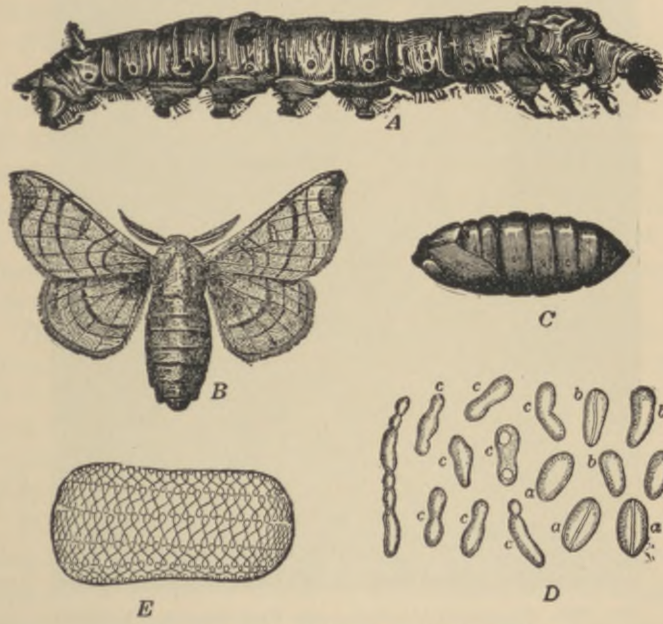


Fig. 173. Life-History of the Silkworm.

A, silkworm in fifth period, full size; *B*, moth; *C*, pupa; *D*, eggs of moth; *E*, diagram showing cocoon and method of winding. (From Matthew: *Textile Fibers;* John Wiley & Sons.)

there are numerous processes of finishing which give the cloth quite different appearances.

There are about fifty distinct and well-known types of wool and worsted materials that result from differences in the fiber, differences in the preparation of the fibers, and differences in weaving and finishing. The machinery, like that of other weaving industries, is complicated and expensive. There are very many small tasks each one of which a man or a woman sticks to for years on end. But it has been said that

FIG. 174. SILKWORM CATERPILLARS FEEDING ON MULBERRY LEAVES. JAPAN. (© Keystone View Company, New York.)

the manufacture of wool requires more intelligence than do other industries.

SILK

Silk is the most beautiful of all textiles. It is likewise the most expensive. Like the other textiles described in this chapter, the beginning of its manufacture is lost in antiquity.

The source of the fiber from which silk is made is the cocoon of the cultivated silkworm, *Bombyx mori.* This silkworm passes through four changes in two months. These stages are *egg*, *larva*, *pupa* and *adult*. When the adults emerge mating takes place. After the female lays several hundred eggs, and within three days after her emergence from the cocoon, she dies.

When the eggs hatch the young caterpillars begin to feed on chopped mulberry leaves. After the larva has shed its skin four times it is full size, about three inches in length. The larva then soon begins to show signs of wanting to climb and spin its cocoon. The two glands behind the mouth begin to secrete their fluid which on exposure to the air hardens into a double thread. In three days the larva has completed its cocoon, and has spun out from 1,000 to 4,000 feet of silk, sealing the whole with a gummy substance.

The first step in the care of the silk from the cocoon is to place a number of them in boiling water to destroy the life of the pupa, and to dissolve the gum holding the fibers together. A number of ends of the cocoon threads are placed together and then "reeled" in preparation for spinning. Before spinning all the gum and the color must be removed.

Degumming leaves the silk very light. To make up the loss in weight the custom of *weighting* the silk has developed. The silk is immersed in a series of solutions, and is charged heavily with crystallized tin and other metals. The tin or other metal gives desirable weight, but its presence cuts the silk fiber. Burn a piece of weighted silk, and the mould of the piece is left in metal. Weaving and finishing give the opportunity to produce the numerous and elaborate kinds of silk.

The principal silk manufacturing countries are France, England, Germany, Switzerland, Italy and the United States. Japan and China lead in the Far East.

CHAPTER XXVIII

OUR BODIES AS WE FIND THEM; AND THE FOODS THEY NEED

(A Preliminary Study)

Living and Working.——Here we are upon the surface of the earth of different ages, and different mental and physical characteristics. People have lived here before us and others will live here after us, perhaps eternally. The fact of living carries with it the evident fact that we are doing something. Whether we are lying on the grass looking at the clouds floating over the trees, or whether we are making the wheels of industry and commerce go round and round, our own body-machines are keeping up incessant activity.

There are some persons who are said to work only when they eat. However, after the hands finish their task of conveying food to the mouth, and the jaws are through with chewing, their owners may lie on the grass if they like, but their body-machines have only begun to work. The resting stomach feels the thrill of the message carried down by the nerves, and at once begins its steady, continuous operations. Later the intestine takes up the task, and when the food is digested, the blood catches it up and whirls it away under the pressure of the great muscular, nerve-controlled heart.

A Wonderful Industry.——Although the story as we give it thus is quickly told, we have only made a beginning on the most wonderful industry the world has ever known,—the industry involved in a living body doing its work. The food is carried along in the great highways,—the blood vessels—and dropped off where transforming stations are in operation.

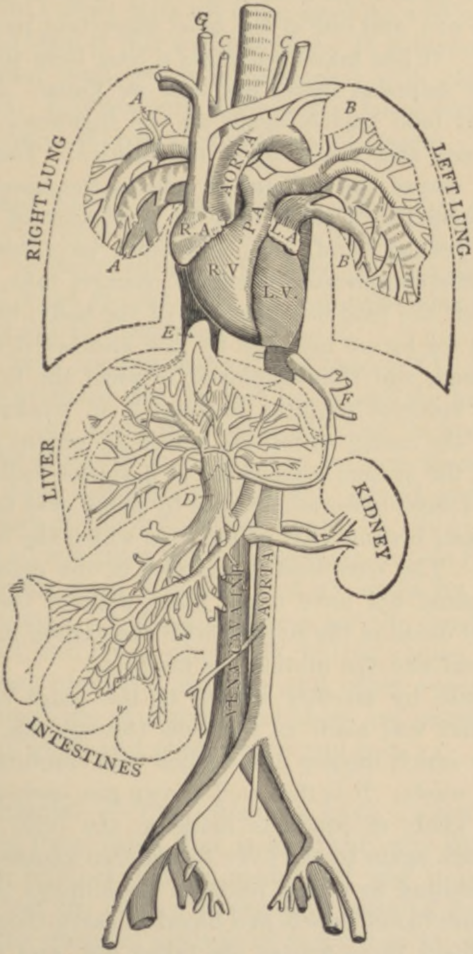


Fig. 175. Circulatory System with the Outline of Other Internal Organs. (From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

The first of these is the liver (Fig. 175). This is one of the greatest in size, and one of the most important parts of the machinery. It has taken scientists a long time to find out what really happens there, but now we know. Next, the transformed food travels again on the highways to every station, great and small, upon the system. That means that every one of the millions of cells in the tissues of the body is reached in a short time by a portion of the food which the resting hand, jaws and teeth have brought in. In these cells complicated chemical changes take place by one of which the food becomes part of the body, by another it is stored for future use, and by still another it is burned up, consumed, and thus employed to yield the heat which the whole machine requires to keep it in working order, or to yield the energy of motion which the organs manifest.

Back on the system somewhere at a station called Lungs (Fig. 175) a light material, Oxygen by name, was taken into the blood and became part of the load which the blood carried along. The complicated changes in the cells just referred to could not have taken place without the oxygen. It is by the union of the oxygen with the carbon in the food that the heat and the motion are produced.

Back again by another branch to the lungs comes the material that was made in the cells through the chemical process by which oxygen and carbon was combined. This material is waste. It is that well-known gas, carbon dioxide.

Certain kinds of products made in the cells, however, must go back again to the liver to undergo another change. They are shifted by a new route to the kidneys (Fig. 175), and there are blood vessels and blood to carry them thither. In the kidneys these wastes are taken out, and the blood freed from these substances travels back to go round and round on its never-ending journey.

It does not take a very active mind to see that if a person is averse to work of any kind, all he needs to do is to stop eating. In a short time his body machine will begin to run down, and soon it will actually stop. It is therefore a very fundamental need which is connected with this habit of using food. It is not only fundamental for us human beings, but also for all animals as well as for all plants.

Our Primal Need.——In studying our bodies as we find them, and possibly trying to improve them, it is both natural and easy to begin with the food we eat, learning the real nature of what we eat, why we eat particular kinds, and what happens to food when it is eaten.

As we have already learned in Chapter XV, our remote ancestors probably ate the soft fruits and the hard nuts of the forest, the roots of plants, and the flesh of animals. We eat the same things to-day, but we have them in greater variety, more elaborately prepared, served and partaken of with more of the deliberation known as "table manners." But with all our great variety, there are certain foods which are staple for us in America, that are eaten by the people of all nations. Chief among these are the meat of cattle, sheep, pigs, and fowls, eggs, milk, butter, cheese, bread and other cereal products, potatoes and other vegetables producing quantities of starch; and there are beans, cabbage, sugar, soft fruits and nuts, water, and salt.

The Nutrients.——The chemists have shown us what there is in these foods that is identical, why substitutions of one for another may be made, and why it is necessary for us to eat the particular chemical material found in the foods. The chemical analysis of every food in common use has been made, and it is known that the thousands of foods are in reality combinations of relatively few kinds of materials. These few kinds are called *nutrients;* and they are severally called the *proteins*, the *carbohydrates*, the *fats*, the *inorganic salts*, the *vitamins*, and *water*.

Typical proteins are the white of egg, the lean of meat, the curd of milk, and the sticky gluten of wheat to be observed in dough. It is also present in many other foods, usually in unnoticed combination with other nutrients. Examples of these cases are beans, peas, and all cereals.

Although the nutrient protein, as the white of egg, is a distinct material, the chemical analysis shows that the elements present are carbon, hydrogen, nitrogen, oxygen, and sulphur. Some proteins contain also phosphorus and iron.

Fig. 176. Foods Representing Nutrients. Protein, by white of egg and lean of meat; starch, by potato and tapioca; sugar, by cane sugar; fat, by butter and olive oil.

The carbohydrates include all kinds of sugar, chief among which are cane sugar, glucose, milk sugar, maltose, and fruit sugar. Starch also belongs to the carbohydrates. Starch is present in corn, wheat, and all cereals, in potatoes and other vegetables. Chemically this nutrient differs from the proteins in being composed only of carbon, hydrogen, and oxygen. The term carbohydrate is made up from the word *carbon* and the word *hydrate*. Hydrate is a chemical term applied to combinations of hydrogen and oxygen that are proportional to the number of hydrogen and oxygen atoms in water; that is, two atoms of hydrogen and one of oxygen. The chemical symbol for water is H_2O. The hydrogen and the oxygen exist in that relative number in all carbohydrates. Glucose is as simple as any carbohydrate; its chemical formula is $C_6H_{12}O_6$.

Fat is a term that requires little explanation. Familiar fats are butter, lard, olive oil, and the fat of meat. Fat or oil is present in small or large quantities in nuts, a limited quantity in cereals, and scarcely at all in soft fruits. The elements are the same as in carbohydrates, but the relative number of each is quite different. A molecule of fat contains many atoms of carbon and many of hydrogen, but few of oxygen. This fact is of great importance in the disposal

COMPOSITION OF SOME COMMON FOODS

From Hough & Sedgwick's *Human Mechanism*

Food	*Water*	*Proteid*	*Starch*	*Sugar*	*Fat*	*Salts*
Bread	37	8	47	3	1	2
Wheat flour	15	11	66	4.2	2	1.7
Oatmeal	15	12.6	58	5.4	5.6	3
Rice	13	6	79	0.4	0.7	0.5
Peas	15	23	55	2	2	2
Potatoes	75	2	18	3	0.2	0.7
Milk	86	4	..	5	4	0.8
Cheese	37	33	..	...	24	5
Lean beef	72	19	..	...	3	1
Fat beef	51	14	..	...	29	1
Mutton	72	18	..	...	5	1
Veal	63	16	..	...	16	1
Whitefish	78	18	..	...	3	1
Salmon	77	16	..	...	5.5	1.5
Egg	74	14	..	...	10.5	1.5
Butter	15	....	..	...	83	3

of fats when we eat them. A molecule, you should understand, is the physical unit of a substance, either of an element or a compound. An atom is the smallest particle of an element. A molecule of water, the smallest physical division, is made up of two atoms of hydrogen and one atom of oxygen. In a mass of oxygen or of hydrogen, or other element, the atoms aggregate themselves naturally into the smallest physical division, that is, into molecules.

The inorganic salts are mineral combinations usually found with other nutrients. They are salts in which sodium, phosphorus, potassium, magnesium, and iron are found. Water also is inorganic, that is, not made by a living thing, and as everyone knows is absolutely necessary to life.

These nutrients occur in certain definite percentages in our common foods. Tables of percentages have been prepared to show the composition of the foods. In the foods selected for this table it will be noticed that the animal foods do not have starch and sugar, but that plant foods have all the kinds of nutrients.

A casual inspection of the table will give you some information on a very important question; that is, the question of why we eat certain kinds of food. By that we mean more exactly why we eat certain nutrients. All kinds of flesh in the list you will see contain water, protein, fat, and salts. Human flesh is known to be like the flesh of other animals in this respect, and also to be like them in not containing starch and sugar. At the same time, all the foods from plant sources not only contain the nutrients mentioned, but sugar and starch also.

Growing and Repairing.——You have been growing larger every year for twelve, thirteen, fourteen, fifteen or more years. It is obvious that your added weight every time you stand upon the scales and test the matter, must come from something outside yourself. Nothing could be more natural than that the added weight should come from the same kind of substance which it now is. This is a fact with very slight exception.

But it is important to know that your body as it exists at any moment you may happen to weigh it does not tell you its whole story of change. While you work, or play, or sleep, the protein in the *protoplasm* or living cell substance of your body is used up to a slight extent continuously. The protoplasm thus consumed must be replaced, and with material similar to it, that is, with protein. Some of the protein which an adult person eats goes into this repair work. The remainder of it is used as sugar and starch are used. Normally the adult does not grow, as you do. That is one reason why a young person, even a child, frequently eats much more than his size would appear to warrant.

In a similar way, a child wants sugar and candy more than do grown persons. With our better understanding of the physiology of foods, adults are less inclined than they used to be to think that the desire for sugar on the part of children is a sign of natural depravity. As a matter of fact, they need it more than adults do. Why does anyone need sugar? Let us see.

The Human Machine.——In the preliminary account of the working of the body you will remember that a great deal was said about the *fact* of working. Every organ is doing something. This is very much what is taking place in any machine, whether it is a reaper, a threshing machine, an engine, a dynamo, or a sewing machine. The parts do not work of themselves, and we must try to determine what it is that makes them go. In the case of the reaper, it is evident that the horses do the work. It may be so with the threshing machine, or the machine may be operated by the power supplied by an engine. We know of course that the power of the engine is derived from the burning of coal or wood, and that the heat thus developed changes water into steam, which in turn by expanding sets the piston rod, and finally the wheel and the belt, into operation. The initial impulse to the work came from the burning of something. As we already know, burning is a chemical process in which oxygen from the air unites with carbon, producing carbon dioxide incidentally, and releasing a supply of *energy* in the form of heat. By simple transformation the heat may become mechanical energy.

Oxidation and Energy.——If anyone is curious to know whether some of our foods will burn and yield energy as coal and wood do, let him throw into the stove fire a piece of bread, a lump of sugar, or a strip of bacon. In some parts of the West in seasons when corn is plentiful and cheap it was sometimes formerly used for burning in the place of coal or wood. Granaries of wheat also sometimes take fire and are burned up. But let no one think that a flame might be seen burning brightly inside his own body after a hearty meal of bread and butter and jam. When foods that will burn in the air are eaten and digested and carried where they come into contact with the oxygen that enters by way of the lungs, the carbon of the food unites with the oxygen without a flame, slowly and at a temperature lower than the temperature at which the food would unite with oxygen in the air. This process by which oxygen and carbon or any other element unite anywhere is called *oxidation*. If you use that term you may cease to think that flaming is a necessary characteristic of this chemical change.

It so happens that the starches, the sugars, and the fats have molecules with carbon atoms in larger number than are necessary to hold the oxygen the molecules already have. This is especially true of fats. Each carbon atom will unite with two atoms of oxygen, and in a common fat molecule there are fifty-one carbon atoms and but six oxygen atoms. Thus the carbon in each molecule could unite with one hundred two oxygen atoms. The hydrogen atoms present add to themselves a great number of oxygen atoms. Between the carbon and the hydrogen an enormous amount of heat may be developed when persons consume fat. The reason that the Esquimaux are so partial to whale, seal, or walrus fat is evident. Arctic explorers imitate the natives, because they must do so, in order to make up for the great radiation of heat from their bodies in the cold climate.

If an Arctic explorer is lost from his base of supplies and cannot obtain any kind of food, his supply of energy would then have to come from his own stored-up fat. But all the time he would lose about four ounces of protein daily from his own body through "wear and tear." When his supply of body fat is gone, the energy required for the work his organs do would be obtained by the oxidation of some of his own protein or flesh. He would then lose weight still more rapidly. In health and plenty the carbohydrates and the fats we eat are oxidized, and the protein of our flesh is saved from what takes place in the body of a starving man. For that reason, carbohydrates and fats are sometimes called "protein sparing" or "protein protecting" foods.

Then, adolescents and grown-ups eat starch, sugar, fat, and some protein for the energy they yield. The remainder of the protein is available for repair. If they play hard, work hard, or grow rapidly, or live in a cold climate, they need more of these foods than the same persons would need under the opposite conditions.

CHAPTER XXIX

THE SOURCES OF OUR FOOD SUPPLY

Natural Foods.——Milk has been called a natural food, because man and other members of the highest class of animals get it naturally without preparation or modification. Milk is also called a complete food, because it contains all the nutrients that are necessary for growth, for repair, and for the supply of energy. These, as we remember, are proteins, sugar, fats, salts, and water. Although we drink milk for a longer period than does any other mammal, we require later the addition of other nutrients. These additional foods that we begin to use early, we become accustomed to by the time we are three or four years of age.

Among the early foods given to young children are certain cereals. In one form or another, cereals are eaten by persons of all ages in all countries. By cereals of course we understand not only prepared grain products like oatmeal, but all kinds of bread made from grains. In a certain sense cereals are also natural foods. Reference to the table given in Chapter XVII will show that they contain all the nutrients, and supply all the needs of human beings. Not only that, but they also supply the needs of plants as well. The meaning of this is that all cereals are derived from seeds, or more accurately from grains. A grain of corn is a fruit produced by a corn plant, which may be regarded as a mother plant. The grain contains the young plant of a new generation; this young plant is called the embryo. It is surrounded in the grain with extremely rich food material which is to be used by the embryo in beginning its life, and in forming the organs of the little corn plant. Chemical analysis shows that all the nutrients are present.

Since you have followed the development of seeds, you know that the material of the seeds is used up in forming the stem, leaves, and roots of the young plants. Having formed these organs, the plant must go on and grow larger by using the materials it obtains from the air and the soil. Our levies upon the seeds, nuts, and other fruits in our food supply is enormous. And you realize that we take these materials because they contain the nutrients which our bodies require. Since the plants need them, too, in a certain stage of their existence, we learn the lesson of one important resemblance between ourselves and plants.

Fig. 177. Group of Natural Foods. Milk, oat meal, orange, egg, meat, honey, corn, hominy, apple.

At the same time, it is worth while to call attention to the fact that a plant well started on its career must later produce for its seeds, as well as for its own growth, a new supply of nutrients. The fact that important nutrients, proteins and carbohydrates, are made from certain raw materials, carbon dioxide and water only by plants should impress upon us our absolute dependence upon plants for our existence. If you think we could get proteins from meat, you should trace the history of that protein through the animals whose bodies have contained it. How many steps is it till you come to plants?

Before we have attained the age of three we have partaken of another natural food—eggs. Eggs stand in the same relation to their producers that seeds do. A mother-being made them and surrounded a germ of the young animal with nutrient of the needed kind. As has been stated already, the white of egg is protein. The yolk contains oil, and also protein, as well as several inorganic nutrients, iron, phosphorus, lime, etc. Directly out of this store of nutrients comes the body of the young fowl, feathers, flesh, bones, nerves and all. The germ is chiefly a microscopic group of cells in which reside the life and the power of beginning the process of growth. The actual substance of the fowl comes from the nutrients which are used under the control of the germ. We eat eggs for the protein, the oil, and the minerals, and they make valuable food.

One very interesting and characteristic fact about nature is the ease with which knowledge of it may be classified and arranged in a comprehensive system. This is what makes it possible to have sciences. They are knowledge classified and brought into systems, the parts of which are related to one another. For example, our foods are either from living sources or from non-living sources; that is to say, they are organic or inorganic. The organic foods are either from plant or from animal sources. Practically all plants that are used by human beings for food develop from seeds. As we have seen, in some cases we consume the seeds, and in others, a portion of the plant; in still other cases, we eat both seeds and a portion of the plant. Our food from animal sources is either the egg, a portion of the animal's body which is derived from the egg, or it may be a product of the animal, as for example, milk, butter, cheese, or honey. The inorganic foods, the salts and the water, come into existence independent of any living thing, but they may be present at a given time in some animal or plant body; in fact, the inorganic materials in which we are especially interested are required in our living body, just as much as are proteins and carbohydrates.

It will be worth while at this point to state more fully the sources of the nutrients. For this purpose the carbohydrates will be divided into sugars and starch.

Sugars.——The sugars that most persons eat in one form or another are glucose, cane sugar or beet sugar (saccharose), and maple sugar. Glucose is produced artificially by removing the starch from corn grains, or from potatoes, and treating it with dilute hydrochloric acid.

According to the method of preparation, we may obtain solid lumps of glucose, or a liquid. Glucose may be obtained

FIG. 178. COLLECTING MAPLE SAP.
(Courtesy of American Museum of Natural History.)

from natural sources by the preparation of the juice of corn, and it occurs in maple syrup and honey. *Fructose* which is very much like glucose occurs in soft fruits. Glucose is not poisonous as some persons think. The chief reason for objection to its use in manufactured food preparations is that it is not as sweet as cane sugar. Another reason is that glucose is often used by manufacturers because of its cheapness, while the price charged for the product is the price of the pure, unadulterated food. Before the United States Pure Food Law went into effect in 1906, it was the frequent custom of some manufacturers to deceive the public, by failing to state on the package that glucose was present, and also deliberately to deceive by intimating that no glucose could possibly be present. For example, in the discussion in Congress preliminary to the passage of the first Food Law a Congressman exhibited the handiwork of one firm that was selling so-called strained honey which was made up of honey and artificial glucose. In order to make the deception complete, a dead honey bee had been placed in the bottle.

FIG. 179. SOME FOODS THAT CONTAIN SUGAR. Milk, jam, sweet potato, carrot, onions, honey, corn, apple, syrup, beets, orange.

Saccharose is obtained from the sugar cane grown in the Southern states, in Cuba, and in Hawaii. It is also obtained from the sugar beet which is grown in some of our Northern states, and in Europe. Saccharose is also to be found in fruits and in maple syrup.

Maple sugar is obtained from the sap of the sugar maple, and is collected by boring holes in the trunks of the trees in February or March, after the first warm weather at the breaking up of winter. The sap is boiled down considerably for making syrup, and still more for sugar. Everyone who gets his maple syrup directly from the farmer believes that at least *his* sugar is pure. As a matter of fact, many sugar makers honestly believe it improves the making of the syrup to put brown sugar into it, and they very commonly do it. Nevertheless, the flavor of maple sugar is nearly always satisfactory.

Sugar also is consumed by us in combination with other nutrients in certain foods. Among the most important of these are the sugar of milk, sugar in vegetables such as sweet potatoes, beets, carrots, turnips.

All our fruits contain sugar, the apples, the pears, the cherries, the plums, the prunes, the figs, the dates, etc. The fact is soft fruits have practically no other organic nutrient, except small quantities of inorganic salts.

Sugars in general are easily digested. Glucose needs merely to be absorbed, since that is the form of sugar found in the blood itself. When carried about to the muscles, digested sugar is oxidized quickly, and yields energy for rapid use.

Fig. 180. Some Foods that Contain High Percentages of Starch. Bread, sweet potato, white potato, beans, peas, oatmeal, carrot, corn, hominy.

Starch.——In nearly pure form starch is obtained from potatoes and from corn grains. The best known food form of starch is corn starch. Other foods that contain large quantities of starch are tapioca, sago, sweet potatoes, turnips, carrots, parsnips, peas, beans, and all cereals. We eat far more starch than we do of sugar, but when the starch is consumed, beginning at the mouth itself a chemical change takes place. Starch is changed to glucose. You may notice it happening in your own mouth by chewing for a long time any cereal, or in fact a piece of bread. The saliva contains the chemical called an *enzyme*, which makes the transformation. The fact is, one may insure his digestion of starch by chewing it until it begins to taste sweet. Although starch is digested in the intestine also, the best plan is not to depend too much on what the intestine is going to do. A stomach-ache sometimes comes from the rapid swallowing of a dish of oatmeal.

Fats.——The chief source of fat or oil is animal. Butter is nearly all fat, but a great deal of fat is derived from cheese along with other nutrients. The fat in milk rises with the cream on the principle that oil is lighter than water, water being the chief ingredient of milk.

FIG. 181. SOME FOODS THAT CONTAIN OIL. Milk, peanut butter, cheese, meat, egg, hickory nuts, butter.

Many persons are averse to eating the fat of meat on the ground that it is indigestible. If it is indigestible it is because it has not been cooked properly. When well cooked the fat of beef, mutton, or pork is quite digestible. As a rule one eats more fat than one supposes, on account of much fat being mixed with the lean. Naturally, the amount of fat one eats will depend largely upon the external temperature. Wherever a person is, he ought to digest easily all the fat his natural longing demands he should eat.

The commonest of food fats or oils from plant sources, or as they are called, "vegetable oils," is olive oil. This is obtained by pressing the pulp of ripe olives in a vat. The most common use made of olive oil is as an ingredient of salads. On account of the expense of this oil, there are being tried preparations of cotton seed oil, of corn oil, and also of peanut oil. The latter seems to be preferred to the cotton seed oil, although both are wholesome. It has been explained already that fats or oils yield very large amounts of energy in the form of heat or muscular energy. To a slight extent fat becomes fat again in the body, but this is not the common result of its use. You may be surprised if you learn that one of the first foods in meat form given to very young children is a piece of well-cooked bacon. You may see the reason if you recall the excessive activity of a healthy baby.

Proteins.——Proteins are often spoken of as nitrogenous foods, on account of their being the only class of nutrients that contain nitrogen. There are many kinds of protein, but for our purpose it is not necessary to distinguish between them. The fate of all kinds of protein in digestion is much the same. Protein is present in many of our foods, but it is especially abundant in the lean of meat, in the white of egg, in milk, cheese, cereals, peas, beans, and nuts.

For a long time physiologists and reformers in matters of eating have been studying and discussing the question of whether it is necessary to obtain some of our protein from meats. Naturally because of the growing feeling of sympathy for the lower animals, there has arisen the conviction on the part of some that we do not need to eat flesh, because the physiological chemists have shown that protein may be obtained in plentiful quantity from eggs and milk, and even from vegetables, from seeds of many kinds, and from nuts.

The question is still an open one so far as decision on the point of the workableness of a purely vegetarian diet is concerned. There is no doubt whatever that beans, for example, contain nearly as much protein as some meats, or even more than some, and that nuts are very rich in this nutrient. The requisite amount of material for repair could easily be obtained from plant sources without overloading the digestive system with other nutrients, and it could be done much more cheaply than it could be done with a meat diet. Many persons who have experimented with eating vegetable compounds of foods that are intended to replace not only the habit but also the taste for eating meat, say that the vegetable compounds lack the agreeable flavor of meat. After a few trials, the tendency is for experimenters to go back to the habit of eating meat.

Furthermore, in the analysis of lean meat there has been discovered a substance called *creatin.* This is the substance that gives to meat its pleasing flavor. In fact, it stimulates the appetite. Creatin is used in soups for the very purpose of stimulating the appetite in a natural way. The vegetable compounds seem to be lacking in this material, as they are lacking in certain other substances believed to be essential to proper digestion, and to the proper building of tissue.

Fig. 182. Some Foods that Contain Much Protein. Milk, cheese, oatmeal, hominy, meat, bread, peanut butter, peas, beans.

We cannot hope to induce persons in the mass to quit eating meat unless we give them a substitute that really satisfies the taste, as well as provides the requisite nourishment. However, there is one thing which we hope to be able to do, and that by offering a substitute which is not only as good, but is even a great deal better. This substitute is to eat less, and thereby to enjoy life longer. This matter will be taken up for discussion in the next chapter.

Inorganic Nutrients.——Water is the commonest of the inorganic nutrients and the cheapest, except when we buy it in combination with expensive foods. In all drinkable water, except rain water or distilled water, we consume also various kinds of inorganic salts, mineral elements in combination with others. One of these is often common salt itself, sodium chloride. The principal elements of these salts are also found in many of our foods.

Iron is of especial value in forming a necessary component part of hemaglobin, which is found in the red corpuscles of the blood. Hemaglobin unites with oxygen which is thus carried from the lungs to be released wherever oxidation is going on. A person whose red corpuscles lack iron is pale or anæmic. We may obtain iron from vegetables, such as asparagus, spinach, lettuce, carrots, parsnips, beets, grains, nuts, eggs, and from meat.

FIG. 183. SOME FOODS THAT CONTAIN MUCH IRON. Lettuce, oatmeal, meat, carrot, beans, egg, peanut butter.

Calcium and magnesium salts occur and are needed in the bones and in the soft tissues and fluids of the body. Calcium salts must be available for the contraction of muscles. Calcium is found in cereals, fruits, vegetables, cheese and milk. Magnesium is consumed with cereals, vegetables, fruits, nuts.

Sodium, sulphur, potassium, and phosphorus salts are found in the living tissues of the body, and are supplied from milk, cheese, eggs, cereals, vegetable nuts, fruit.

Other Important Sources of Nutrient Supply.——Whole wheat bread, graham bread and bread made from patent flour, contain the outer parts of the grain which are rich in mineral salts.

Butter is the most digestible of fats; 97 per cent. of it is available as food, the highest percentage of any food. Cheese is a staple article of food, and one pound contains as much protein as one and one-half pounds of meat.

The yolk of eggs is a very valuable food for growing children, by reason of its richness in protein, fat, lime, iron, and phosphates. Nine average eggs of one and three-quarter ounces each contains as much nourishment as is contained in a pound of meat.

An ounce of oatmeal contains more nutriment than one ounce of the usual proprietary breakfast foods.

Legumes (peas and beans) are especially rich in nitrogen, the chief element of protein, because of their power to fix nitrogen from the air. They are also rich in starch. However, a too free use of legumes except by persons of vigorous constitution, leading outdoor life, brings on indigestion and flatulence.

Nuts are rich in fats and protein, but the nutrients are inclosed in dense cellulose fiber, making digestion difficult.

Fresh fruits and green vegetables are not eaten so much for the nourishment they contain as for the salts of potassium, lime, and sodium they have.

There are certain unmodified foods that can be depended on to supply all that is necessary to living: grains, vegetables, fruits, meats, eggs, milk. Artificial foods are inadequate of themselves. They are: corn starch, sago, tapioca, syrups, sugars, butter, lard.

Vitamins.——Since the year 1911 a great deal has been learned about the fundamental conditions of nutrition through experimentation with the *vitamins*. In that year Casimir Funk, a German physiological chemist working in America, gave this name to a newly discovered substance in foods which he believed to be curative of an oriental disease called "*beri-beri*." This disease is common in Japan, the

Philippines, and in other oriental countries where the diet consists largely of polished rice. Mr. Funk obtained from rice polishings a substance which he fed to birds that had been given polished rice to eat for some time. The result was that the birds recovered from beri-beri, which they had as the result of eating only polished rice. Mr. Funk named the new chemical substance "Vitamine" to indicate its importance and its chemical nature. The word is made up of two words, *vita*, life, and *amine*, which is the term used by chemists to apply to substances containing nitrogen. However, long and careful study has not shown that the vitamins do contain nitrogen, or what the chemical composition of this product really is. But of the physiological nature of the vitamins there is very definite knowledge, as there is also of the sources of the vitamins in food.

The vitamins are known as Vitamin "A," Vitamin "B," and Vitamin "C." Doubtless when chemists know the composition of these substances they will propose discarding these letters, and will give them more descriptive names. With the names "A," "B," and "C" go terms which describe their physical nature in solutions. Vitamin "A" is said to be fat-soluble, "B" and "C" are water-soluble. This means that they are capable of dissolving in fat, or in water.

The numerous experiments that have been carried on with foods in their effects on man and other animals show with very little question that certain "deficiency" diseases are due to the lack of one or another of the vitamins, and that when the vitamins are supplied the deficiency diseases are cured. The commonest of these diseases is "rickets." Sometimes children have weak legs. This may be because they have not been given the food that will cause their protoplasm to lay down lime in the bones. *Beri-beri*, *scurvy*, and probably *pellagra* are other deficiency diseases traceable to the lack of one or another vitamin.

Besides having the property of preventing deficiency diseases, the vitamins have the still more general and important property, especially for children, of stimulating growth. It is now positively known that if a person or an animal consumes enough protein, starch, sugar, fat and mineral substances to furnish all that is needed to keep up the waste of protoplasm, and for energy, and does not have the vitamins, life will continue no longer than when nothing at all is eaten. Thus, if a child is undersized it is certain that it has been given foods that do not contain enough of these vitamin products.

We must know, therefore, how to secure for the children adequate supplies of Vitamin "A," "B," and "C." Vitamin "A," fat-soluble is found plentifully in milk, butter, cream, mutton fat, beef fat, and also in various lean meats, in eggs, in the germs of wheat, corn and rice, in many vegetables, and in seed foods. Vitamin "B," water-soluble, is found in lean meats, eggs, whole grain cereals, yeast, many vegetables, seeds, fruits, nuts, milk, even in skim milk. Vitamin "C," the most recently discovered vitamin, the one believed to prevent scurvy, has been found in lean meat, in vegetables, and in fruits.

Babies are given orange juice early. It is now known that tomato juice, even the juice of canned tomatoes, contains the valuable vitamins which stimulate growth. Green vegetables are disliked by many children, especially spinach, carrots, and the like. But the grown-ups owe it to their children to train them to eat as many green vegetable foods and salads as possible, at least once a day. In a former section you learned about the existence of minerals in the vegetables. We have now added the vitamins to our storehouse of useful knowledge.

CHAPTER XXX

WHAT TO EAT, HOW MUCH, AND WHY

Why Some Grow Old Early.——If you have been observant, you are acquainted with persons of forty to fifty years of age who seem about as old as other persons among your acquaintances who are seventy to eighty years of age. They are really quite as old in the physiological sense.

Between 1895 and 1900 several articles and books were written by some of these old young men telling of their experiences in breaking down in the prime of life, suddenly realizing it, and then trying to "pull themselves together." Those who have published their stories were of course able to get back to what they believed to be their normal condition, but the many hundreds and possibly thousands of others who have tried to regain their health, and have failed—these persons never write stories of that kind. Or if they should, no one would publish them, for the thoughts and the troubles of dyspeptic persons would not make acceptable reading.

From Old Age to Youth.——One of these sometime chronic dyspeptics, perhaps the best known of them all, because of the entertaining stories he has written of his experiments, is Mr. Horace Fletcher. At the traditional age of early breakdowns he suddenly found himself near the end of his physiological tether. He began to experiment with eating less and less, and chewing everything he ate until all kinds of food he took were reduced to a liquid condition. Before long he was able to eat anything he liked, and as much as he liked. Curiously enough he found that he was eating less than he had formerly eaten, and that his temperament was cheerful, and most surprising of all, his strength was greater than it had ever been. He was then about fifty-five years of age. In order to test the value of his experiments scientifically, he put himself under the direction of Professor Chittenden, of Yale University, one of the foremost food experts and physiologists in our country. Mr. Fletcher's body efficiency was tested in certain strength measurements, the same that are given to the athletes of the University. The result of the tests showed that Mr. Fletcher was stronger than any of the young fellows in the athletic squads.

FIG. 184. HORACE FLETCHER. (Courtesy of Frederick A. Stokes Company.)

The explanation of this remarkable result was that Mr. Fletcher not only got every bit of energy his food contained by thoroughly preparing it for digestion and assimilation, but also that his body was free from all the weakening poisons which develop from unused foods during the attempts of overworked organs to dispose of them. This leads us to wonder what the Yale crew itself might not be able to do if the members followed a better system of eating.

Eating as a Habit.——We are told by those who have passed through the horrors of trying to break such vicious habits as drinking alcoholic liquors and smoking opium, that the misery is indescribable. Although one who overeats does not suffer to that extent when trying to reduce the quantity of food consumed, the habit may be even more firmly fixed because of the fundamental necessity of eating something. It is natural for us to live without drinking alcohol or smoking opium, but it is not natural to go without eating food. Then again, one may suffer from placing himself in a situation where he will be over-stimulated to eat excessively. This result might come from eating highly spiced, stimulating foods, and from eating in large companies in restaurants where the noise and the music break down the resistance of a normal mind that pays attention to what its body is doing. Under these conditions, one is led on and on by enticing flavors, forgetful of the fundamental purpose of eating. Those who are in the business of managing fashionable restaurants have other desires than those that are best for persons who want to get the most in happiness and efficiency out of their bodies.

It took a long time for the excessive drinking of intoxicating liquors at table to come to be regarded as vulgar even by well-mannered persons. It may take a longer time for the vulgarity of overeating to strike the minds of persons of good breeding. However that may be, our generation even now could avail itself of the facts which show that overeating is the cause of monstrous waste in the world's happiness and in its ability to get things done, and done well.

The Chief Bad Habit in Eating.——It is becoming clear to many well-informed persons that our greatest single mistake in eating is consuming too much meat. Meat affords a large amount of protein. In our country it is a frequent custom to eat meat at every meal of the day. An indication that this is not necessary is to be found in the fact that Europeans seldom have meat for breakfast. And some Europeans, especially the Italians of the poorer classes, seldom have meat at any meal. Millions of Japanese, the

Chinese, and the East Indians ordinarily do not have meat at all, living on little else than rice. Some have rice and fish. But since the Russo-Japanese War the Japanese have been eating much more meat, because the experience of that war seemed to indicate that the use of meat enabled the soldiers to put forth greater efforts in their hard marches. The Chinese are now raising hogs and other animals for meat more than they ever have before.

Where to Begin to Reform Easily.——Experiments and observations carried on by food experts in Europe and in America show considerable variation in what may be the real needs of the human body so far as protein for the repair of the worn-out tissue is concerned. The estimates of the need given vary from two to six ounces. These amounts mean the dry protein without estimating the water and other nutrients contained in the food. The lower estimate would imply practically eating meat once a day, the higher at least twice a day. The strong tendency, however, is to reduce the meat ration to once a day. The first change that one might make in the reform of eating, and make without a serious feeling of being deprived of a need, would be this reduction in protein consumed.

You might notice then what foods you eat which seem to belong to one another in a sense. You realize that bread and butter go together. The reason is that they complement one another in making up a balanced ration. Undoubtedly the human race has discovered facts of this kind by crude experiment. The bread contains the protein and the carbohydrate, and the butter contains the fat. Another composite food is pork and beans, there being mostly fat in the pork, and protein and starch in the beans. This, by the way, is a food which is staple over a great portion of the world, and is much relied upon in armies and in working camps for railroad construction and other public improvements. Meat and potatoes also complement one another. Macaroni and cheese are much relied upon by the Italians for protein, starch, and fat. These facts are already in our possession from the experience of the race. We can begin right there, and build upon the information.

Persons who cannot afford more than one main dish at dinner do not have more than that, and usually get along very well, provided the dish is one of the natural complementary combinations. Those who can afford for dinner soup, fish, entrée of meat, a roast, three vegetables, salad, dessert, crackers and cheese, and coffee, very often try to have them all. They probably wonder how the poor manage to live. The poor, if they are intelligent and fortunate enough not to be blinded by envy, may wonder how the others manage to live. The worst of the tendency to one extreme is that the poor have too little, if not in quantity, then certainly in variety, which often amounts to the same thing, for the reason that sameness prevents the occurrence of a healthy appetite.

Fig. 185. Groups of Complementary Foods. Bread and butter; meat and potato; pork and beans.

Thinking and Planning Before Eating.——The planning of a bill of fare for a family requires as much judgment as does any other piece of work involving important consequences. If one has ham for breakfast, it might seem to be traditionally required that he should have eggs also. But if he recalls the composition of those foods he will see that he is duplicating both protein and fat. There would be no objection to having the ham and egg, provided the usual portion were cut in two, and enough bread and cereal were added to give a balanced ration, and further provided, that a person did not have the same kind of strong food for dinner also. Many persons think they must have ham and eggs for breakfast, whatever else they may have to go without. The fact that they live after thus indulging themselves only shows how resistant is the human constitution. Similarly, if one has beef, a large plate of beans is a duplication of the protein. Other faulty duplications are chicken soup and boiled chicken; white potatoes and sweet potatoes, the starch being duplicated here. Still others are made by families that think they must have three vegetables at dinner.

The "high cost of living" characteristic of our time, has at least one phase which is not without benefit to us. It has given the stimulus to many families that must try "to make both ends meet" to find some way to accomplish that great object. Necessity lends an important aid to intelligence. It is important in the interest of the family exchequer to know that the cheapest foods which are available as fuel to supply energy are rice, potatoes, bread, beans, macaroni, and corn. Fats are somewhat more expensive, and proteins are a great deal more expensive.

One of the best of menus for a growing boy or girl of high school age is given by Professor W. S. Hall, in his book, *Nutrition and Dietetics*. The recommendations are based on important fundamental principles, which will be explained wherever it is necessary.

Breakfast

A cereal with cream and sugar
Buttered toast
Cereal coffee
One boiled egg
Fruit (grapes, apples, bananas, oranges or berries)

LUNCH

A purée or cream soup with crackers or croutons
Bread and butter
Fruit
Rice pudding or custard

DINNER

An ample portion of meat
Potatoes (baked or boiled)
Side dish of vegetables
Fruit, stewed or canned, with graham wafers

This menu is enough for an adult also, at least for one who is doing work that does not require a heavy expenditure of physical energy.

Professor Hall recommends that if girls feel exhausted by the work at school, they may in addition when they reach home make for themselves an egg lemonade, using the yolk only of two eggs with half a lemon. This will give them renewed vigor, the egg supplying iron for the red blood corpuscles, and will not interfere with an appetite for dinner. Further, it is permitted with the calculations upon which this menu is based to eat candy (most blessed of concessions!), provided, the candy is eaten immediately after a meal.

The Principles Applied.——It will pay us now to take up and consider the menus of the three meals, and thus to comprehend the principles that underlie the suggestions. It is necessary to understand principles, because they contain the reasons. Otherwise you may be trying to remember suggestions which you do not understand. The cereal contains a fairly large quantity of protein, and a considerable quantity of starch. With the sugar added, and the cream, a well balanced food is obtained in this one combination, and also a very palatable food. There is the objection to soft cooked cereals that they do not require chewing to prepare them for swallowing. As was stated in the last chapter cereals should by all means be chewed. Even with chewing, the gums and teeth need the exercise they will get from chewing buttered toast. That is why the toast is introduced. Besides, the bread and butter make a very delicious balanced food, provided it is not allowed to stand while the toast becomes cold. Cereal coffee is recommended as a substitute for the berry coffee. It is nourishing and not merely stimulating. Few persons realize that berry coffee contains no energy-producing food whatever, except the cream and sugar used with it. Eggs contain protein and fat, and another ingredient already mentioned—iron. Many young persons tend to become anæmic; that is, they do not have enough haemaglobin in their red blood corpuscles. The iron from the egg makes it possible for the haemaglobin to carry more oxygen. Tincture of iron when used as a tonic only stimulates the body to use the iron in the food, and cannot supply the needed iron itself. Fruits contain sugar which supplies energy for work. They also contain palatable flavors, the acids necessary to counteract alkalis in food, and the mineral salts, the latter being very necessary to supply material for building bone.

The lunch is very simple, and, even if variety is obtained by having foods of similar nature, may not appeal to those who have been going to the delicatessen counter for frankfurters, or to the push-cart for "hokey-pokey" and "lollypops." However, those who follow the suggestions offered will have less trouble than others on the morrow, and on the days after that. The soup is warm, making the stomach feel comfortable at once. The ingredients are protein and starch, and with cream, all three organic nutrients are present. The crackers have a small quantity of protein and starch, giving the teeth something to do. Bread and butter is the balanced food used by everyone. The rice or custard pudding, contains protein, starch and sugar, and in the case of custard, fat as well.

The dinner may look like a starvation allowance to those who think they must have a seven-course meal. But really, does it not offer the possibility of great relief from the necessity of having an enslaved being standing behind us at table, as well as having enslaved beings sitting in our chairs? No great worry here whether you have taken up the pieces of cutlery in the correct order, because if you are firm in your desire for simplicity of living, you will have this dinner or another like it as a guest, and at home also. Besides, there will be less of formalism, and more time for sincerity, fewer dishes to wash, and more time really to live. The spirit of slavery to fashion is responsible for the elaborate meals prepared for well-to-do American families to-day. Excessive eating is not only unnecessary, but it makes real, hard, and useless work.

FIG. 186. GROUP OF HEALTHY CHILDREN.

But to the other reasons for eating this dinner. The meat yields the well-known protein, some fat, the creatin which stimulates appetite, some iron for the red corpuscles, and some inorganic salts for the bones and the nerves. It really seems we could not get along without meat. Potatoes are the "foil" for the meat; they contain the starch, and on transformation to glucose yield energy. Besides being generally cheap, potatoes yield a large amount of alkaline ash or minerals. These alkaline minerals help in counteracting the uric acid which results from the oxidation of the waste products of meat. An excess of uric acid is believed to be related to the development of rheumatism.

The side dish of vegetables might be carrots, beets, turnips, cabbage, spinach, chard, cauliflower, or kohl-rabi. Others might just as well be taken instead. The green vegetables contain iron as well as other inorganic salts, the important elements of which are calcium, magnesium, sulphur, sodium, phosphorus (see p. 347). The others contain starch, protein, and a little sugar.

The menus here recommended are supposed to be sufficient for young students, and for adults engaged in the moderately hard pursuits of life. This means that along with the regular daily work in school, or at any kind of work at which young persons engage normally and safely, this amount of food is enough to supply all the normal waste of muscular tissue, and enough to yield the requisite amount of energy through the oxidation of sugar and converted starch and fat to keep the body warm in all kinds of temperate climate weather, and enough to give the energy needed for muscular exercise. Because the amount is not great, the tendency will be for all the food to be really assimilated, that is, to become a real part of the tissue of the body, or to yield energy for its immediate use. Whatever we do, we must not store up poisons in the body, and hasten the day of physiological old age.

CHAPTER XXXI

THE CARE AND THE PREPARATION OF FOOD

Old Prejudices and New Ideas.——There was once a man who on arriving with his family in a country place on a July day endeavored to make arrangements with a farmer's wife to furnish artificially cooled milk for his baby girl for the summer. The man explained that if fresh, warm milk is set immediately in pans in a tub having cold water in the bottom, many bacteria that naturally grow in milk will be prevented from developing. "Nonsense," replied the woman, "Just look at my boys! Do they look as if germs had hurt 'em?"

There are many persons who naturally resent any interference with their old ways of thinking and doing, and some especially resent the changes that science is slowly but surely making in their environment. And besides, it is a common fault of mankind to reason from a limited number of facts. It is not known whether this particular woman had lost any sons in infancy, but we all know cases of families that lose young children from intestinal troubles in summertime. Without question most of these cases are due to milk that has not been properly cared for.

Experience, the Source of New Ideas.——The laws that govern the sale and distribution of milk in large cities are based upon the tragic experience of thousands of bereaved parents. Nobody guessed it would be a good thing to have laws to control the milk collecting and distributing industry; we have absolute knowledge of facts upon which public judgment was based. But the laws are not strict enough, or at least they are not enforced rigidly enough. Milk contains the bacteria that cause intestinal trouble in babies. These bacteria can be prevented from developing in dangerous numbers only by immediate cooling. At the same time the souring bacteria of milk may be kept in check by the cooling process. Souring bacteria are not disease bacteria, but souring renders the milk unfit for general use. Certain communicable diseases are easily carried in milk, especially typhoid fever and diphtheria. These may make their way into the milk through the carelessness of the persons who do the milking. A person with one of these diseases may be on the farm, or on an adjacent farm which is connected through the water supply, and through carelessness in disposing of sewage the water supply may become infected. Or flies may go from filth which contains the germs of disease to the milk pails or other vessels. Agents of the departments of health in large cities in our country not only examine samples of milk furnished by the milk companies as the milk reaches the cities, but other agents visit the dairies, in some cases hundreds of miles from the cities, and there make inspection of the premises. Infected milk is condemned, and dairies found to be supplying impure milk are prevented from selling any milk until the premises are set in order.

FIG. 187. MILK INSPECTION SCENE. Examining Petri dish cultures for bacteria colonies in Department of Health, New York. (Photo. by A. Tennyson Beals.)

Although laws give the city a measure of protection from disease through its milk supply, there is no plan for protecting the families in the country itself, where there are no city-delivering dairies, or for protecting the families in small towns. These families have to take their chances. One of the results is that the public health in the country in typhoid is not so good as it is in the cities.

Although it is very important to care for the milk of a community, the public health and also the general need of economizing, make it highly desirable to know something about why other foods also should be looked after before they are brought to the kitchen for cooking.

DEATH RATE PER 100,000 OF POPULATION DURING 1917 IN REGISTRATION STATES

Diseases	*Average*	*Cities in Reg. States*	*Rural Part of Reg. States*
All Causes	1,401	1,515	1,298
Typhoid	13.3	10.1	16.2
Measles	13.7	10.1	17.0
Scarlet Fever	3.5	4.0	3.0
Whooping Cough	10.5	9.4	11.6
Diphtheria	15.7	19.4	12.3
Tuberculosis of the Lungs	126.6	138.1	116.3
Cancer	81.2	94.4	69.3
Diabetes	16.9	20.1	14.1
Organic Heart Disease	152.9	168.5	139.0
Pneumonia	147.2	177.3	120.3
Acute Nephritis and Brights Disease	105.3	123.0	89.5
Violence	93.7	104.5	84.1
Suicide	12.9	15.9	10.3

(Analysis made by Mr. Frederick L. Hoffman, Statistician of The Prudential Insurance Company of America.)

The Cold Storage System.——In these modern days there has developed the cold storage system of keeping vegetables, fruits, eggs, and meat. There exists a great deal of prejudice against the idea of keeping food in this way. But chemical and bacteriological examinations tend to prove that no injury results to the food. They are just as healthful as fresh foods, *unless the food was bad when it was put in storage.* The fact is that the cold storage method has made it possible to obtain certain articles of food throughout the year that formerly could be obtained only for a limited period. Food is kept in cold storage by commercial firms engaged in the business, but to a certain extent separate families may find it convenient, and certainly economical to keep fruit, vegetables and even eggs (preserved in "water-glass") buying them in large quantities when they are cheapest, and protecting them in clean, cool, dry and dark cellars, or better in cold storage rooms, constructed so as to have two to four walls with inclosed air spaces or with sawdust. Many popular scientific periodicals give directions for making these rooms.

Carrots, parsnips, etc., may be buried in dry earth or sand in the storage room or cellar. Potatoes should be kept in a cool dark bin. Apples should be culled and wrapped and kept in a temperature just a little above freezing; some housekeepers do not open barrels of apples until they are ready to use them. Smoked meats should be kept in a well ventilated cellar.

Bread and vegetables must be kept free from molds; cheese and meat must be kept away from the flies because of the danger of typhoid fever being carried into the food, and also for the reason that flesh-flies and certain other flies lay their eggs on these foods. The eggs produce the "maggots" or larvæ that spoil the food. Screens will keep the flies from the meat, but they will not keep out the bacteria. Partially decayed flesh is one of the most dangerous of all substances to eat, because of the possible presence of "ptomaines," which are the poisonous excretions of certain bacteria.

Chemical Preservatives.——In addition to low temperatures, man has discovered other means of preserving foods, the most familiar being salt, sugar, and vinegar. In more recent years other chemical products have been employed in certain cases. The best known of these are, salicylic acid (water-glass), formaldehyde, boric acid, and benzoate of soda. A very little formaldehyde will keep milk fresh for a month, but formaldehyde is a deadly poison in quantities a trifle larger than is sometimes used for preserving milk. Hence its use should never be permitted. Benzoate of soda has been the center of a long warfare between certain groups of chemists in this country. But it appears to be conceded now that this chemical is not injurious. It is used in keeping food from showing incipient decay.

Cooking.——We have inherited two traditions about cooking. One is that only girls need to know about cooking; the other is that there is nothing so good as home cooking. The first tradition persists in spite of the fact that cooking is a profession with many men, especially in France, Germany, and Italy. Besides, the tradition is pointless anyway, for we all eat. The other tradition persists and is thoroughly believed in by nearly everyone. But each is thinking of his own family, whose cooking he became used to during the first part of his life. As a matter of fact, home cooking is often "villainous." If you were not brought up on saffron-colored biscuits and on beefsteak fried until it resembles leather in hardness, and on pancakes and ham always at breakfast, on greasy doughnuts, and on vinegar pie (there is such pie), then you are the proper person to test scientifically the value of home cooking. If your stomach does not resent the insult, a few repetitions will compel it to do so. The superior quality of home cooking is largely in the imagination.

There are truly scientific principles in cooking, which in general have not been worked out in the home where a number of other industries are in operation. Men ate food before there was any cooking. In all probability the discovery of cooking was an accident. Charles Lamb in his delightful essay on Roast Pig may not have missed by far the actual way of the introduction of cooking. Cooking makes things taste better, and nobody could have foretold that. Therefore, the cooking which makes things taste best is the best cooking, provided of course that no practical danger to the digestion has been introduced.

Another principle of cooking which also must have been discovered by accident is that it makes easier the division of food into eatable particles. This comes about by the softening of the cell walls of plant tissue (the *cellulose*), by the swelling or bursting of the starch granules, and by the changing to soluble gelatine the tough *connective tissue* of meats. The advantage has been that one could eat all he required in a much shorter time than was possible formerly, and the digestive fluids could more easily reach the smallest particles of the food, provided too much is not swallowed at one time.

In America vegetables are commonly brought into the necessary softened condition by cooking in water, after which the water is thrown away. Incidentally, a great portion of the easily soluble mineral salts so abundant and valuable in vegetables goes into the sink with the water. Europeans, especially the French and the Italians, cook many of their vegetables in butter or in oil, using no water at all except such as boils out from the vegetables. This is always enough to prevent the scorching of the vegetable tissue. Our American way seems to amuse European experts in the art of preparing food. We cannot deny that we are often indictable on the score of national wastefulness.

One of the principles ignored in that form of home cooking which produces the leathery steak is this: The juices of meat may be retained only by a rapid searing of the surface, followed by a slower softening of the fibrous tissues through the application of less heat. All roasts are properly cooked in this way. If the cooking is prolonged the juices will all be driven out, or dried up altogether. Thus primitive cooking, such as encasing the cleaned fowl or fish in wet paper plastered over with mud, and the whole placed in ashes, with a fire burning above is the very best, for none of the juices can escape. Try this while you are camping, and you will agree that you never ate delicious meat before.

On the other hand, if you desire to extract fluids from the meat or the vegetables, the cooking should be done slowly, starting in cold water, and heating for a considerable time over a slow fire. This is the way to prepare soups.

So much misery has resulted from the general practice of frying foods that a prejudice has arisen against it. But thin slices of potato, egg plant, and griddle cakes, and doughnuts may be made very palatable and digestible if fried quickly in a considerable quantity of hot fat, the food being in the pan a very few minutes. The trouble generally is that a small quantity of fat is used, and the cooking is continued until the fat is scorched, or until it has soaked into the food, and has become cold. How many pasty-featured persons we have seen who live on food prepared in that way!

The chemistry of cooking is one of the most fundamental matters in practical living. Let us hasten the day of "home economics" and "domestic science," whether we continue to have home cooking, or instead have professional cooks who make an art of their work.

CHAPTER XXXII

EXTRAS

Tea and Coffee.——In the menus given in Chapter XXX you will recall the fact that tea and coffee and cocoa were not included, but that a substitute, a cereal coffee, was mentioned. This was done on the basis of the belief that at least by young persons tea and coffee should not be used. A fuller explanation is due you.

Tea and coffee, in spite of the differences in appearance and taste, are almost identical in the chemical properties and in their physiological action. The chief substance of tea is called *theine;* in coffee the same principle is called *caffeine.* In both tea and coffee there is also *tannic acid.* When either is boiled the tannic acid is extracted. The action of this substance is to hinder digestion and directly to injure the mucous membrane of the stomach. The taste of tannin may be noticed when drinking tea that has been allowed to boil vigorously for some time. It is bitter and astringent. Caffeine and theine are powerful stimulants of the nervous system, and of the heart to a less extent.

Authorities agree that tea and coffee properly prepared, being as free of tannin as possible, and used in moderation, are probably not injurious to persons in normal health who are not given to other unhygienic habits. Practically, this means that you can endure them. But it is also to be understood that neither does one any good, except as stimulants of other sorts do one good in an emergency. Persons who are nervous or have poor digestion might better try the substitute cereal coffee, or simply hot water, if they feel the need of a warm liquid. Many persons drink strong coffee to keep them awake for an unusual task. This is very foolish, and scarcely less foolish is the growing social custom in America of taking "afternoon tea." One is liable to drink more tea than is good for him. If you are drinking tea for social purposes, it is much like eating for social purposes. If you want to be *very* sociable, logically you must keep on eating and drinking as long as anyone else does. Really, such a practice is very foolish.

Cocoa and Chocolate.——Cocoa and chocolate are being increasingly used as methods of preparing these products of the cocoa bean are improved. Chocolate is generally used in candies, and cocoa as a beverage. Both materials are rich in protein, fat, and carbohydrates, but it is only when consumed in solid form that much nutriment is obtained from them. The active principle is called *theobromin*, and has the same general effect as theine. Except for the active principle, which has a mild stimulating effect on the nervous system, chocolate and cocoa are valuable only when used as condensed foods, although condensed foods themselves are not as useful as foods having greater bulk. This is because the small and the large intestines must be kept busy to create healthy conditions.

The Nefarious Soda Fountain.——The soda fountain and its accessories furnish a long list of "extras." There is of course a definite craving for the products of the place, even when sociability is not an object. Lemonade and orange juice relieve thirst, although not so effectively as water. They also have beneficial effects on the operations of the kidneys. Beyond these two the ingenuity of the trade has put forth a great variety of extremely sweet concoctions, which not only do not relieve thirst, but they even prevent the normal coming of the appetite by the introduction of sugars which lead to fermentation developing in the stomach and intestine.

There is a strong tendency toward the development of a vicious soda-fountain habit among our young people. Interference with normal digestion is almost sure to result, and a foolish habit of excess is fastened on one. If a person has enough nourishing food, the chances are that he will be less likely to be a frequenter of the palaces of marble slabs and nickel fixtures.

CHAPTER XXXIII

THE ORGANS OF DIGESTION, AND WHAT GOES ON IN THEM

The Organs as Parts of a System.——Like other systems in the structure of our bodies, the digestive system is complete in itself, but yet definitely connected with other systems. In this fact the system of organs in the body make up a unit being. This, of course, is the point of Æsop's fable of the Stomach and the Limbs.

In the order of their occurrence the organs of the digestive system (Fig. 188) are the mouth, the tongue, the teeth, the gullet, the stomach, the small intestine, the large intestine, and the rectum. Organs that belong to the digestive system and act as *secreting* organs for the production of digestive fluids are certain *glands*. The best known of these are the *liver*, the *salivary glands*, and the *pancreas*. The products of these glands empty into the continuous tube at definite points, and have certain actions upon the food passing along. Other glands microscopic in size, lie in the walls of the stomach, in the small intestine, and in the large intestine.

Looking into One's own Mouth.——A study of the mouth may be made before your mirror. Incidentally, you may learn some things you have never noticed before, and you may be reminded of the teeth that need the attention of the brush, and of the dentist. And the brown color of your tongue may be the sign that your digestion is at fault. The reason may be that your teeth have not been looked after for a long time. Persons of high-school age should have twenty-eight teeth. A little later, from eighteen on there will be four more, the "wisdom" teeth.

If the additional four do not make their appearance near

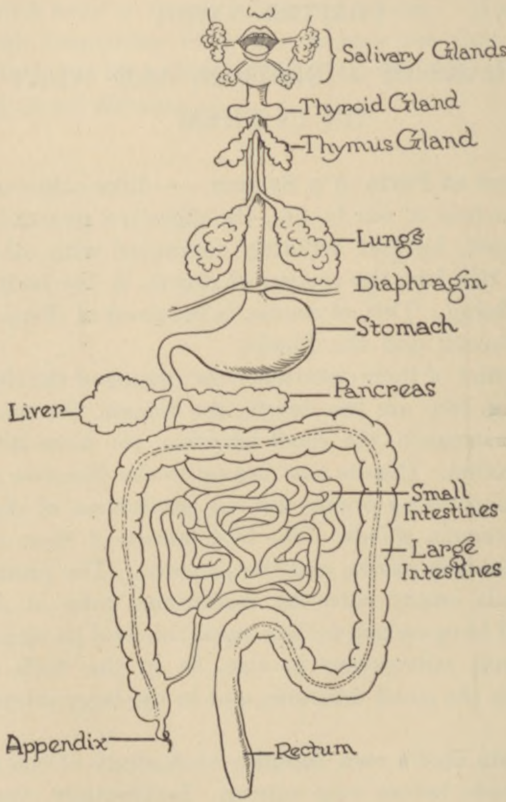


FIG. 188. DIGESTIVE SYSTEM OF MAN.
(From Weidersheim: *Grundriss der verg. Anatomie.*)

the age of eighteen, you need not think Nature has cheated you, for the tendency in the white race is for the wisdom teeth to become smaller from generation to generation. In many persons they never appear above the gums at all. But if you have lost any of the eight incisors (Fig. 189), or the four canines, or the eight premolars, or the eight molars, or indeed if you lose them before you are forty, then you will have committed a physiological crime.

Mistreated Teeth.——The author often spends his summers in a part of New York State where the country people have a curious way of taking it for granted that by the time one

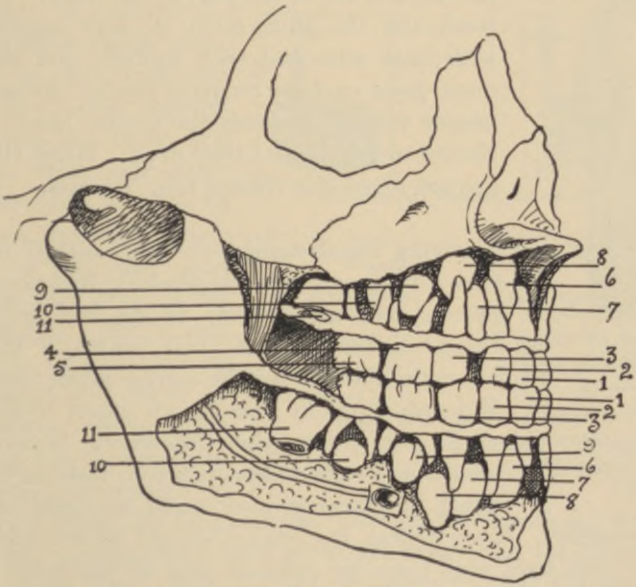


FIG. 189. UPPER AND LOWER JAWS OF CHILD.
Showing milk teeth and beginning of permanent set. (From Flint: *Human Physiology;* Longmans, Green Co.)

is thirty-five, he will have lost practically all his adult teeth. So, if you ask the age of a woman there, you may receive the reply, "Well, she's got her teeth." Interpreted, this means that she has bought her seemingly inevitable set of false teeth. The combined causes of this condition of affairs is probably the perennial consumption of griddle cakes and ham, the neglect to eat vegetables containing mineral salts, especially lime, the failure to clean the teeth with a brush, and the ignorance of the need of having the tartar scraped from the teeth by a dentist.

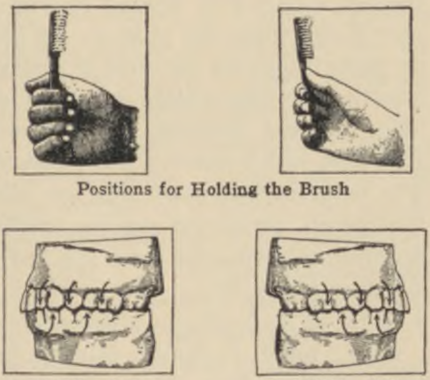
Far removed as the teeth seem to be from the processes in the stomach and in the intestine, they nevertheless receive their supply of nutriment from those organs, just as does any other part of the body. The teeth and the gums must be kept supplied with lime salts and with protein, and they must have exercise on hard foods. From a proper variety of foods the tissues have the chance to select what they need. When they are not given this chance they weaken.

FIG. 190. VERTICAL SECTION OF TOOTH.

(From Weidersheim: *Grundriss der Verg. Anatomie.*)

Knowing the Reasons.——The author has found in his experience in teaching that young persons are more likely to do the proper things in the care of their health, if they know the reasons for the advice given them. But unfortunately you cannot afford to wait until you know the differences between alkalis and salts and acids before forming the habit of cleaning your teeth regularly and thoroughly. Nevertheless, the reason should be available. The thin hard coat over the exposed part of the teeth is called the *enamel;* the fangs are covered with a softer material called *cement.* Beneath both is the main part of the tooth, and this is called the *dentine.* At the center is the hollow space with its blood vessels and the nerve.

If food material is allowed to remain between the teeth, it begins to decay under the action of bacteria which are always in the mouth. In the decay an acid is formed which in turn will dissolve a little of the enamel. This may keep up until a hole has been formed through the enamel into the dentine. In the dentine the hole develops more rapidly, and before a neglectful person is aware of his condition a toothache may be a final warning, in many cases a warning that comes too late to save the tooth. Brushing the teeth not sideways, but downward on the upper teeth inside and outside, and upward on the lower teeth inside and outside, and back and forth on the crowns, should be done at least twice a day. A good and inexpensive tooth powder is orris root and chalk. The general custom for those persons who look after their teeth at all is to brush them when they go to bed, and soon after they arise in the morning. But if you have thoroughly cleaned the teeth at bedtime, then what have you to remove in the early morning? It appears that the frequent bad taste in the mouth on rising in the morning may have given the suggestion for cleaning the teeth then. Would it not be better to wash the mouth with warm water then, and after breakfast to clean them with the brush, and also with dental floss, if your teeth cannot be cleaned thoroughly with the brush? Try dental floss anyway after you have used the brush, winding the floss partly about the teeth that lie close together, and drawing back and forth close under the surface of the gums. You will find that thick, mucous deposits with tartar which the



Positions for Holding the Brush

Left Side of Jaw — Right Side of Jaw

Proper Direction of Brushing

FIG. 191. CARE OF THE TEETH. (Courtesy of American Museum of Natural History.)

brush does not reach have been cleared away, leaving the gums enlivened.

Lurking Places of Trouble.——Tartar is the hard limy material that may collect especially at the base of the crown of your lower incisors inside. It is poured out in liquid form with the saliva. Its formation does not mean that something is the matter with you. Some persons have more than others. It is this material which makes it necessary to have the teeth cleaned with a steel scraper at least once a year, or twice a year if the collection is large, for the tartar offers too good an opportunity for the acid of decayed food to work on the enamel. Besides, a large collection of tartar offers a breeding place for the bacteria of the dreadful Rigg's disease or *Pyorrhea*, which causes teeth to become loose and to fall out. The bacteria that start here are often carried elsewhere by the lymph, producing serious troubles of many kinds. At the time of having the teeth scraped for tartar a good dentist will look for cavities. Ten to fifteen minutes given to filling a cavity at its beginning stage saves money and misery later.

Never mind, it doesn't hurt to have teeth scraped or to have small cavities filled. If you have a little brother or sister whose permanent set of teeth is about to come in, take a look at his or her back teeth. Every effort should be made to keep the back teeth especially of the milk set in place and sound, until the natural time for losing them comes, at six or seven years of age. Otherwise, the first permanent molars coming in just behind will slip into the places of the back milk teeth, with the result that the lower jaw will not be stimulated to grow long enough to give the face the proper form and the teeth regularity of alignment. The permanent teeth will come in just where their predecessors were, spaces between and all, only larger. But the spaces between permanent teeth can be made more regular and the teeth set straighter when taken early by a good dentist. Have a thought for the youngsters, and they will have reason to thank you when they are old enough to realize how much you have done for them.

"Dental Insurance."——A final word on the important subject of teeth should be given to the matter of having a good dentist. It is unfortunately too easy in most states for young men to obtain a diploma to practice dentistry. Public opinion is not yet exacting enough to demand the thorough preparation which is warranted by the importance of this work. Until it is, and indeed, as a direct means of developing a stronger public opinion on this question, one should never encourage the liveried criers of dental companies who block the sidewalks in many of our large cities. Their masters should go into a more worthy business than preying upon the misfortunes of the rest of us. It may and probably will cost more to have the services of a dentist who has received thorough scientific training in one of our professional schools of high standing. But it is well to remember that each one of us has only one set of adult or permanent teeth. The effort to earn another dollar to pay for expert care and advice leading to the saving of our rare possession should be gladly made. A good dentist with pride in his work and in his profession will not advertise on the street corners. His office will be a model of neatness and order. His instruments will be polished and *sterilized*, for some of the most loathsome diseases may be transmitted through the mucous membrane of the mouth. When a good dentist works at your teeth, a feeling of respect and confidence will come over you, for he handles his instruments with tenderness and with skill, and with fingers that have been washed since the last person left the chair. With these suggestions you should know a good dentist from a quack.

The Teeth at Work.——The teeth do the first bit of work of the digestive system. Therefore, there must be enough of them to engage every piece of food brought within their range. The gums around should not be tender; otherwise, the stimulus will be given to the tongue and the cheeks to shift the food to some other group of teeth. Have you ever noticed yourself doing this? With all the teeth in the best of condition they should attack bites of reasonable size, and reduce them to a condition approaching fluidity. You recall that Mr. Fletcher claims to be able to make every kind of food liquid. How long it would take one to do this with various kinds of food only a trial will tell. As a matter of fact, you always chew a mouthful many more times than you think you do. Only a few persons swallow their food as birds do. Chewing a mouthful twenty-five times is not unusual; some chew each mouthful more than that, and do not weary in well doing.

The Tongue.——The tongue is an organ with several functions or uses. You can distinguish two points as those of a pair of calipers closer together on the tip of the tongue than you can on any other part of the body. It is therefore a highly developed organ of touch. Doubtless we make a great deal of use of the tongue unconsciously in determining whether a piece of food has been chewed until it is small enough to be swallowed easily, and also in detecting hard things in soft food. Many babies dislike food mixtures of hard and soft particles, which they must distinguish by touch organs on the tongue and on the lining of the cheeks.

The surface of the tongue is covered thickly with little prominences, called *papillæ*. In all of these are nerves coming up and branching into fine filaments. Some are touch papillæ, and others are taste papillæ; still others are temperature papillæ, useful in distinguishing degrees of heat.

Owing to the fact that the body of the tongue is muscular and firmly attached at one end, it is adapted to acting immediately in the interest of the whole body when information comes to it through any of the organs of sense. This action is manifested by pushing objectionable things out, or by shifting desired food under the teeth to be further masticated, or pushed back into the pharynx (Fig. 192) for sending down the gullet (Fig. 192).

The tongue is also an organ of speech. Until you try to see what sounds you can make with the tongue lying motionless and flaccid on the floor of the mouth, you can scarcely realize how much you depend upon it in speaking. A large part of the mobility and the beauty of the human voice come through the action of the tongue.

Fig. 192. Diagram of the Pharynx. (From Weidersheim: *Grundriss der verg. Anatomie.*)

The Pharynx.——The pharynx mentioned in a previous section is not exclusively a part of the digestive system. It is the "cross-roads" of the digestive system and the respiratory or breathing system. The gullet is a narrow tube extending from the pharynx down to the stomach, and is about twelve inches long. It has no other organs connected with it, and the food passes rapidly through it.

The Stomach.——The organ most frequently located wrongly by persons who know little of anatomy is the stomach. A "stomach-ache" may be in the stomach, but it usually is in the small intestine. The customary way of becoming acquainted with the stomach through its aches is misleading. If you feel at the lower end of the breast-bone, and note that this is about the halfway point of the trunk, you will not be far from a position just in front of the stomach.

The human stomach is a large pouch with a capacity in the adult person of about three pints. The larger end of the pouch lies near the left side of the body. Near the end the

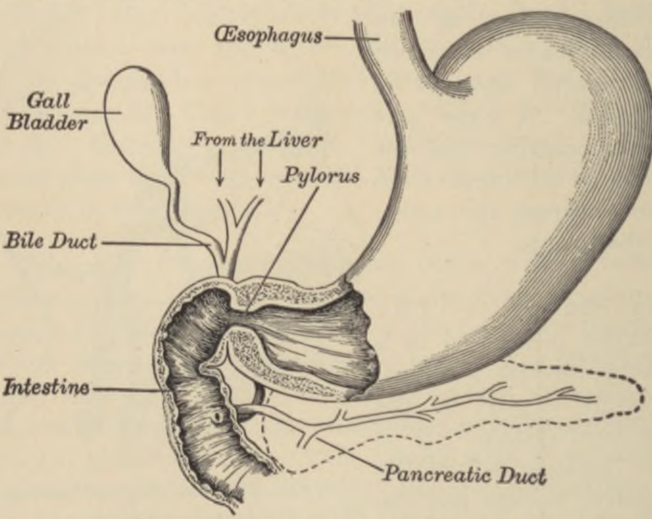


FIG. 193. STOMACH AND SMALL INTESTINE.
(From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

gullet connects and carries the food to the recess formed at the large end. The curved, tapering stomach bends across toward the right side of the body, and at its end connects with the small intestine.

The Small Intestine.—The small intestine folds upon itself many times, disposing in this way of about twenty feet of length. The small intestine connects with the large intestine very much as the stem of a corn-cob pipe connects with the bowl, by going in at the side near one end. Another resemblance in the comparison is to be noted in the fact that the large intestine starts upward just as the bowl of a pipe lies when in use. Imagine now a cone-shaped sac hanging by the base from under the bottom of the bowl, and you have the well-known, troublesome, and at the present, useless, *vermiform appendix* (Fig. 194). The large intestine extends upward on the right side and around to the rectum, a total length of five feet in a grown person.

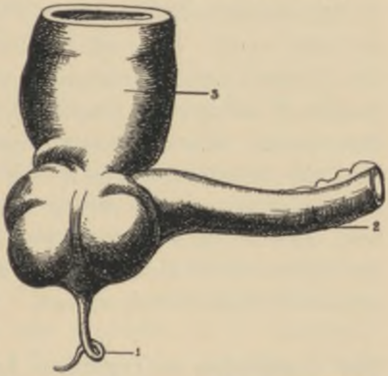


FIG. 194. VERMIFORM APPENDIX. 1, appendix; 2, small intestine; 3, large intestine. (From Weidersheim: *Der Bau des Menschen.*)

The Digestive Glands.—The digestive glands are located as follows: one pair of salivary glands in the muscles of the cheeks just in front of the ears, a second pair of salivary glands under the jaws near the hinges, a third pair of salivary glands under the base of the tongue. All these send their secretion into the mouth. You may find inside your cheek at about its center a little lump upon which the side salivary glands open. The liver lies over the stomach. Through the bile duct connection is made with the small intestine close to its beginning near the stomach. The pancreas, a soft, yellowish-brown gland, lies in the fold of the stomach and the first part of the intestine, and sends its connecting tube down to the intestine near the opening of the bile duct. In cattle and pigs the pancreas is called the stomach sweetbread; it is by that name that butchers know the organ.

Enzymes.——It has already been intimated that long retention of the food in the mouth is one of the most important steps in the process of digestion. The mastication of the food prepares it for what comes after, no matter where the digestion is to take place. But for the digestion of starch it is immediately useful to have every part as small as it can be made, so that the digestive enzyme (a transforming chemical called *ptyalin*) in the saliva may reach it easily, but the masticated food should be kept there until it begins to taste sweet. This will be the sign that the beginning of the chemical transformation to sugar has been made. If the starch of oatmeal or bread or potato is swallowed before this change occurs it must pass through the stomach and into the intestine before it will again come under the influence of an enzyme which can change it to sugar. The first step in efficient digestion is thorough mastication in the mouth of all kinds of food, no matter whether you can swallow it immediately or not.

The Conditions of Digestive Action.——The food passes not by dropping, but under the influence of waves of contraction, through the gullet into the stomach. Even before the food has reached the stomach, connecting nerves have caused the glands in the walls of the stomach to secrete the *gastric fluid.* Of course we are not conscious of this as we are conscious of our mouth "watering" on seeing or even thinking of something good to eat; but the stomach "waters," too. The saliva being alkaline in reaction stimulates the gastric glands still further to pour out their fluid. Gastric fluid is ninety-nine and one-half per cent water, but in the remainder there is two-tenths of one per cent of hydrochloric acid, and two important enzymes, *pepsin* and *rennin.* The acid changes the contents of the stomach from its alkaline condition to an acid one. The two enzymes begin to act upon the protein in the stomach contents. They have no effect upon the starch, or upon the fat.

When food is taken without appetite, the preliminary flow of digestive fluids does not occur, and digestion is more difficult in consequence. These fluids are not secreted well under conditions of worry and vexation. Children ought if possible to be prevented from crying at the table, for anger and fear dry up the mouth, and the stomach also. The normal wave-like contractions of the stomach do not take place when the person is under the influence of strong emotions from any cause. This has been learned by observations made on cats through the aid of X-ray pictures by Professor W. B. Cannon, of Harvard University. We have good reason for believing that similar things happen in the stomach of human beings. Nervous persons often complain of a feeling of heaviness in the stomach. This is probably due to the stagnation of the contents of the stomach. As Professor Cannon has written, "Neither scolding parents nor snarling children facilitate the digestion of a Christmas dinner." One might add, "Neither can one long retain normal health if he frequents noisy restaurants where dishes are clattering, where orders are bawled out, or where loud orchestras and talking almost as loud collectively or severally keep one's nerves in a state of irritated tension."

After two or three hours under normal conditions and with good mastication the stomach contents are reduced to a completely liquid condition, and the stomach by periodic waves of contraction in the tapering portion of the stomach has forced the food out through the "gate" of the stomach into the intestine. If any hard particles remain, they are turned back again and again from the gate until they are changed to small bits. If this cannot be done in the usual time, an hour or two more may be given by the overworked stomach, but after that the stomach throws off its undeserved burden. You feel very ill for awhile, but you have learned a lesson which ought not to go unheeded.

Some persons cannot digest certain foods, or foods in certain combinations. You learn by experience what your stomach can do. Sometimes one is troubled with a "greasy" feeling coming up from the stomach, or with "belching." These troubles are due to the production of gas in the stomach by bacteria which are causing fermentation and the decay of food. If the food is thoroughly masticated, and is not taken in too large quantities, and if one lives a healthy life with enough exercise, troubles of this kind are not likely to appear.

From the Stomach to the Small Intestine.——During the process of digestion in the stomach the contractile ring of muscle at the lower end of the stomach relaxes every five minutes, and the gate is open, permitting a small quantity of liquid and partially digested food to pass into the intestine. Here the nutrients of all kinds, the proteins, the carbohydrates, and the fats, sustain their greatest changes.

The first effect upon the food coming into the intestine is a change from the acid condition of the stomach to an alkaline condition. This alkali, sodium carbonate by name, is produced by the intestinal glands which occur thickly set along the entire course of the small intestine, and tends to counteract not only the acid coming from the stomach, but also the acids formed in the intestine by the decomposition caused by bacteria that are always present in varying quantities, more in unhygienic eating, fewer in healthful living.

What the Enzymes Do.——The pancreas sends its secretion, also strongly alkaline, into the intestine near its union with the stomach. The secretion contains three different enzymes. One is called *trypsin*. This enzyme is important in completing the digestion of the proteins, breaking up the molecules, carrying them through steps of chemical change that are very complicated, and finally bringing them into a condition where the molecules are small and are known as *peptones*. Another enzyme is *amylopsin*. This one is very much like the ptyalin of the saliva, for its work is changing the starch to sugar. The third enzyme from the pancreas is called *lipase* or *steapsin*. Its action is to break up the molecules of fat into what are called *fatty acids* and *glycerin*. The appearance and nature of digested fat is largely that of fluid soap.

The liver sends its secretion into the gall bladder, and from there it passes by the *bile duct* into the intestine near the opening of the pancreatic duct. The bile does not contain an enzyme. The contents of the bile are in a measure waste products of the liver, but experiments have proved that if the bile does not flow naturally into the intestine over half of the fat eaten cannot be used by the body at all. The enzymes from microscopic glands of the wall of the small intestine which act upon carbohydrates there are called *sucrase*, *maltase*, and *lactase*. *Erepsin* from a similar source acts upon protein.

When food in the stomach has passed through the alkaline or neutral conditions, and is mixed with gastric fluid, the proteins begin to be digested. In detail, the process is as follows: the hydrochloric acid in the gastric juice converts the proteins of the food into *meta-protein* or *syntonin* which in turn is transformed by the enzyme pepsin into *proteoses*, and finally into *peptones*, in which form absorption occurs. In the small intestine the proteins are acted upon by another important enzyme *trypsin*, from the pancreatic juice. In an alkaline solution this enzyme changes protein to proteoses. These further change to peptones. From this stage change continues through the combined action of trypsin and erepsin into the compounds called *amino-acids*. Of course, we realize that the chief value of the information contained in this paragraph so far as young students are concerned is that it indicates the great complexity of the chemical transformation of protein in digestion. As a matter of fact, no one who is not a chemist with expert knowledge of the organic branch of his science has a very definite understanding of what such terms as "amino-acid" and "proteoses" really mean. Nevertheless, the description of the main features of the digestion of protein are given here for the sake of completeness.

During the process of digestion in the small intestine, the contents of the cavity are being slowly pushed along by a series of wave-like contractions occurring at considerable intervals. Between these intervals, and related to the outpourings of food from the gate of the stomach, the intestine becomes segmented by muscular contraction here and there over and over again, thus providing for the repeated shifting of the contents and their thorough mixing for complete digestion. Finally, the undigested portions of the food are pushed out into the large intestine. But the probability is that the small intestine is never empty except when fasting is prolonged beyond the usual period.

Appendicitis.——There was a time, as people began first to hear of a new disease called *appendicitis*, when it was thought one should not swallow grape seeds or other small hard objects that might not digest. There is no reason for swallowing undigestible things, but, if swallowed, they do not cause appendicitis. The real cause of this disease is to be found in the lack of normal and healthy activity of the large intestine. Riding, running, rowing, rapid walking, baseball, basket ball, captain ball, football, as well as more generally productive activities, such as sawing and chopping wood, hoeing the garden, pitching hay, plowing corn, and running after little brothers and sisters, are all preventives not only of appendicitis, but also of other dangerous or debilitating conditions of the large intestine. Incidentally, you should know that the vermiform appendix is a small organ which has slight use in the human anatomy, but in the lower animals such as the rabbit and the squirrel, it is large, and aids materially in the digestion of food. Being reduced in size and degenerate in man, it is liable to be closed up by becoming inflamed. In this condition the blood does not circulate normally. If massage does not reduce the inflammation, decomposition of the appendix may set in. In extreme cases an operation must be performed and the appendix removed. If ever you feel a sharp, "doubling-up" pain, continuing for a long time in the abdominal cavity near the groin of the right side, you should speak to your parents about it, and suggest that you be permitted to visit the doctor. If the pain is very severe, the doctor should be called at once. Putting the matter off as a case of "indigestion" may be dangerous. It is quite likely that deaths from "bowel complaint," as described by doctors of former generations, was really due to appendicitis.

The Large Intestine.——The large intestine appears to be a long way from the head, but nerves connect them. The headache proves it. The large intestine receives and sometimes holds for too long a time a considerable quantity of undigestible and undigested materials, setting up the condition known as *constipation.* Except for a small amount of digestion and absorption going on in the large intestine the main thing that should happen to the contents is for them to pass along and out of the body as regularly and as completely as possible. When this work is slow or is impeded, bacteria will cause decay in the material, creating poisons which are absorbed by the blood, finally acting upon the nerves, and resulting in headaches and general lassitude. Constipation tablets and other laxatives are not of permanent value, although they may give temporary relief.

Large, vigorous movements of the trunk, especially before breakfast, are useful in cases of constipation. Oftentimes one is benefited by eating freely of fresh fruits and of bran muffins. The latter especially stimulates to activity the mucous lining of the intestine. Two glasses of water drunk before breakfast also is a help. A great deal of water taken even at meals is now known to be in line with healthful living, provided the water is not used to facilitate the gulping of food.

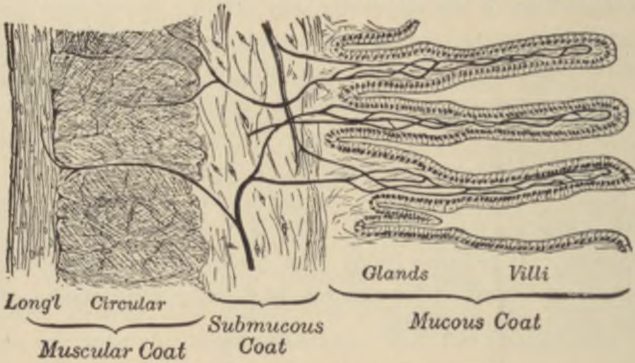


FIG. 195. SECTION OF SMALL INTESTINE.
(From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

If careful attention to diet and a generous amount of exercise will not cure the scourge of constipation, then the help of a physician should be enlisted.

Absorption.——The question must already have arisen in your mind, "What happens to the food that is changed to glocuse sugar, peptones or amino-acids, and fatty acids and glycerin through all these processes in the intestine?" The answer is to be found not only in the general reduction of the quantity of material in the intestine, but also in what takes place in the organs lining the intestine which are concerned with its removal. These organs are the *villi* (Fig. 195). They are microscopic, finger-shaped filaments extending out from the interior wall a short distance into the cavity. They increase the surface of the interior many times. The villi are the absorbing organs of the intestine. The nutrients pass into the cells of the villi, and into the blood vessels, or into the lymph vessels, by what is called the process of *osmosis*. In the process of osmosis liquids separated by a permeable membrane tend to pass through and mingle with the liquid on the other side. They do this readily if the particles in solution are small enough, and if there is a physical attraction between the materials separated.

In the blood protein products begin the process of becoming proteins again; the fatty acids and the glycerin are made into fats, but the glucose sugar is not changed at all.

CHAPTER XXXIV

THE CIRCULATORY SYSTEM

Your Own Circulatory System Under Examination.—Before we can follow the course of the absorbed products of digestion through their many changes to their destinations, it is necessary to understand the structure and the connections of the circulatory system which transports these products. We shall begin by studying the food transportation system at a point easy of access.

FIG. 196. FINGER ON THE PULSE.

If you separate your jaws slightly, and place the tip of the middle finger in the hollow space just in front of your ear, you will obtain proof that the silent little "engine" at the center of your chest is working. Press ever so lightly, and you will receive a suggestion as to whether the pumping is strong, regular, and healthy. Take your watch, and count for one minute the beats or pulsations, and you will know what is the number of heart beats for *you*, in your present state of health, and position of body. The number will not be the same that you may have heard is definite for all human beings, but it will be correct for you, if you are in good health. In other healthy persons the number will probably be a little different.

The blood that is passing in the vessel you are examining is on its way to your brain and scalp. If you have the curiosity to know more about the pulse, ask some one to test your pulse in the same place while you are asleep, and do it yourself again after a hard run. Of course, you will discover some variation in the number of beats, and also in the force of the beats.

While you have been experimenting, your entire supply of blood, perhaps a little over ten pints (twelve to fourteen in an adult) has been coursing through your arteries and then through your veins many times. As a matter of fact it requires but half a minute for all the blood in the human body to leave the heart, pass through the most extensive part of the blood system and return to the heart again. This represents a great total weight of blood carried in a day and a great store of energy to keep the little engine going. And yet, it is not altogether correct to speak of the heart as an engine, unless we think of it as a pumping engine.

The Operation of the Heart.——The study of the working of the heart shows that the power manifested in the contraction of its muscular tissue, under the control of a fine adjustment of involuntary nerves, is making a double force pump operate as perfectly as could be. These two pumps lying side by side and separated only by a dividing wall, look like one organ from the outside, but examination shows the heart to be composed of two quite distinct pumps. Each pump is made up of two chambers; the upper chambers are called *auricles*, and the lower ones *ventricles*. The upper chamber on the right side is a receiving chamber for the blood that comes back to the heart from the body in general. The lower chamber receives the blood from the upper chamber. From the right lower chamber the blood is forced out to the lungs; from the left lower chamber the blood is forced to the organs of the body generally.

The auricle of the right side receives blood from the distant organs of the body, in fact, from all the organs except

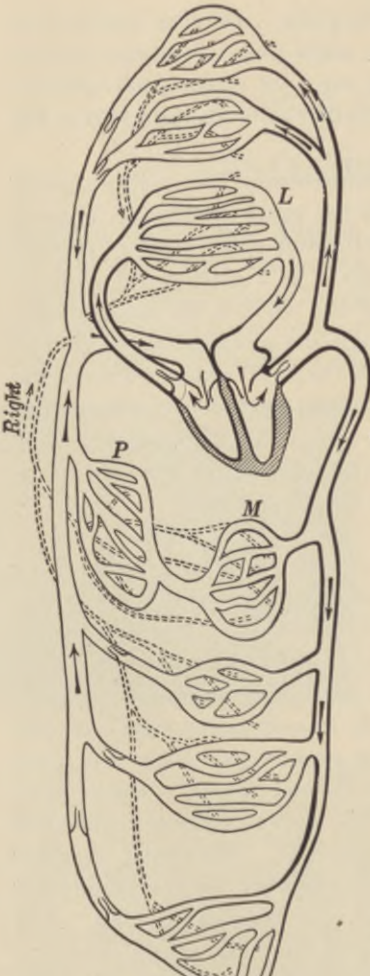


Fig. 197. Heart and Organs of Circulation. *L*, lungs; *M*, mesentery; *P*, liver. (From Hough and Sedgwick: *The Human Mechanism;* Ginn and Company.)

from the lungs. The blood in the receiving chamber flows down into the pumping chamber; the pumping chamber feels the stimulus of the presence of blood, contracts its muscular walls, closes up the gateway by which the blood entered, and the blood flows strongly out through an artery to the lungs for purification, as far as the carbon-dioxide waste is concerned. After passing through fine vessels called capillaries, because they are fine like hair (Latin, *capilla*, hair), the blood comes back from the lungs to the receiving chamber, the left auricle, of the left pump. Again the blood flows through the opening into the lower chamber, the lower chamber now contracts and by means of thicker, heavier muscles than lie in the ventricle of the right pump forces the collected blood into the great artery (called aorta) of the general body system. From the branches of the great *aorta*, the blood passes around and through the muscles, the bones, the nerves and brain, the liver, stomach, small and large intestines, kidneys, to go through another system of capillaries, and then into the veins. The veins have thinner walls than the arteries. They unite into larger and larger vessels from the exterior organs and the internal parts, and finally come to form the large trunk vein, the *inferior vena cava* (Fig. 175) running parallel with the aorta along the body cavity near the backbone. Branches from the arms and the head unite to form the *superior vena cava* (Fig. 175,G). Both veins unite at the heart, and pour their contents into the right auricle. To say that all this complicated and circuitous route can be passed over in thirty seconds seems unbelievable, but it is true.

The Meaning of the Circulatory System.——It is obvious that the highly complex and vigorous circulatory system could scarcely have been developed in man without there being some fundamental need for it. Naturally, the mechanism is not an end in itself, but it is a means to an end. The end is getting the digested nutrients distributed to the vast multitudes of body cells where they are needed.

If you were examining a railway system for the first time, your interest would be not only in the tracks, the "cuts and fills," and the country round about, but you would have an interest in locomotives and the vehicles for transportation. So we shall give a little attention to the parts of the blood system that do the carrying, since we know already what is to be carried.

The Composition of the Blood.——If some one of your class desires to sacrifice himself for the common good, a needle can be sterilized over a gas flame or a lamp flame, wiped on a bit of sterilized gauze or absorbent cotton, and thrust quickly into the tip of a willing finger. You may thus obtain a drop of blood which you can apply to a glass slide and prepare for use on the stage of a compound microscope. Of course, you will be surprised to see that the blood is not red at all, but yellow. This is because the tiny red blood corpuscles are partially transparent. It is important to know that these biconcave plates contain a substance called *haemaglobin*, which has the power of combining with oxygen where it meets it in abundance as in the lungs, and giving up the oxygen where free oxygen is lacking, as in the tissues. But the red corpuscles will not give the flush of youth and vigor to your cheeks, or vitality to your whole body, unless these same corpuscles have enough of iron in them. Look up chapters on foods, or recall the sources of iron in foods.

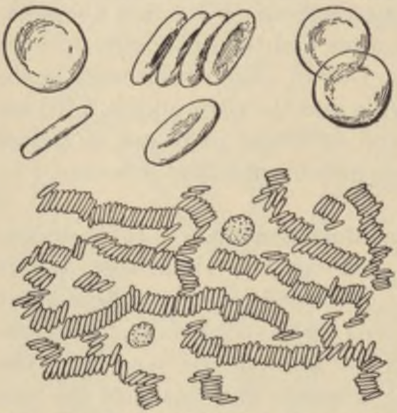


FIG. 198. RED AND WHITE BLOOD CORPUSCLES. (From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

In the drop of blood you have collected there may be one or two pale, white irregular bodies, a trifle larger than the red corpuscles. These are called the white blood corpuscles. They have many uses, but one of the most famous is the activity of these corpuscles as eaters of other cells. The technical term for that kind of cell is *phagocyte*, which is Greek for "a cell that eats." As a rule the things eaten by phagocytes are bacteria. You may see white corpuscles that have collected in great numbers as a faint ring about a small splinter in your hand. The white corpuscles wander through the tissues, being able to pass through the walls of blood vessels, which red corpuscles cannot do, and collect about an infected region where bacteria are sure to be. These bacteria are the natural prey of the phagocytes, and have been observed under the highest powers of the microscope actually in the protoplasm of the phagocyte. Prof. Elie Metschnikoff, the late Director of the Pasteur Institute of Paris, studied and wrote much concerning these white cells that act very much as if they were creatures within creatures, capturing our disease enemies, and no doubt often saving us from affliction without our being any the wiser.

That part of the blood which does all the work of transporting the food is the liquid portion, called the plasma. This is ninety parts water and ten parts solid. Part of the solid manifests itself when blood clots. If you separate it from the red corpuscles, you will have a large quantity of tough yellow fibers, called fibrinogen. The general color of the plasma is pale yellow, as may be seen when blood stands for a few hours. The clot and most of the red corpuscles will be in a mass, and the plasma will show as the pale, yellow serum.

It has already been stated that the arteries divide into smaller and smaller branches, finally reaching and carrying blood to every little group of living cells in the body. In their ultimate branches the arteries pass over into the finer branches of the veins, forming thereby the connecting capillaries. Since there are organs to be supplied with blood that are near great arterial trunk lines, there are sets of capillaries in all these organs. Capillaries are not necessarily far away from the heart.

The Lymph System.——The walls of the capillaries are thin, being adapted therefore to the easy passage of fluid back and forth between blood vessels and cells. If it were not for this fact the food flowing swiftly about in the blood system would keep on flowing along the same track. Although the cells are very small, there are nevertheless spaces between them. These spaces are connected with one another in a vague and extremely irregular system. The spaces are called lymph spaces, and the system they make is called the *lymph system.* Lymph is very much like blood with the red corpuscles left out, but its condition may vary considerably, due to the abundance or scarcity of food or waste.

When the food in solution begins to make its way by osmosis through the walls of the capillaries, it may go into an adjacent cell that needs it, or it may flow about the cells and on to other cells in the vicinity. Finally, it may pass into the lymph spaces and thus into that system. In case the liquid food passes into a cell it would possibly undergo changes which will be discussed presently, and there might come out from the cell some of the waste of the cell. This waste would pass into the lymph spaces, or it might go into the capillaries. If the waste goes into the lymph spaces, it is carried on in a sluggish stream into large and still larger tubes until a trunk (a large conducting vessel) has been reached. There are two of these in the body, one from the lower portion of the body and the legs, and a branch of it from the left arm and side of head. The other important trunk line of the lymph system comes from the right side of the body and the head. Both pass to the nearest large vein close to the point where the veins enter the two auricles of the heart. There each pours its contents into the veins, and the veins quickly deliver their

Fig. 199. Portion of the Lymph System. (From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

burden into the auricles of the heart. At those points, and in a considerable part of the large blood vessels leading from the heart, the lymph and the blood are mixed. It is apparent that the lymph is supplied from the capillaries in large part, but in the course of lymph vessels there are large lymph glands where white blood corpuscles are made, and often where impurities are attacked and disposed of. You may find the little masses or lumps of lymph glands made in the arm-pit, and also in the groin of the leg.

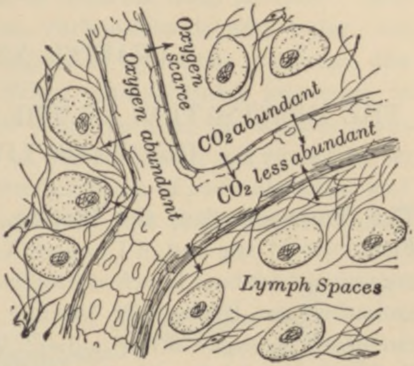


FIG. 200. EXCHANGE OF OXYGEN AND CARBON DIOXIDE BETWEEN CAPILLARIES AND LYMPH SPACES. (From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

CHAPTER XXXV

THE DESTINATION OF THE INCOME AND THE OUTGO OF LIVING

The Transportation, the Storing, and the Oxidation of Food.——At the end of Chapter XXXII we left the three organic nutrients as liquefied proteins, fats and carbohydrates embarked on their swift journey through the dark and circuitous passages of our bodies. They have been changed in the process of digestion, but they are back again in their own chemical form although entirely separated from physical combination with other nutrients.

The first stage of the journey is very short. All the blood vessels that collect from the small intestine, the stomach and the large intestine carry blood and its burden through the *portal vein* (Fig. 197) to the liver. In the liver the portal vein branches into numerous capillaries. Through the walls of these capillaries most of the glucose passes out and is taken up by the cells of the liver and is immediately changed to a material resembling sugar but called *glycogen*. After a heavy meal the liver may contain as much as 10 per cent of its weight in glycogen. The glycogen is stored in the liver cells only a short time, generally being doled out and changed meanwhile to glucose again, and sent along its journey before the next meal. The glucose that is stored in the liver is likely to be carried farther and stored as glycogen in the muscles.

While the glucose is in the blood, and as it passes through muscular tissue in the internal organs and elsewhere, oxidation takes place between the glucose and the oxygen that is carried by the red blood corpuscles. Thus a ready supply of energy for work is afforded. Incidentally, the muscular energy is transformed into heat energy which gradually, and in health regularly, passes off from the body as waste. Also the products of oxidation, carbon-dioxide and water, are ultimately given off by organs of excretion, the lungs, the kidneys, and the skin. When carbohydrates are eaten in greater quantity than the body requires, the surplus tends to be converted into fat. A person cannot tell except by an experiment in eating known quantities of carbohydrates, and by weighing himself periodically, just how much carbohy-

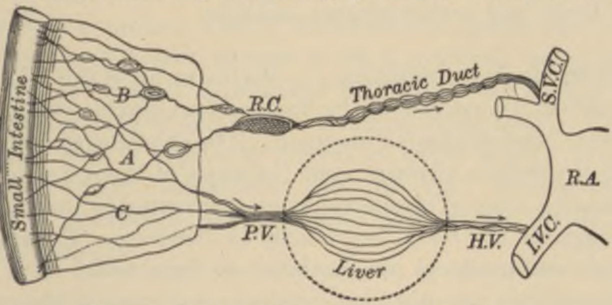


FIG. 201. PATHS FOR PRODUCTS OF DIGESTION.
(From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

drates his own body does require or could use without becoming fat. The weight of an adult should be constant. The weight of an adolescent should not vary greatly from the rate of increase indicated by the table on page 195.

It was stated in Chapter XXXIII that during the passage of the fatty acid and the glycerin or glycerol through the intestine wall they recombine into fat. This result is due to a peculiar reversing action of the enzyme *lipase* which is known to have the power of digesting fat. The absorption of fat is carried on by the lymph vessels in the villi of the intestine (Fig. 195) rather than by the capillary blood vessels. It is the presence of large quantities of fat droplets in the lymph vessels near the small intestine that gives to these vessels their milk-like appearance; hence their name *lacteals* (*Latin lac,* milk). Fat is deposited as droplets in the cells of the body, or it may be oxidized as fuel in the blood.

The absorbed products of protein digestion on passing into the blood begin to rebuild their chemical structure, which is not completed until the cells are reached. Experiments indicate that absorbed proteins become available at once for fuel as well as available later for their especial function of cell formation and repair. To some extent proteins which have been digested and absorbed are transformed in the body into carbohydrates and fats.

End-Products in Digestion.——As the result of the oxidation of protein compounds in the body carbon dioxide, water, and certain "end-products" are made. The chief element of these end-products is nitrogen, and the most of them are formed through a maze of chemical changes occurring to some extent throughout the body, but chiefly in the liver. There some simple end-products are combined to form *urea*. *Uric acid* and *creatinin* are other end-products occurring in the urine.

The Loss and the Repair of Protein.——In the human body two and one-half parts out of one thousand of its protein are used up daily. But this loss takes place without relation to whether we work hard or sit still. It is due to the "wear and tear" of the machinery of the cells in operation. Wherever the cells are that need repair or wherever the addition of new cells may take place, there are certain protein-containing foods which, each one of itself, will supply the various protein needs of the body. These are such foods as meat, eggs, fish, milk, and cheese. They are called *complete* or *perfect* proteins because of their adaptability to all situations where protein is needed. When digested each of these foods may be broken up chemically into seventeen different parts. These several parts pass into the blood, and while they are on their way to the cells are reconstructed by stages and in different groupings, the final stage occurring in the cell destinations where the protein is of course different in the various kinds of tissues. Thus, from the same milk or eggs protein may be produced exactly like the protein of muscle cells, brain cells, or liver cells.

The Chief Sources of Energy.——At the same time that our bodies are building up their tissues they are also tearing down tissues. But the production of waste does not always imply that a process wholly destructive in nature has been in operation, for when glucose or fat is oxidized, and carbon dioxide and water are produced as wastes, the energy set free is manifestly of great value to the working body. There are three sets of organs by means of which wastes are excreted, the lungs, the kidneys, and the skin. Besides being organs of excretion, the lungs also take in the important element, oxygen.

The Structure and Connections of the Lungs.——The lungs (Fig. 202) are two large, spongy-walled sacs occupying the greater portion of the chest cavity. They lie to the right and left of the heart, and connect near their upper ends by two *bronchial* tubes to the *windpipe* (Figs. 202, 3). The windpipe connects at the top with the *larynx* or voice box and opens by a slit-like passageway into the *pharynx*. The lungs lie like two expanded balloons within the chest cavity, for the gases are inside, and there is no air between the lungs and the wall of the chest.

Near the bronchial tubes each lung is supplied with a large artery and a large vein. Branches extend to the smallest air-sac, and form capillaries there. We learned in Chapter XXXIV that the venous blood returning to the heart from the extremities and from the digestive organs in the trunk passes from the heart by the right ventricle to the lungs. Thus, through the pulmonary artery comes the blood that has been collecting wastes which the lungs may give off.

The Waste Excreted by the Lungs.——Carbon-dioxide is the waste given off exclusively by the lungs. It is carried to the lungs in the blood plasma and excreted from the capillaries into the smallest spaces in the lungs, and forced out in the act of expiration. Water is excreted in the same way by the lungs in considerable quantity in the form of vapor. The presence of water in the expired breath may be shown by blowing the breath against a mirror. Heat also is given off by the lungs noticeably. The great extent of surface within the walls of the lungs makes possible the excretion of the quantities of heat, water, and carbon-dioxide which go out from these organs.

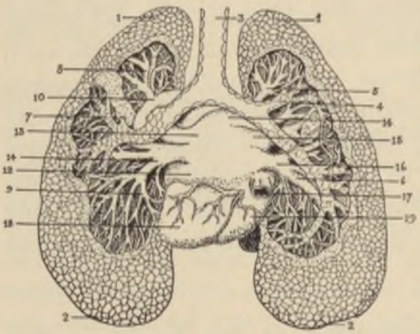


FIG. 202. THE LUNGS. (From Flint: *Human Physiology;* Longmans, Green Co.)

For a long time it has been thought that carbon-dioxide is a poison. Recent experiments have failed to show that this waste is poisonous, or that the odor characteristic of an ill-ventilated room is poisonous. The cause of discomfort in a "close" room seems to be connected with the amount of heat in the surrounding air and with the ability of the body to free itself of its own heat. This matter will be taken up in some detail on page 407.

The Structure and Connections of the Kidneys.——Down in the "small" of the back, lying within the abdominal cavity against the muscles of the back, on either side of the spinal column are the two kidneys (Fig. 203). Two branches from the aorta extend to the kidneys and there divide into numerous capillaries. At a great number of points in the muscular tissue of the kidneys the capillaries turn on themselves in several loops forming the centers of microscopic masses. Fitting closely around each of these loops of capillaries is an inner wall of a double-walled sac (Fig. 203). The outer wall of this sac forms the boundary of what is called a *renal corpuscle* (Fig. 204), and connects with the slender *kidney tubule* (Fig. 204). The tubules join with others into large and still larger tubes and ultimately connect with the *ureter* (Fig. 203), one of which passes from each kidney to the *bladder* (Fig. 203).

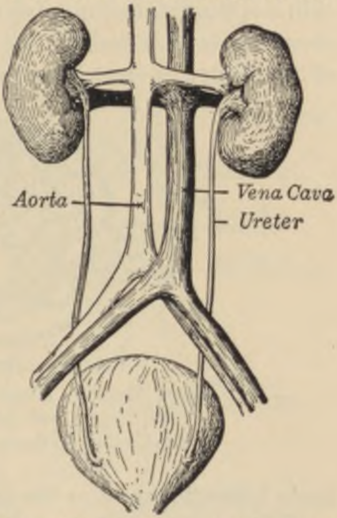


FIG. 203. KIDNEYS AND CONNECTIONS. (From Hough & Sedgwick: *The Human Mechanism;* Ginn and Company.)

Since only a portion of the protein waste may pass through the kidneys in one circuit of the blood, the body is never free of protein waste. But when a person eats too much protein his body is liable to contain a dangerously large amount of the poisonous protein waste. When through excessive eating or through the drinking of alcoholic liquors the active cells of the kidneys become crowded with fat, or the connective tissue cells constrict the kidney tubules, cells in the renal capsules die, and permit digested protein to escape and allow poisons to be retained. Another affliction of the kidneys is called *diabetes.* In this disease the glucose in the blood escapes and passes off with the waste.

Most of the excess of mineral ingredients we get in our food passes off with the excretion of the kidneys. These minerals are salt, lime, phosphates, etc.

The Structure and the Functions of the Skin.——The third important organ caring for the waste products of living is the skin. Of the three execretory organs of the body the skin has the greatest number of additional functions. Besides excreting certain wastes, the skin gives form to the muscles of the body, prevents the ingress of disease bacteria to the

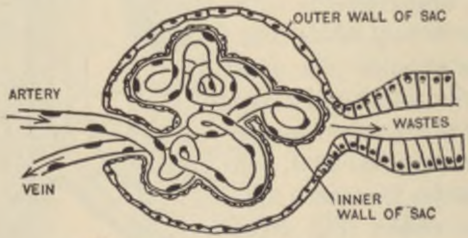


FIG. 204. RENAL CORPUSCLE.
(From Ritchie: *Human Physiology;* Copyright 1908, 1915, 1920 by World Book Company, Yonkers-on-Hudson, New York.)

parts beneath, contains the organs of the sense of touch, and regulates the heat of the body.

There are two distinct layers in the skin (Fig. 205), the *epidermis* and the *dermis*. The epidermis is composed of the flattened surface cells of a variable number of layers, being greater where pressure is constant, as for example, in the palms of the hands and on the soles of the feet. The lower cells of epidermis contain brown pigment granules which give the characteristic color to the different races of men. So far as the color is concerned the difference between races is due merely to the difference in quantity of the brown pigments present in the deeper epidermal cells.

The dermis contains all the specialized organs of the skin.

The boundary between the dermis and the epidermis is marked by alternating peaks and valleys. On the peaks are located the tactile (touch) organs, which contain the ends of nerves and the capillaries of blood vessels. The arrangement of the tactile organs may be observed in a very complicated form in the ridges on the finger tips.

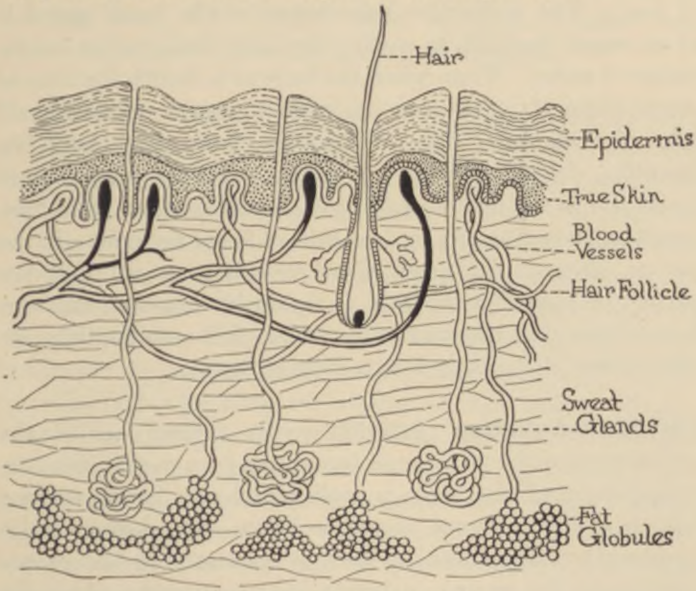


FIG. 205. SECTION THROUGH SKIN.
(Weidersheim: *Grundriss der verg. Anatomie.*)

The organs of the skin that perform the work of excretion are the sweat glands. These glands consist of a slender tube which lies in many coils in the deepest part of the dermis, and extends with a few turns straight through the dermis and the epidermis to the surface. Many blood capillaries lie about the coiled base of the sweat glands, and pour out considerable quantities of water. The water comes to the surface and passes as vapor into the air. This vapor, called perspiration, is escaping into the air at all times, but is noticeable only when because of vigorous exercise or hot weather the vapor is sent off so rapidly that the air cannot absorb and carry it away as quickly.

At the same time that the perspiration is passing off from the body there escapes with the water a considerable amount of heat. The distinctive importance of the sweat gland is as an organ that aids in cooling the body through the evaporation of water. Thus, when the body is in health the normal evaporation of water from its surface carries off the waste heat of oxidation. When the nerves of the skin check the quantity of blood flowing into the capillaries, water cannot reach the sweat glands, and heat cannot escape. The temperature then goes up, and a state of fever prevails. If the nerves contract the small blood vessels so much that the supply of blood to the skin is seriously impeded, the surface of the skin becomes cold, and a chill results, although the interior of the body is in a state of fever.

The Heat-Adjusting Activity.——In normal health the adjustment of the working of the organs is so perfect that the temperature of the body is maintained at a point varying less than half a degree above or below 98½ degrees Fahr. Apparently this amount of heat is necessary to the proper working of the organs, although heat is a waste which the body is constantly ridding itself of. If a man exercises more vigorously, or engages in hard manual labor, or if he goes on a trip of exploration to the Far North, his body craves more food, and especially food of the heat-producing kind, namely, fat. But under all these varying circumstances the heat of the blood in health remains the same.

The Hygienic and Moral Values of the Warm Bath.——Adjacent to the tubes or *follicles* in which the hairs of the skin lie are pairs of *sebaceous* or *oil glands*. They secrete a clear oil which keeps the hair soft and probably tends to check undue evaporation from the skin. But when the oil collects in large amounts discomfort and uncleanness of the body result. Then it is that a warm bath with soap relieves the body and gives it the splendid feeling of power which has real spiritual value. The late Dr. Luther Gulick, in his excellent book, *The Efficient Life*, expresses a belief that a bath improves the moral character of a person.

Ventilation in Relation to Heat.——As suggested on page 402, the problem of ventilation is one connected with the amount of heat surrounding the body. It is also connected with the amount of moisture present in the air. A number of persons together in a room where the windows are closed, and no ventilating system exists, create conditions that shortly become intolerable. The heat given off by their bodies with the air heavily laden with moisture will act as a hot gaseous blanket about the persons there, making them extremely uncomfortable, beside lowering the vitality of their bodies. Experiments of starting an electric fan in such a room have resulted in making the persons feel more comfortable, because of the breaking up of the blanket of moisture, even without changing the temperature. The explanation of this effect is that more moisture may then pass off into air which has not been receiving moisture from the same source. If in addition, the air is cooled to a point approximating 68 degrees Fahr., and fresh air containing about 50 per cent of its maximum moisture is admitted, then complete comfort is attained.

We all know that on a warm day in summer when the moisture in the air is considerable, or as the fact is stated technically, when the humidity is high, the perspiration sticks to the body, failing to evaporate. Thus other moisture-bearing heat cannot get out from the sweat glands. On another day with the air relatively dry and the temperature higher, we may feel comparatively comfortable.

The existing systems of ventilation are based on the assumption that the condition to be rid of is carbon dioxide. In one of the commonest systems the air is made to come into the room at the top, and the "bad" air to go out at the floor. Many experts now think that the conditions of the room would be better if the air should be made to enter at the bottom, and the heated air to leave at the top.

CHAPTER XXXVI

THE NERVOUS SYSTEM AND THE CONTROL OF LIVING

The Supremacy of the Human Brain.——There are few persons who do not know that the brain of an animal is the organ that rules its body. And of course, everyone knows that the brain of man is the most highly organized, and is the greatest ruler, of all the kinds of brains that have ever existed. Not only does man's brain rule his own body, but it even extends its dominion over all living things. As indicated in Chapter XV, p. 168, the possession of a brain superior to the brain of other creatures makes man the ruler of all life.

In spite of the general understanding of the function of the brain, we often hear persons speaking as if they thought that although the brain controls the mind and the activities, the heart is nevertheless the organ that has control of the feelings. Even to-day it may appear "hard-hearted" to deny to that very useful organ any part whatever in the control of the feelings or in their production. It may sound strange to students of the twentieth century to hear that although the ancient Hebrews believed that the heart is the chief seat of the soul, and of the higher feelings, they also thought that the kidneys are the seat of the mind. But the Babylonians of a still earlier day located the mind in the liver! It was not until about the year 500 B. C. that the Greek anatomist, Alcmæon, maintained that the brain is the seat of the mind, of the source of feeling and of movement, and that all sensation is carried to the brain by means of *nerves*. But from that time until the middle of the nineteenth century very little accurate information about the nervous system was added.

To-day however, a great mass of knowledge is available, not only concerning the finer structure and the connections of the nervous system, but also about the intricate activities of the nerves in their control of every bit of work the organs of the body perform, and the basis this control gives

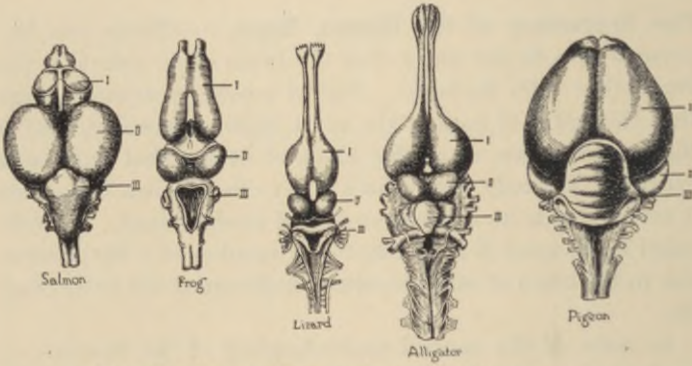


FIG. 206. DORSAL VIEW OF BRAINS OF VERTEBRATES.
(From Weidersheim: *Grundriss der verg. Antomie.*)

for conditions of health and for the habits of every individual. For many years the chief interest in the study of the nervous system was in the actual tracing of the connections of nerves with parts of the brain and with the organs of the body. Later the physiologists and the psychologists (students of the mind) carried on their interesting experiments to learn how the nerves acted in transmitting impulses, and how it is that our very habits are formed in the normal working of the nervous system. It may be that our moral character has its basis in the accumulated activities of the nervous system.

The human brain viewed even externally is very complicated. For that reason it will be helpful to put ourselves in the position to comprehend it by way of evolution. Figure

206 shows the upper or dorsal surface of the brain of a fish. You will observe that the fish brain is made up of sections of unequal size, and that these sections are capable of being separated into right and left portions. In the latter respect the brain is a paired organ.

The Parts of the Brain and their Functions.——The first portion of the brain is called the *olfactory lobes*. Sensations

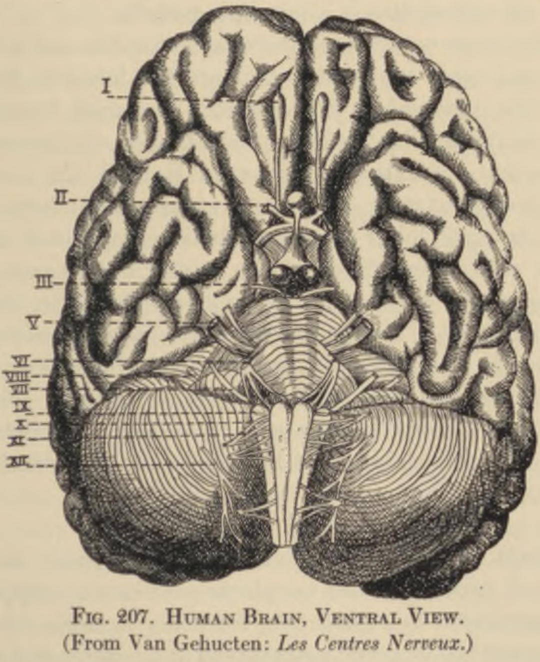


FIG. 207. HUMAN BRAIN, VENTRAL VIEW.
(From Van Gehucten: *Les Centres Nerveux.*)

of smell center there. The relatively large size of the *olfactory lobes* indicates that smelling makes up a considerable part of the lives of fishes. The first conspicuous section is the *cerebral lobes* of the *cerebrum* (Fig. 206, I). The function of the cerebrum in the higher vertebrates is thinking, but the fish is able to do relatively little thinking. The second section is called the *optic lobes* (Fig. 206, II), and it acts as the center of the seeing activities. Smelling and seeing thus constitute a large portion of the lives of fishes.

The third section of the brain in the vertebrate series, very small in the fishes and in the frogs, is the *cerebellum* (Fig. 206, III). This division of the brain appears to have charge of the complicated and automatic coördinations of the muscles. Connecting the brain with the slender *spinal cord* in all vertebrates is a tapering *medulla.*

In the lower vertebrates the olfactory lobes are relatively larger and more important than are the lobes in the birds and in the mammals. The cerebrum, however, begins small and insignificant in the lower vertebrates and grows more conspicuous and important upward through the birds and the mammals to man. In certain groups of the lower vertebrates the optic lobes are enormous in comparison with the volume of the remainder of the brain, and in comparison with the size of the body. As we go up the scale, the optic lobes lose none of their importance as centers of seeing, but they become relatively less significant and finally are covered up by the overgrowing cerebrum and cerebellum. The cerebellum starts in the fishes from a mere ridge across the brain behind the optic lobes, and becomes a much folded region in man.

The Brain as a Central Station.——The brain has been compared with a central telephone station or switchboard. The comparison is a good one, for every message from outlying organs is connected and relayed at a central station, and sent to some other organ. There are twelve pairs of nerves connected with the brain on its under surface, and extending outward to all the sense organs and to many of the organs of the upper portion of the body. These nerves are like cables of wires coming into the station in that each nerve is composed of hundreds and in some cases thousands of exceedingly fine *nerve-fibers* (Fig. 209) capable of carrying nerve impulses inward or outward according to the connections at either end of their course.

The first of the cranial nerves are the *olfactory nerves* (Fig. 207, I) connecting the lobes of that name with the lining of the nose. The impulse which results in the sensation of smell in the brain is conducted inward on the first pair of cranial nerves. The second pair are the *optic nerves* (Fig. 207, II). This pair of nerves is made up of about one million nerve-fibers, one end of which connects with the retina of the eye; the other end lies in the optic lobes. The nerves cross beneath the brain. In some cases the nerve-fibers within the optic nerves do not cross to the lobe on the opposite side of the brain, but in most cases the fibers do make this crossing. All the fibers of the optic nerves belong to the class known as *afferent* fibers; they bear impulses to the brain (Lat. *ad*, to; *fere*, to bear).

There are three pairs of very small nerves numbered *third*, *fourth*, and *sixth* (Fig. 207, III, IV, VI). They are connected with six slender muscles which through the impulses they receive over the nerves turn the eyes from point to point and focus them for vision. All of the nerve-fibers in these nerves are called motor-fibers since they carry impulses that cause movement. Thus, the sensory fibers of the second cranial nerves carry a message to the brain, and the motor-fibers of the third, fourth, and sixth carry the instructions into effect.

The *fifth* pair of cranial nerves are very large, and are divided into three branches (Fig. 207, V). These cables of nerves carry many of the afferent fibers from the face, the linings of the nose and the mouth, and from the teeth. The efferent fibers in the nerves control the muscles by means of which we eat our food. The *seventh* pair (Fig. 207, VII) control the expression of the face, and are efferent fibers. The *eighth* pair (Fig. 207, VIII) of nerves is connected with the hearing and with maintaining the balance of the body.

The *ninth*, *tenth*, *eleventh*, and the *twelfth* pairs of cranial nerves spring from the medulla, and connect with the tongue and the pharynx, with the digestive system, with the lungs and with the heart. There are both afferent and efferent fibers in these highly complicated nerves.

The Nerve Units and their Activities.——Owing to the great difficulty there is of investigating the finer structure of the nervous system, it is only within recent years that zoölogists have learned about *nerve-cells* or *neurons* (Fig. 208). A neuron is composed of a nerve-fiber and a *nucleus* (Fig. 208) with a surrounding mass of protoplasm from which usually extend a great number of tree-like branches called *dendrons* (Fig. 208). Although the nerve-fiber is in some cases nearly as long as the human body itself it is practically invisible to the unaided eye because of the small diameter. With a compound microscope one may see running through the very middle of the fiber the *axis cylinder* or *axon* (Fig. 208). Surrounding the axon are one or two layers of protective sheaths made of fatty material which give the nerves their characteristic white appearance. About every millimeter of length there are constrictions in the sheath which are called the *nodes* of *Ranvier*.

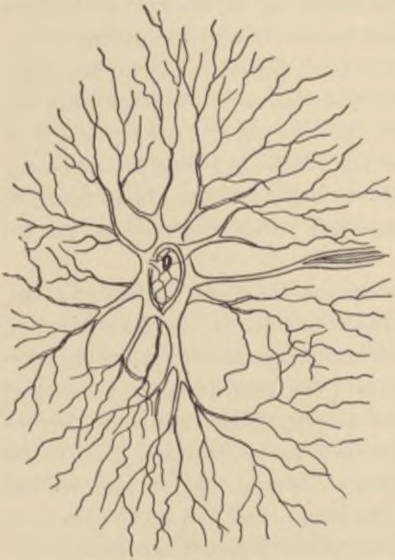


FIG. 208. NERVE CELL.
(From Stiles: *The Nervous System;* W. B. Saunders Company, Philadelphia.)

Wherever a nerve-fiber emerges on a surface exposed to stimulation, such as the retina of the eye, the inner ear, the linings of the nose and the mouth, on the skin and in the various internal organs of the body—in all of these surfaces the axons divide into still finer branches and are distributed in minute collections of surface cells where the fibers receive their stimulation. All the fibers carry the impulse resulting from stimulation at less than 200 feet a second, and each sensory or afferent fiber carries an impulse which results in a single characteristic sensation. Thus the nerve-fibers running from the retina of the eye to the optic lobes, whether stimulated by light, pressure or disease cause the brain to make the sensation of seeing.

If you get a splinter in your finger the nerve-impulse which gives you the pain runs along the axons of nerves that join the spinal cord between your shoulders. The impulse passes the nuclei of the neurons where they lie protected by the spinal column, and pass with the short branches of the neurons into the spinal cord. Here the axons branch many times, and connect with dendrons of other neurons giving over to them the impulse received at the skin. There are two paths open to the impulse.

Reflex Action.——By one path (Fig. 209) the impulse may pass to the dendrons of still another neuron which has its nucleus imbedded in the spinal cord and then outward by the motor nerve-fiber to the fine branches of the axon to the muscle-fibers of the muscles in the finger. The result of course is the immediate withdrawal of the injured finger. A nerve-impulse going over this path is an example of *reflex action.* By means of reflex action we save ourselves many times from serious injury, because the withdrawal of the injured or threatened member is done more quickly than would be possible by the other or "thinking" path.

The thinking path is the same as the reflex action path up to the point of transferring the impulse from the sensory fiber in the spinal cord. There the impulse passes to the dendrons of fibers that extend up and down the spinal cord. These in turn connect with neurons which cross the midplane of the cord and come to their termination in the surface or "cortical" area of the cerebrum of the brain on the opposite side. The pain is consciously or knowingly felt at that time,

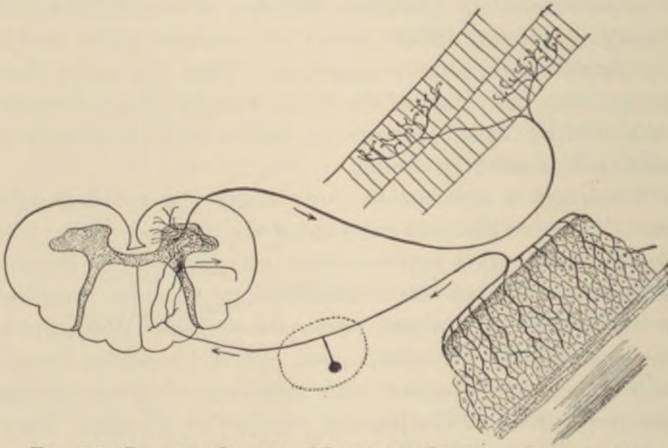


FIG. 209. DIAGRAM SHOWING MOTOR AND SENSORY CONNECTIONS. (From Van Gehucten: *Les Centres Nerveux*.)

and the impulse is sent out by parallel fibers which connect soon with the motor-fibers that are connected with the muscle-fibers.

Practically all the acts of young children are reflexes. Among them are sucking, coughing, sneezing, hiccups, vomiting, crying, clutching a finger or a stick, drawing up the legs, breathing, swallowing, changes in the size of the pupil of the eye, muscular contraction in fear, and pushing away undesired things. Some of the same acts are of course reflexes for adults as well. In each case the stimulus brings a quick response in action, the impulse goes no further than the spinal cord at the nearest point to the nerve bearing in and carrying out the impulse.

As one grows older, other reflexes make their appearance, like balancing, throwing up the hand to protect the head, and walking. But walking is a thing that has to be learned, and of course the activity involves knowing what one wants to do. To this extent walking is not pure reflex action.

The Source of our Habits.——In the development of the individual another class of quick, non-thinking responses to stimuli makes its appearance. This class is personal and is not likely to be characteristic of human beings in general. This is the class of *habits* and *accomplishments*. Everything we learn to do starts from a stimulus, whether through our sense organs, or through the training of the muscular system. An essential factor in the learning process is the activity of the human will. The will places the sense organs into the proper relation to the environment to receive the stimuli of light, sound, taste, odor, pressure, heat, cold, and pain. The nerve-impulse passes with comparative slowness along one of the twelve pairs of cranial nerves, or one of the thirty-one pairs of spinal nerves up one or more relay neurons to the cortical layer of the cerebrum.

Observations made on persons afflicted with nervous diseases or with injuries have made it possible for specialists in the study of the nervous system to determine with considerable accuracy the brain areas which control the portions of the body. The motor area for all the organs is located in a wide band that extends from near the ears across the top of the cerebrum. The auditory or hearing area is beneath the temples, and the visual or seeing area is in the portion of the cerebrum that occupies the back part of the head. The surface layer of the brain is gray in color and contains great numbers of the nuclei of the brain cells, while the deeper portion is a vast aggregation of nerve-fibers connecting with the other organs of the body. These fibers are white in color.

There are a great many possibilities in the paths which a nerve-impulse may take while it is passing from neuron to neuron on its way to and through the cortical area. This is because the neurons have many branches, and through these branches come into contact with many different neurons. There is good reason for believing that with every passage of a nerve-impulse over an afferent series of neurons and a return impulse over an interlocking series of efferent fibers a definite association of the fibers is made, and the initial stage of a habit is formed. The oftener a nerve-impulse passes over a certain path the easier it is for the impulse to go that way, and the more firmly the habit is fixed. Whether the impulse does pass that way or by some other way depends upon the will. After numerous repetitions of the act the will needs only to initiate the action, and it is carried on more or less automatically. It may even be, as is thought by some biologists, that the cerebellum or the medulla may take over the control of the necessary transference of the afferent impulse to the efferent track. Thus, a good swimmer even after being a long time away from the water may start the process of swimming by an act of the will, when immediately he finds he can swim by the nerve tracts that learned the lesson long ago, and swim as well as ever. The cerebellum takes charge, and his brain is relieved of responsibility, if indeed, it could have recalled its former lessons and their difficulties. Similarly, a baseball player learning the art of striking the ball with his bat, or of catching it in his hands, after much wild flaying of the air, or many sprains and bruises of the hands, ultimately strikes the ball with a suggestion of the automatic skill of a Babe Ruth (Fig. 210), or catches it with the sureness of a faithful fielder. Habits such as these, and piano playing, typewriting, linotyping, weaving, etc., give to their possessors efficiency and the saving of time. Whether the cerebellum takes entire charge of these activities, or whether the cerebrum maintains connection with the activity, the fact remains that thinking is seldom involved except to start the process of carrying out manual habits once learned. Thinking on some other matter may even be carried on at such times.

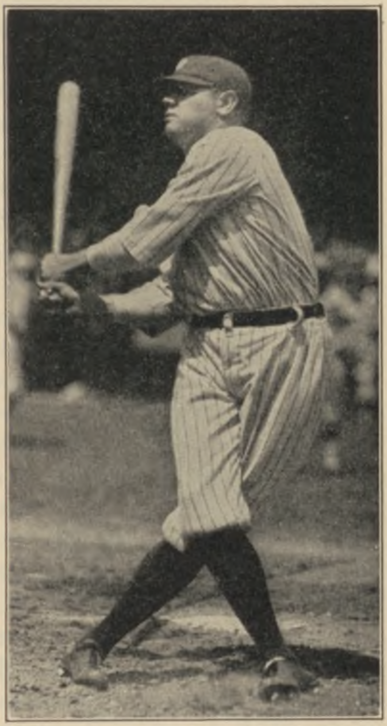


Fig. 210. Babe Ruth at the Bat. (© Keystone View Co., New York.)

Why Some Brains are Better than Others.—Many problems have arisen in connection with the mechanism of the human brain; and many theories have been advanced to account for some brains working better than others. Certain of the theories have long ago been abandoned as valueless. For example, it used to be thought that a person with a large head is necessarily possessed of a large brain; and a person with a large brain was supposed to have great mental power. Of course, it is true that human beings have larger brains in proportion to the weight of the whole body than has any other creature that has ever existed. But some of the largest human brains that have been examined belonged in life to very ordinary persons or even to imbeciles, and some of the smallest brains weighed belonged in life to our ablest men. Again it was thought that the "bumps" on the surface of the skull could be taken as indications of the presence of some unusual mental trait immediately beneath. The absence of a bump on the elaborately charted brain area was thought to be proof of the absence of the trait that belonged to that spot. These fanciful ideas held the attention of men for many years. Even to-day the "science" of phrenology is believed in by some otherwise intelligent persons. A later theory to account for variations in intelligence assumes that the more intelligent have more and deeper folds in the gray or cortical layer of the cerebrum. This theory is still regarded by some scientists as having value. Theories are explanations or interpretations thought out by scientists to account for a known or partially known series of facts. While a new theory is being worked out, the old one cannot be given up entirely. The present or newest theory to account for the relative value of brains is in line with certain descriptions that have already been given.

The brain is made up of neurons or cells. Connections are made between cells by means of the numerous fine terminal branches. It seems extremely likely that in some brains the connections of brain cells inherited from ancestors are more numerous and more perfectly made than similarly placed cells are in other brains. Not only does it appear that some persons receive a stimulus and understand an idea more quickly than do others, but also the ability to express a thought or a feeling seems naturally greater with some persons than with others. This inherited excellence is part of what constitutes brain organization. The other part of brain organization is what a person does for himself. Certain authorities regard this part as of greater importance than the inherited portion.

It was once the custom to encourage boys, especially, by telling them that no success in life was too great for them to win, if they only made up their minds to attain it. Many older persons do this still, believing, however, in the preeminence of "genius." Wiser persons nowadays are not inclined to set before the young such ideals improbable of accomplishment as "being President," or as becoming the richest man in the county," and for more technical reasons than that both of these ideals are founded upon narrow selfishness. So eminent a psychologist as the late Professor William James (Fig. 213) of Harvard University many years ago pointed out the very great influence of the continued use of the nerve tracts in the formation of habits and ultimately in the formation of special and general intelligence and of character.

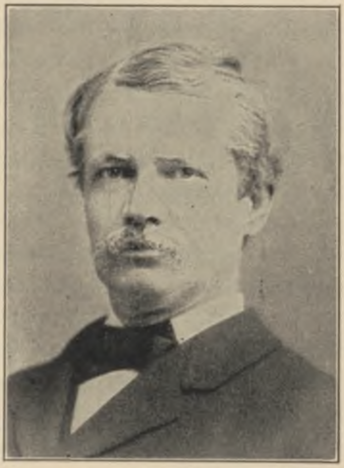


FIG. 211. DR. WILLIAM HANNA THOMSON. (Courtesy of John S. Brownne, Librarian, New York Academy of Medicine.)

Going into Training with our Brains.——This field of human endeavor—practicing on your nerve connections to make them do what you want—offers unlimited opportunity for the development of that type of mentality which we may call *acquired genius*, and for that brand of human character which may be summed up in the phrase *complete control of one's bodily resources*. This is the game in life worthy of the attention of all.

The Will the Master.——One of the leading American writers and specialists on the nervous system was Dr. William Hanna Thomson, of New York City. Dr. Thomson pointed out that the human brain with all its elaborate complexity does not make the thinking or the successful man, except as account is taken of that quality which drives or controls the brain, the human will. The will makes its first effort very early to control the brain and to build up the mind, which is all the material the brain collects in the way of experience. Dr. Thomson believed that the will not only stores the young mind with information collected from all available creation, but also that all knowledge-getting is closely correlated with the hands which mediate between the material world and the brain tracts of experience. The hands, and usually the right hand, do the things that result in significant ideas about such factors as distance, form, texture, sensation and all the qualities that go to make up whole ideas.

Dr. Thomson believed that the right hand for all right-handed persons is so fundamentally important that its habitual use accounts for the location of the speech centers on the opposite hemisphere of the brain. Right-handed persons who have been paralyzed on the right side only are still able to see with their eyes, taste with their tongues, to hear well, and to breathe satisfactorily, because these organs are connected with functioning nerves from the unparalyzed left side. Left-sided paralysis of right-handed persons does not interfere with the speech or other idea-receiving or idea-expressing centers. The obvious way to account for these facts is to suppose that the hand is of great importance in developing the power of expression. Observations have been made in cases where parents or teachers have tried to change the natural inclinations of children from left-handedness to right-handedness. A definite result has seemed to be that the children were put back in the learning process.

The closest scrutiny of human brain tissue by means of microscopic study has failed to reveal any structure on one side of the brain that is not present on the other, and yet it seems to be evident that one side of the brain has powers that the other does not have. This appears to indicate that the brain can be trained through the connections it already has, and that the human will may operate effectively with what the brain already possesses.

Nerve Activity without the Will.——However, one portion of the nervous system is outside the domination of the will. It is called the Autonomic Nervous System (Fig. 212). In the old text-books it was called the sympathetic nervous system. This portion of the nervous system is "self-regulating," which is the meaning of the word *autonomic*. The chief centers of this system are located in two chains of ganglia lying in the body cavity adjacent to the backbone, and connected by nerve cords into two lines extending forward and backward. There are other autonomic pathways, such, for example, as the tenth cranial or *vagus* nerve. The autonomic system is made up of a complicated series of "paired" or "opposite" nerves by means of which adjustments in the work of the organs of the body are made automatically. The stimuli which start into operation a given set of autonomic nerves are present in such conditions as food either actually in the stomach or only visible to the eye. The autonomic system secretes digestive fluids, the saliva in the mouth or the gastric juice in the stomach. The need of oxygen in the muscles or the presence of carbon-dioxide waste are conditions which will stimulate the heart, the blood vessels, and the lungs to varying degrees of activity. The degree of activity in health is adjusted by the working together of the paired nerves.

Working under the Will.——Although the operations of the internal organs cannot be modified by a direct act of the will, there are ways in which indirectly they may be influenced greatly. We may eat at one time or at another, or we may run or not run as we please, or we may breathe fresh air or impure air as we like, or we may keep our bodies

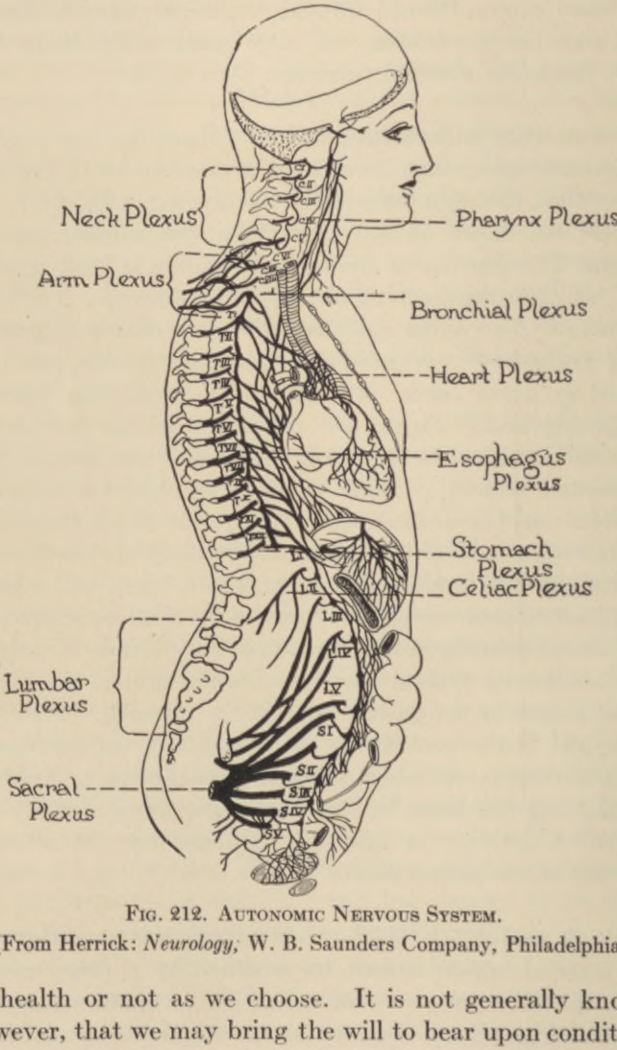


FIG. 212. AUTONOMIC NERVOUS SYSTEM.
(From Herrick: *Neurology,* W. B. Saunders Company, Philadelphia.)

in health or not as we choose. It is not generally known, however, that we may bring the will to bear upon conditions that will determine the extent to which certain very small but very important glands secrete their fluid. These are the ductless adrenal glands, lying adjacent to the kidneys. Some basic facts connected with this matter were given on page 383.

We know that during periods of great emotional stress, such as fear or anger, an increased amount of adrenalin, the secretion from these glands, is poured into the blood. The effect of this chemical is to cause suspension of the work of the digestive glands, while stimulating to greater activity the nerves that control the skeletal muscles. The point was made that strong emotion at the time of meals works ill to the digestion, and that anger at that time must be carefully avoided. But adrenalin has important uses, and is coming to be looked upon as a valuable chemical resource. About 1896 Professor William James called attention to the fact that every person had within his body a very great supply of untapped capacity for work. Nearly everybody knows that once in a while unusual need arises for the sustained and severe expenditure of muscular and nervous energy. Sometimes we are surprised at our own feats or at the feats of others. Professor James maintained that the unusual might become the common occasions with great profit to the productiveness of the human race. Not that we should wrack bodily machines

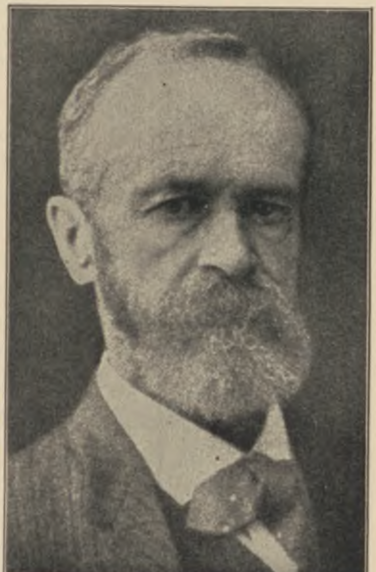


FIG. 213. PROFESSOR WILLIAM JAMES.

in "speeding them up" to the limit of their endurance, but that we should deliberately calculate to make our bodies "pay for their keeping" by giving them all they can do efficiently while we work—and then letting them enjoy a good rest.

In recent years skilled experimental physiologists have learned that the coming of fatigue through the formation of certain fatigue poisons in the muscles may be postponed by the presence of adrenalin. The adrenalin is poured out under the control of the autonomic nervous system during great stress of emotion; but emotion is subject to considerable control by the brain and central nervous system. This is the indirect control we may exercise over the work of the adrenal glands. The practical problem then is to discover some means by which persons may easily and naturally approach efficiency, and make as complete use of their resources a great deal of the time as was done once by a tired farmer boy, who at the close of day welcomed a suggestion to go swimming, and while in the excitement of the sport responded swiftly and successfully to the call for help from a boy smaller than he.

Work and its Enjoyment.——There is a difference of opinion among many persons as to whether work is really enjoyed by the persons doing the work. We have proof enough that enjoyment is a prerequisite to efficiency and to the accomplishment of a considerable amount of work. A ditch-digger and a poet who are stimulated to work simply by the necessity of having something to live on may be equally indifferent to the quality of their work, however much the public may indicate its preference for the work of the ditch-digger by paying more for it. Still, we should not decry the value of the food stimulus to any worker, for no less a poet than James Russell Lowell considered it fortunate and a stimulus to industry in writing poetry that one must work in order to have something to eat. But when one can say sincerely that he has added the great stimulus of *enjoying* his work, there is present the condition of a natural and easy approach to productiveness.

Persons whose physical resources are slight or whose wills have not been trained to drive ahead the physical resources swiftly and efficiently often exclaim in wonder at the physical or mental labor accomplished by others. And frequently advice is given to hard workers to spare themselves, or they will "have nervous prostration." A classic instance of a career important in biology is that of Charles Darwin who in spite of serious illness throughout a long life accomplished a prodigious amount of work. Work did not make him ill, and it seldom if ever causes anybody to break down. There are, however, certain contingencies which may operate to cause the breakdown, and not the least of these is the act of stopping work. Another is that a person may be so unwise as to cut down his sleeping time. But the two great contributing causes to nervous breakdowns are unhygienic eating and an uncontrolled will that wanders into worries. If a person feeds himself as carefully as he would feed a horse of which he expects a humane amount of service, he would have attended to the first requirement. If in the early days of his existence a person has provided himself with a store of reasonably good mental and physical habits, then he should have no worries.

Habits as Tools for Living.——We find in this chapter that we have come around again to the topic of habits. It is a good subject to talk over once more, for habits are the equipment of life. In a very important sense they are the spiritual tools of our existence. Professor James said there are three classes of habits: good, bad, and those that are neither good nor bad. The good, of course, we will cleave to as we would to a good bat that has served us well, or to a friend who has stood by us. The bad we shall try to break up by interposing chains of associations that will imperceptibly take their places. The tracks of the old bad habits, both physical and mental, are there, but we may be able to cover them up by not using them, or possibly by giving that portion of the mind which manifested them more profitable work to do.

The habits that are neither good nor bad Professor James said should be changed now and then anyway. This suggestion may be somewhat mystifying until we understand that habits that are neither good nor bad are mostly those which make up our personalities, especially those elements which neither help nor hinder other persons particularly. For example, if you know that a certain key will unlock your chest of drawers, and some day you lose the key, you are put to serious inconvenience unless you are able to change that habit of opening the chest with a key, and can solve the problem with a button hook or with a piece of wire. Anyone who learns early to solve all manner of physical problems seldom finds himself a prey to circumstances; he controls them. It goes without saying that the almost universal childish desire to "do it myself," to which we referred in Chapter I, makes the easy approach to the acquirement of the valuable habit of being able to adapt oneself to unexpected circumstances. It was suggested in that chapter that older persons make a great mistake when they take from the young the opportunity to learn how to get out of difficulties more or less unaided.

Similarly, in the matter of getting ideas about things, there are many persons who have learned nearly all they know of life from books. Their information is usually more or less stereotyped and uninteresting, and they are very dry persons themselves. They are drier still when they pore over books of one sort dealing with a narrow field of information. On the other hand, persons who seldom read a book cut themselves off from being in touch with other minds that have looked upon life from different points of view. Those who work with their hands all the time, or engage in commercial or other financial pursuits all the time, or travel all the time, or do nothing in particular all the time, never "touch bottom" in dealing with the mental or moral problems of life, and indeed never have any of the real fun of getting the better of the difficulties that arise in the higher realms of living. In short, they never learn the habit of adapting their minds to new situations and of keeping their minds free from worries and fresh and young while growing older physically. Dr. Thomson has called attention to the valuable trait of keeping our minds young. He tells the story of the great English statesman Gladstone, who throughout a public career of sixty-six years never lost the power of directing a flexible and vigorous intellect toward any matter that developed out of his experience in a long and successful leadership. The mind of our own great Lincoln had that same freshness and freedom from rigidity to so great a degree that he was able to save himself from breaking down in our long and troublous Civil War. Many equally active but less well known persons live their lives with considerable satisfaction to themselves and with great benefit to society in general. It pays to keep our habits that are neither good nor bad from becoming fixed. Thereby they really become "good" habits.

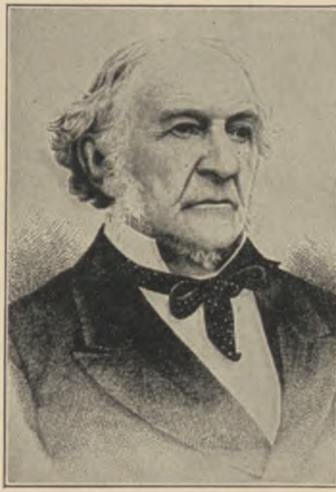


FIG. 214. WILLIAM GLADSTONE.

The Independent Mind.——It would never do for anyone to plan for himself a mind like Gladstone's or Lincoln's even if his ancestors had given him the basis for such a mind. The prime quality of a flexible mind is its independence. "Copy cats" are always ridiculed. It would be a fortunate circumstance if our system of education permitted more opportunity for everyone concerned to have wide ranges of experience. Not only would that give each one a chance to know *what* many groups of mankind do, and *how* they do their work, and so whether we individually would care to carve out a career in the same fields. But it would also furnish us with some understanding of the social relations existing between different bodies of mankind. In these two lines, therefore, we would be set to thinking, for thinking is what the mind does when it comes up against facts. Out of our thinking come the *ideas* which deal with facts and make them understandable to ourselves and to others. "That's a good idea," we say. This means that some one has set his brain to work on a problem and has solved it, or has made a fair start toward solving it.

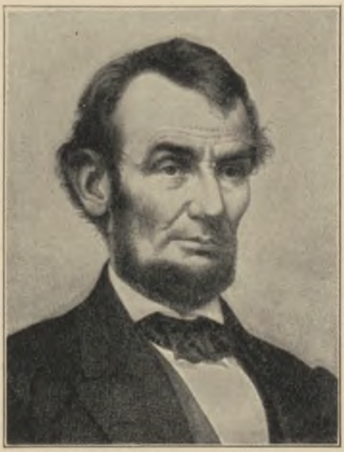


Fig. 215. Abraham Lincoln.

Our civilization has paid perhaps too much homage to persons who have had ideas and could put them into attractive form. Many persons are so lacking in self-respect that they always seem anxious to have the idea or the opinion of another person,—of almost any other person. Perhaps this has had something to do with the fact that unscrupulous persons have been able to have considerable success in abstracting money from the funds of those who showed so much dependence. Although we may blame our system of education for the prevalence of the dependent habit mentioned, we must not forget that in past ages it was only the few who were supposed to be able to think and to have authority as thinkers. We now realize, however, that genius is largely a matter of mental discipline and of dealing with many experiences by thinking *through* them to the underlying ideas. Therefore, we need mostly to encourage a wider use of the habit of having a great variety of experience, of letting our individual minds do their own thinking, and developing their own ideas.

The Ideals of a Thinking Brain.——There is still another important step which the thinking brain will take almost of itself. It will form *ideals*. One of the most valuable of contributions which a thinking brain may make in the interest of its fellow beings is a *clean* ideal, a *good* ideal, a *high* ideal. The thinking brain may also create a selfish or a destructive ideal. What the brain does, depends on what the will makes it do. An ideal is the image of what one is working toward; it is the imaginary form of what an object in life will look like when it is accomplished. It is easy enough to describe an ideal, because everyone has them. For example, I want to make a lot of money, because men are estimated on the basis of their wealth; or so that I may subscribe freely to public charities, and to the aid of deserving persons. Or I want to be paid well for my work, because I regard my work as important, and as being well done. Or I want to have a good balance in the bank, so that my family may live in comfort. Here are a number of ideals about money which may or may not constitute the chief ideal of a person's life, and are to some extent selfish, to some extent good, and to some extent mixed or incomplete.

The ideals of most persons are selfish, even when they flatter themselves that they are doing it all for their families. A considerable number of persons have mixed or incomplete ideals. This is mainly because it is not the easiest of problems to develop ideals that hold well together logically, that are sincere, and that have the virtue of being practical in the long run, not on the basis of cash in hand, but on the basis of some great good to be attained in the lives of all.

Persons of thoughtful temperament and of analytic inclination like to work out their own ideals, and to plan and shape their careers. For, anyone can see that a career that is shaped has the chance of getting somewhere, while those careers that are not planned may drift anywhere,—and usually do. So powerful is the human will over circumstances that a well-conceived plan and a set of ideals will, figuratively speaking, especially if joined with other wills, force itself through steel and concrete battlements. In spite of great obstacles which everyone knows exist, marvelous accomplishments have been won by millions of ordinary human beings. Everyone of us ought to try to be one of those millions, and thus justify our existence to our own conscience, and also fill out a career happy and generally satisfactory to ourselves and useful to mankind.

The cultivation of ideals is one of the most interesting occupations the mind can engage in. Persons who find pleasure and satisfaction in the pursuit of finer and cleaner notions of living, and in associating with other persons with ideals of similar kind, have gone a long way toward actually living finer and cleaner lives, for the thinking and the associating make the possibility of doing. Such persons are not likely to need the advice of the nerve specialist either. Ideals are not merely dreams, but they are clearly conceived thoughts that take hold of the mind and the body, and make them over, if that is necessary. They carry the person into good company or bad company according to the nature of the ideals. They make or mar his very existence. It was ideals of a dangerous kind that brought on the World War, and it is ideals that may make universal and continuous peace possible when mankind comes to have consistently conceived ideals of that kind. The universal will determines what mankind shall be and do.

CHAPTER XXXVII

THE SENSE ORGANS AND THEIR CARE

The organs of sense constitute the transforming stations between the contacts of experience and the central nervous system. Grains of sand may be blown against our faces. The contact of the sand with the skin is immediately transformed in the touch organs or nerve endings in the skin into a message to the central nervous system. A mouthful of hot potato or a piece of ice on the skin stimulate the temperature sense organs, and they transform the condition of heat or cold into a message to the central nervous system.

The organs of taste in the mouth and the organs of smell in the mucous membrane of the nose transform the chemical stimuli into nerve messages which result finally in sensations of taste and smell. The complicated ear transforms the air-waves of sound into the phenomenon of hearing. The eye transforms light wave stimuli into nerve messages which result in the sensation of sight.

Regarded in another way the organs of sense serve as the gateways to our knowing powers, our understanding. Through these several gateways the world, its facts, its activities and all that is done in it may flow into and increase our knowing, our consciousness. Without the sense-organs there would be no way for us to know anything. Without knowing, individual conscious existence would be impossible.

The perfect working of the sense-organs is brought about through the normal development of the individual, and by the protective care of those sense-organs that are most liable to be injured. The most susceptible to injury are the eyes and the ears. The organs of touch, although not liable to injury, are capable of being trained to delicate activities, as for example, they are among jewelry workers and others who handle delicate or small objects or carry on intricate activities with their fingers. The organs of taste are capable of being trained and made more discriminating, as among tea-tasters. Skilled musicians gain their capacity to play difficult music through long training of the ears, coördinated with the delicate control of finger and arm muscles. The eyes also may be trained to see things that are unnoticed by the average person.

Ordinarily, we may not think of the tactile (touch) and temperature sense-organs as being protected, but they are. These sense-organs lie beneath the skin, or in membranes within the body. The organs of taste and smell are protected within special cavities. The ear appears to be an external organ, but the external part is only the sound wave-collecting portion of the ear. The *middle ear* is within the skull, and the membranous "drum" separates it from the external ear. Deep within the skull beyond the middle ear lies the *inner ear* with its complicated structure and its auditory or hearing nerve endings. No sense-organ is so well protected as the ear.

The eyes are set in deep, fat-lined sockets in the skull. The eyeball is inclosed in a very tough coat, and over the eyeball lie eyelids, eyelashes and eyebrows which keep out dust, strong light and perspiration. The swift contraction of muscles in the eyelids protects the eyes ofttimes from serious injury without our thinking what is happening. At the outer corner of each eye is a lacrymal or tear gland which pours out a watery solution that flows over the eyeball into the tear-ducts leading to the nasal chamber.

Nature's provision for the protection of the sense-organs must be supplemented by intelligent care on the part of those who are old enough to understand the reasons for extra care. Those who have "colds in the head" realize that the mucous membrane of the nasal chamber is inflamed and covered with a large amount of mucous. Capacity to detect odors is reduced to a great extent, so much so that we sometimes realize that certain things we thought we had always tasted were really smelled.

THE CARE OF THE EARS

Sometimes in the winter time the doctors have a great many cases of "ear trouble." These for the most part are the cases of children. They have "running ears." Our grandmothers, or at least our great-grandmothers, did not think much about them. As a matter of fact running ears may become sources of grave danger, because a case of running ear may be associated with *mastoiditis*.

Running ears come from inflammation induced by bacteria passing up the *Eustachian tube* from the pharynx to the middle ear. Pus gathers in the middle ear, and finally bursts the drum or tympanum of the ear. Pain in the ear is sometimes the sign that the drum is stretched by the presence of pus. It is much better to have the drum lanced, because before the drum bursts naturally some of the bacteria may get into the spongy bone spaces and induce mastoiditis. Lancing insures perfect draining. This is properly accompanied by syringing with normal salt solution or boric acid to assist in keeping the external ear passage free from injurious bacteria. Sometimes *erysipelas* bacteria get into the running ears if the draining is imperfect. Once in a while an after effect of measles is running ears and mastoiditis. A good doctor keeps a close watch on the eardrum in all measles cases. Nowadays, intelligent families keep on hand an ear syringe which permits of water going in one tube and the waste coming out another. In a week or two a lanced eardrum will heal up, and the hearing of the patient usually is not affected.

Many persons have a very bad habit of "picking the ears" with the head of a pin or with a toothpick. The effect of this habit is to irritate the eardrum, and also to irritate the skin of the external ear passage, thus causing the formation of a small but painful ear boil. The best way to free the ears of excess wax and of dirt is to cover the blunt end of a toothpick with absorbent cotton, dip it into warm water, and with this clear the external ear passage carefully.

Earache with children is sometimes the result of the hardening of a thick layer of wax on the eardrum. Doctors sometimes prescribe "drops" for softening the wax. Warm water and a syringe will also remove the cause of the trouble.

THE CARE OF THE EYES

The things that young people do to their eyes tend to bring on trouble which later in life they try to correct by using eyeglasses. Among these bad habits in mistreating the eyes are reading in a dark corner of the room, reading with the face to the source of light and the printed page in the shadow, reading in bed, reading in unnatural and awkward positions that induce strain on the part of the eyes in accommodating themselves to the unnatural positions.

Eyestrain tends to become chronic, and may go from bad to worse, ending in relative helplessness to use the eyes efficiently. Various bodily disorders tend to aggravate eyestrain. Good health and exercise, including exercise of the eyes themselves, tend to bring the eyes back to normal condition. The great biologist, Charles Darwin, suffered much from eyestrain which was associated with intestinal difficulties.

When the eyes of a human being are suffering from eyestrain, or from *strabismus* (cross-eye), from near-sightedness, or from far-sightedness, the oculist usually prescribes eyeglasses with particular specifications of degrees of curvature of the lenses. If the eyes become unsuited to the glasses, the lenses must be changed for others with different curvature.

Usually that is the most that is done. However, experiments among oculists and others show that systematic daily exercise of the eyes on "Snellen cards" do help the eyes to be relieved of strain and other affections. Possibly this line of experimentation holds much satisfaction for the future. It seems so, although glasses may still be useful in certain cases. It does seem somewhat lacking in reasonableness that of all the sense-organs the eyes should be subject to an uncommonly large group of hindrances. It also seems inappropriate that about the only treatment given is a mechanical one, the nature of which indicates that something is missing from the eyes. There are two ways out for young people, one is better care in youth, the other is more exercises with the eyes themselves.

When particles get into the eye, the lids may be turned back and the particle cleared off with a soft cloth or brush used by another person. As a rule, the glass eye-cup containing boric acid is the best thing to use to clear out the particle, as it aids the natural movement of the tear fluid which flows across the eye from the lacrymal gland at the outer corner of the eye to the tear duct at the inner corner. In cases of inflammation of the membranes of the eyes, the eye-cup and boric acid are also helpful. Besides, children like to use the eye-cup. It is fun, and the treatment gives the eyes a feeling of comfort. Incipient eye infections also may be warded off in this way. However, the most dangerous eye infections are liable to menace the sight of the child at birth. It is the custom now for doctors to drop some *silver nitrate* into the eyes of the new-born child as a precaution against infection, which otherwise might cause permanent blindness.

The proper care of the sense-organs not only insures the retention of valuable aids in making our way through life, but it also makes possible our very existence as normal human beings.

CHAPTER XXXVIII

THE BONES AND THE MUSCLES; AND THEIR PROPER CARE

The Skeleton.——A man is very little taller than his skeleton (Fig. 93), and very little broader than the bones of his shoulders and his hips. The bones of his head, chest, arms, and legs are but slightly different in shape from their entire parts in life. Thus, it can be said truly that the skeleton gives form to the body.

Mechanically the skeleton is more wonderful than any form-giving structure that has ever been invented. This is true of the skeleton as a whole, as well as of any of its parts. The entire skeleton gives form to the young child, newly born. But this form is quite different from the form of the grown man, and the difference is brought about by a gradual process of change taking place in the parts naturally and readily while the body continues at work. Young bones are soft, being composed in large part of *cartilage*. Even when the bones have become harder, they are growing longer and thicker by a process in which the hard tissue is destroyed, and its place taken by new hard material. There are certain cells called *osteoclasts*, the business of which is to destroy bone cells, making way for more bone cells of the same kind. There are many other instances in the skeleton of mechanical adaptations to the needs of the body.

That important organ which rules the body, the brain, is protected in a rounded box by bony plates being fitted in a complicated system of *mortised* and *tenoned* joints. Any ordinary jar or shock cannot injure the brain. No pillar ever made has the flexibility with the strength that is possessed by the *spinal column.* This flexibility is obtained by the drawn-out S-shaped curve of the whole column and by the elastic cartilaginous pads alternating with the bony sections of the column. The vital organs in the chest cavity are protected by the arched ribs which resist pressure. The ribs at the same time are adjustable to permit the up and down movement characteristic of breathing.

All the long bones are curved, adapting them to ready bending. They are also hollow, giving greater strength for the same amount of material, and greater surface for the attachment of the tendons of muscles. At all movable joints the bones are wider, thus distributing the wear over more square inches of surface. The greatest flexibility and variety of movement is attained at the wrists and in the fingers, where the bones are small and numerous, and the surface for movement relatively very large.

The Care of the Skeleton.——The most we can reasonably advise in regard to the care of the skeleton is to suggest that everyone help to create such conditions of work, and also of play, that the risks to "life and limb" will be reduced to the minimum. Without doubt these risks are far greater now than is necessary.

The first care that is needful to give the bones is in the way of proper food. The principal food of bones is lime and phosphorus and their salts. There is the dreadful disease called "rickets" characteristic of childhood which comes from neglect, or inability, of parents to provide those foods which contain vitamins, referred to on page 349. Persons of all ages must have the mineral salts, but the need is particularly one of growing individuals. The young especially need the vitamins.

The white race, like others, has strange ways of deforming the skeleton for the sake of "beauty." We do not flatten the head with a board, nor bind the feet so that they will not grow larger than a child's. Once, we girdled the trunk until the ribs turned in like the neck of an hour-glass. Happily, public scorn and growing intelligence has turned strongly against this habit. But we are now under the spell of the fad of tipping the foot forward with high unstable heels, so that the weight of the body rests on the toes. We smile at the pictures representing the appearance of the skull of the Flathead Indians, and pity the Chinese women of an early day. But their age-long customs are now being altered rapidly, while our bone twisting habits are the results of shallow fashion under civilization, possibly to be replaced by some other whim equally bad. Although the waist-binding habit of women in the civilized world is being modified, the vice of wearing high heels has become so firmly fixed in the early part of the Twentieth Century that it is impossible to buy ready-made certain qualities of women's dress shoes with sensible low heels.

FIG. 216. FASHIONABLE HEELS AND ARMY SHOES.

Many persons think the reform of dress for women is a problem for the women themselves to work out. To a certain extent this may be true, but it appears that a stronger campaign could be made on the basis of improving the conditions of comfort and health for all persons as human beings. Of late years a form of shoe known as the "army shoe" has come into general use in the army of this country, hundreds of thousands of pairs having been sold by certain firms that make a specialty of this particular type of shoe. Men outside the army in all branches of life have experimented with these shoes, and have increased their comfort greatly thereby. The shoes are broad, with thick soles, and with low heels that run well under the foot. Women who are interested in the development of better conditions for themselves and for other women will doubtless ask that the same ideas be carried out by manufacturers for them.

There is an organized effort in this country being furthered under the name of the Correct Posture League which is endeavoring to create better ideals leading toward the more

FIG. 217. STANDING POSTURES.
(Courtesy of American Posture League.)

satisfactory development of the body. Although some of the directions given for maintaining the proper posture are especially applicable to the muscles, most of them apply to the skeleton as the fundamental structure involved. Our sitting and standing positions in time give the skeleton its permanent set. If we practice on keeping our shoulders back, and well squared, our chest high and arched forward, and the neck perpendicular, we shall effectively counteract another foolish fashion known as the "fashionable slouch."

Modern desks at school are made so that the back follows the natural curve of the human form, and gives it support where it is needed. They do not shove the trunk forward at the shoulders, thus leading to the strain that makes one want to try all attitudes to obtain relief.

The Muscles.——Every movement made by the body or by any of its parts involves the activity of a muscle. The muscle acting may be as great as those of the back and the leg, or it may be composed of relatively few cells. In any case the activity always results from the contraction of the muscle cells. The contraction of the muscle is brought about by the stimulus that travels along the efferent nerve fiber. The way this happens is explained in Chapter XXXVI. Although muscular tissue is accustomed to respond to the stimulus carried by nerves, experiments have shown that muscles have the power of contracting when a stimulus is applied to them directly.

The best known muscles of the body are under the control of the will, being connected with nerves that join directly with the spinal cord and brain—the central nervous system. These are sometimes called *voluntary* muscles. Other muscles, as for example, those of the stomach, intestines and other visceral organs are under the control of the *autonomic* nervous system. This connects indirectly with the central nervous system, but is not under the supervision of the will (see p. 421). The muscle cells of the first kind are spindle-shaped and marked by numerous cross markings, for which the name *striated* is used. The involuntary muscles are made up of plain, flattened muscle cells.

Nearly all of the voluntary muscles are connected to bones by means of tough *ligaments* or *tendons* (Fig. 218). Movement of a part is brought about by the contracting muscle pulling on the tendon, which in turn brings the bone nearer to the central part of the skeleton. A few muscles, like the circular muscle around the mouth, contracts and performs its function without involving any movement on the part of a bone.

Work and Rest.——Every muscle of the body should be put to work; and each should also be allowed its chance to rest. The full development of all the muscles requires their

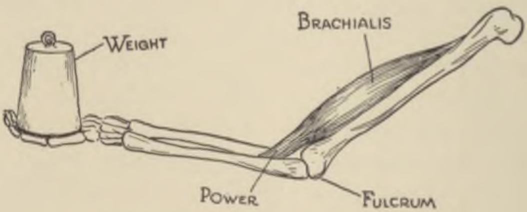


FIG. 218. MUSCLE AND LIGAMENTS.
(From Mackenzie: *The Action of Muscles;* Paul B. Hoeber, New York.)

being employed regularly in their several functions. Otherwise, degeneration ensues. Yet, even in the healthy condition of muscles they tire of their labor, and must rest. The heart itself rests, for between the beats the muscle fibers recuperate. The stomach and the intestine have more rest. The voluntary muscles also require their opportunity for recuperation, which they obtain chiefly during sleep. But they need more, and under proper living conditions get it while the person is lying down, or sitting at ease.

In Chapter XXXVI some suggestions were offered on the point of having useful occupation for the mind. Much of what is given there applies to the value of occupation for the muscles. But aside from the mental uplift one gets from using his muscles in productive labor, the muscles themselves have the needed stimulus to development; and they are educated by the training for performing their labor with increasing efficiency.

Every person who can engage skilfully in various kinds of manual effort grows in power to control his environment, and incidentally commands greater respect among his fellows than he would without this ability. The all-round man may not be a great man in the estimation of the world, but he is more likely to be a perfect man in the sense that fundamental weaknesses are not so liable to exist. Besides, he is sure to be the happiest man of any, for he has so many anchors on life itself.

Athletics.——Fisher and Fisk in their book, *How to Live*, say there are two great forms of activity, work and play; and that there are two great forms of inactivity, rest and sleep. Rest and sleep are of course absolutely necessary. And so are work and play. But work and play seem more full of inspiration, for it is more obvious that something is being done.

Work is the great function of adult life; and it is a man's job. Play is the thrilling interest of childhood; and it is also the training school of the mind and the muscles for the more solid business of mature years. Athletics is the organized play of the adolescent period. As such it has important biological and also educational value.

Athletics in schools was practically an Anglo-Saxon institution in the beginning, starting in England and spreading to America. In America athletics has become general. The boys of every race represented in the schools and colleges take part with eagerness, showing that custom and systems of education in other countries have been responsible for the absence of athletics in their schools.

City schools engage in athletics more than do country schools. This is partly due to the greater development of city schools, and partly to the fact that city boys crave the activity that comes to country boys more readily. Yet country boys have play energy to spare, and where organized play has been developed prove their ability fully. Organized play will perform the same useful function for boys from any environment, and for girls whose mothers never had the opportunity of engaging in the modern games. Athletics, of course, develops stronger muscles, but it also aids in the attainment of physical poise, symmetry of form, and the harmonious adjustment of the various parts of the body. And incidentally, through athletics the organic functions of the body, digestion, circulation, assimilation, elimination, are carried on more perfectly.

FIG. 219. HIGH SCHOOL BOYS IN CROSS COUNTRY RUN.
(© Keystone View Co., New York.)

A very useful phase in the development of athletics in the schools is the fact that games are being introduced in the daily course of study. This insures proper attention being given to the organization of play, and to the need of every young person being put down for some of the training that in the early days of athletics in America used to go to the favored boys with the largest shoulders and the swiftest legs, boys who needed the training less than others.

Athletics is for young human beings, and not for boys alone. Thus, all forms of athletics that will bring the results sought should be employed, for both boys and girls with whatever modification in form experience suggests. To football and baseball we have added basket ball, captain ball, prisoner's base, dancing.

As our various forms of athletics develop still further, we may bring in more of the spirit which the Greeks displayed in their games, the spirit of imagination and beauty. It appears that one school of wrestling in Russia holds to the importance of beauty in the play of the muscles, and in their development.

A practical value of athletics from the point of view of educational administration is recognized by wise educators as a means to the normal development of "school spirit" or "college spirit." Pride in the school team in football, baseball, or basket ball may easily grow into pride in the institution as a whole, in the scholarship of the school, and in its standing in the community.

Overweight and Underweight.——A person may gain in weight by the addition of muscular tissue, and of course muscular tissue is added until adult years. But considerable increases in weight in youth, and moderate increases in weight in adults is liable to be due to the storing up of fat cells between the muscles and about the thin membranes near the intestine. As a person grows stout the amount of surface in relation to the weight of the body decreases, thus lowering the radiating surface for heat. Hence, foods that might develop heat energy are diverted into energy stored in the form of fat. Those who are fat tend to grow fatter.

In some cases overweight may be corrected by means of athletic exercises, but usually it cannot be corrected in that way. Perhaps as many quack doctors prosper at the expense of overweight persons as from any other physical ill. None but the most reputable physicians should be trusted in any case.

There are certain kinds of food which are best for overweight persons to eat. Among these are lean meat in small quantity, vegetables that do not have high percentages of starch, such green vegetables as carrots, parsnips, beets, etc., and fruits. One should avoid much sugar, fats, and foods cooked in fat, nuts, butter, cream, and pastry.

Thin persons sometimes need special consideration at the hands of the physician. They require usually a large amount of energy-producing food, such as fats, starch, and sugar-containing foods. If they are anæmic, they should have foods that contain iron, like eggs and green vegetables. Sometimes cod liver oil is prescribed to bring a person up to the normal weight.

Studies made on the subject of weight of body in relation to general health and length of life bring out the fact that the average weight of persons of 30 years of age if maintained throughout life gives the best condition for all. A table of weights for men and also for women of the various heights has been prepared, and is recommended as a useful guide to follow.

TABLE OF IDEAL WEIGHTS

Men

Height	*Pounds*	*Height*	*Pounds*	*Height*	*Pounds*
ft. in.		*ft. in.*		*ft. in.*	
5	126	5 7	148	6 1	178
5 1	128	5 8	152	6 2	184
5 2	130	5 9	156	6 3	190
5 3	133	5 10	161	6 4	196
5 4	136	5 11	166	6 5	201
5 5	140	6	172		
5 6	144				

Women

Height	*Pounds*	*Height*	*Pounds*	*Height*	*Pounds*
ft. in.		*ft. in.*		*ft. in.*	
4 8	112	5 2	124	5 8	146
4 9	114	5 3	127	5 9	150
4 10	116	5 4	131	5 10	154
4 11	118	5 5	134	5 11	157
5	120	5 6	138	6	161
5 1	122	5 7	142		

CHAPTER XXXIX

THE BUILDERS OF BIOLOGY

Everyone who is interested in Life, observes accurately and records his observations correctly is a builder of the science of biology. Although the science of biology, as a more or less complete body of organized knowledge, is comparatively new, the beginnings of it extend back to the time of the Greeks. Some of the great names connected with the upbuilding of biology are given in this chapter with short accounts of their work.

FIG. 220. ARISTOTLE.

Aristotle (384–322 B. C.).—In history, Aristotle is known as the teacher of Alexander the Great, and as the leading philosopher and scientist of his time. In the study of plants and animals he was the first to point out the absolute necessity of knowing the facts of structure and development. He also proposed a system of classification of animals which was accepted without question by later investigators for hundreds of years.

Aristotle knew a great deal about the development of animals from the egg, and held a theory in connection with that process which to a certain extent is believed in at the present time. He even prepared drawings of many structural features of animals, but these, like the most of his three hundred contributions to human knowledge, have been destroyed.

Aristotle expressed incompletely but clearly the idea of organic evolution by recognizing and calling attention to the gradation of organisms from the lowest to the highest,—man. After his time, it was over two thousand years before anyone learned more about the process of evolution than Aristotle had thought out. In fact, for hundreds of years men were inclined to inquire first what Aristotle had written on this or that topic, rather than to apply the scientific method of inquiry which the great thinker himself had devised.

Vesalius (1514–1565 A. D.).——Through the long dark ages and for a considerable time after the "re-birth of learning" in the fifteenth century, no important advance in biology was made. Vesalius was the greatest of the early anatomists. Others before him tried to put the new spirit of learning and truth into the study of biology, especially in that branch of applied biology known to-day as *Medicine.* But Vesalius was the first of the anatomists to break the old bonds of authority, and to see things as they really exist. Others relied on the writings of *Galen* (131–200 A. D.) who had written on the anatomy of the human body in the second century of the Christian era.

Vesalius was born in Brussels in 1514. Early in life he dissected birds, rabbits, dogs, and other animals. He began to study medicine in Paris at the age of 18. It is said of him that at the third lecture there in the amphitheater of Silvius, the professor, Vesalius pushed aside the ignorant surgeon-barbers, who in those days were employed to dissect at medical schools, and made the dissections properly.

In later years Vesalius became a professor in the University of Padua, Italy, where large numbers of students flocked to study medicine under him. The greatest work that has come down to us from Vesalius is his *De Humani Corporis Fabrica.* In this book excellent drawings of the anatomy of the human body artistically done indicate the clearness and the truthfulness of the method by which Vesalius worked. The scientific method was thus reëstablished in the domain of knowledge.

Harvey (1578–1657).——The fame of William Harvey rests upon the fact that he was the first to apply the experimental method to physiology. His greatest single contribution was the discovery of the circulation of the blood. By a study of the structure of the blood vessels of the lower animals, and by observing the effect of placing ligatures on arms and legs of living persons, Harvey learned that the blood flows in a circuit, and that the heart is the propelling organ.

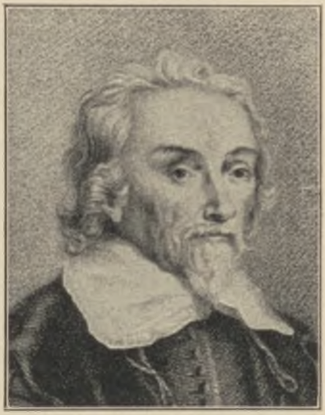


Fig. 221. William Harvey.

Biologists are inclined to consider Harvey, the English physiologist, and Vesalius, the Belgian anatomist, as among the most important of the founders of modern biological science, because of their exact methods of work and the fact that their active labor covered the two important fields of anatomy and physiology.

Harvey was born when Shakespeare was fourteen years old. Thus they worked at approximately the same time. At the age of nineteen Harvey went to Italy to study medicine in the University of Padua, having graduated from Cambridge University (England) in the same year. After four or five years at Padua he received a degree called in those days Doctor in Physic. He then returned to England where he began to practice medicine and to give public lectures.

Malpighi (1628–1694).——Compound microscopes were invented in the seventeenth century. These instruments, although very crude then, opened up rich fields for discovery in the finer structure of plants and animals. One of the most famous of the early *histologists* (scientists studying tissues) was the Italian physician Marcello Malpighi.

Where practically nothing is known, discoveries must appear easy for the first investigator on the ground, but Malpighi was very skillful in devising methods of observation where success would be difficult even with our modern appliances. He discovered the air spaces in the lungs of the frog, and suggested fairly accurately the position of blood and air on opposite sides of membranes. He saw the blood corpuscles passing through the fine blood vessels, that is, the capillaries. He worked out the finer structures of several internal organs in the lower animals and inferred the existence of similar structure in man. But the most extensive piece of work on a single species was his study of the anatomy of the silkworm. This sort of detailed study on a small and somewhat insignificant creature was a new idea. Even to-day the drawings published by Malpighi are considered remarkable.

Malpighi was born in Bologna, Italy, of well-to-do peasant parents. He was given the best education the times afforded, but was twenty-one years old before he had made up his mind on a career for himself. At about that time his parents died. But in spite of the burden of looking after seven younger brothers and sisters, he was able to begin and carry through his work at the University of Bologna.

Malpighi served as a professor of the University of Bologna, Pisa, and at Messina. Many honors came to him from his country and from England for his contributions to science. His period of productive labor covered forty years.

Linnæus (1707–1778).——The great Swedish naturalist, Carl Linnæus, developed and perfected the two-name system of distinguishing the species of plants and animals. The naming of plants and animals in the well-known dead languages, Greek and Latin, has insured their identity being understood everywhere. Besides, the brief and accurate descriptions of the species that was a part of the system which Linnæus developed enabled scientific men to determine whether an animal or a plant was a member of a species already described. If the species on comparison turned out to be new to science, it could be named and described, and its identity become a part of common scientific knowledge.

Fig. 222. Carl Linnæus.

Starting with the species as the lowest group of individuals Linnæus perfected the entire system of classification of living things, bringing out in the complicated "System of Nature" the natural kinships among living things, based upon the likeness or unlikeness of structure throughout the great divisions of the animal and the plant kingdoms.

Thus, the work of Linnæus consisted more in organizing and arranging the facts of biological science than in contributing new knowledge. But the enormous saving of energy and the resulting increase of efficiency in dealing with the knowledge about living things under the existing system of classification may be faintly imagined if we think what would be the task confronting a student who is directed to study in a library where the books are stored in piles as they happen to be brought from other places.

In the dignified Carl von Linné, as he called himself after being granted a patent of nobility by the King of Sweden, it is difficult to recognize the poverty-stricken student at the University of Upsala, who mended with paper and birch-bark cast-off shoes given him by friends in order that he might ultimately obtain his degree.

Cuvier (1769–1829).——Georges Cuvier, the great French anatomist, lived at a stage in the development of biology when there was considerable interest in the structure of the bodies of animals. But he was the first to plan the study of the structure or the anatomy of the entire animal kingdom. This was a gigantic undertaking, even though we understand that he was not undertaking the study of every species, but merely of the typical animals. The importance of this comprehensive study undertaken by Cuvier made comparison of the anatomy of animals on a large scale possible for the first time.

Fig. 223. Georges Cuvier.

Cuvier was deeply interested in nature from early boyhood. He studied at the academy in Stuttgart, Germany, and later went to Paris where at the Jardin des Plantes he met many able scientists who gave him great encouragement, and whose leader he ultimately became. From a shy, perhaps somewhat shabbily dressed provincial youth, Cuvier developed into a cultured gentleman with commanding influence in the nation.

Napoleon Bonaparte appointed him director of the higher educational institutions of the Empire, and scientific France perhaps over-honored him by accepting his teachings against the new theory of evolution.

Bichat (1771–1801).——By some authorities on the history of biology Bichat, the French histologist, has been placed among the first four or five greatest biologists. He lived to be only thirty-one, but in that short life accomplished a prodigious amount of work of very high order. His work was the study of the tissues or groups of cells of the organs and the activity of the tissues in health and disease. The work he did complemented and extended that of Cuvier, and in many respects was more difficult to do. In spite of the fact that Bichat studied the finer structure of organs and made sketches of the cellular structure, he did not use the compound microscope.

Bichat was born in the Department of the Aisne, France, the region of terrible battles in the World War. As a boy he was bright and industrious. He went to Lyons to study medicine, but the French Revolution forced him to go to Paris. There he studied under the great surgeon Desault, and later became professor of anatomy.

Müller (1801–1858).——Johannes Müller is credited with being the founder of the modern science of physiology, and also with being one of the ablest and most magnetic teachers in European universities.

Under Müller physiology was placed on a comparative basis. He not only endeavored to bring the knowledge of physiology into an organized whole, but he also extended it on the basis of experimenting into the allied fields of physics, chemistry, and psychology. The methods of physiologists who study problems to-day find their source in the general method of work and in the faithfulness to truth that were so ably begun by Müller.

Schleiden (1804–1881); **Schwann** (1810–1882); **Schultze** (1825–1874).——The names of Schleiden, the botanist, and Schwann, the zoölogist, have been associated in biology since 1839 in connection with the cell-theory of structure. Before their time the nucleus of the cell had been seen, and so had protoplasm, but the idea that living bodies are composed of cells had never been stated. As it was stated finally by Schleiden and Schwann it was in some respects incomplete and inaccurate, but corrections were made rapidly by other workers who came afterward.

It was not until 1861, the first year of the Civil War in America, that Max Schultze, a very able German zoölogist, practically completed the definite conception of the cell as the unit of structure of all organic things. He demonstrated the fact that the cells consist of minute bodies of protoplasm inclosing a dense, still more minute mass of protoplasm called the nucleus. Schultze pointed out the fact that many animal cells have no cell wall. In those cases the cells consist of the nucleus with its mass of protoplasm.

Since the time of these workers, the cell-theory has been developed still more until now it includes four phases, as stated by Professor Locy, of Northwestern University, "(1) the cell as a unit of structure, (2) the cell as a unit of physiological activity, (3) the cell as embracing all hereditary qualities within its substance and (4) the cell in the historical development of the organism."

Virchow (1821–1903).——Rudolph Virchow, a professor in the University of Berlin, spent a long and fruitful life in the interests of science, theoretical and applied, and also in the political and social welfare of his country. Virchow's chief contributions to biology were in connection with pathology, or the science of diseased tissues. He was also one of the first to state the theory that the material for inheritance is contained in the egg and in the sperm of each species.

Virchow discovered that every cell in the bodies of plants and animals is derived from previously existing cells by the process of cell-division, thereby correcting errors in the theories of earlier workers.

Pasteur (1822–1895).——In front of the Pasteur Institute in Paris stands a bronze statue representing a shepherd boy trying to beat off a mad dog that is attacking two children. The statue commemorates the discovery of the antitoxin of hydrophobia by Louis Pasteur, the best loved and one of the greatest of French biologists. The story goes that the shepherd boy who was himself bitten while protecting the children was brought to Paris in an effort to save his life. It was impossible to save the boy's life, but the knowledge of his heroic conduct coming to Pasteur started the great scientist on the problem of finding a cure for the dread disease. This he succeeded in doing, and the erection of the Pasteur Institute by popular subscription was one of the results. There are now Pasteur institutes in the large cities throughout the civilized world. In all of them treatment for the bites of mad dogs is applied, and in some, the causes of other diseases are studied.

Fig. 224. Louis Pasteur.

Pasteur started his scientific career as a chemist. But while making some studies on fermentation or souring, which was then thought to be due to chemical causes, discovered that minute organisms are the actual cause. He discovered that the souring of milk and the fermentation of wine, forming alcohol, are caused by these minute living bodies. From these discoveries and from those made by others, especially Koch, of Germany, and Lister, of England, that new branch of biology, bacteriology, came to be created. Bacteriology as a science came into being during the period of our Civil War. In that same period Pasteur discovered a way of combating the insects that were destroying the vineyards of France.

FIG. 225. JUPILLE. (Courtesy of the American Museum of Natural History.)

About the year 1868 Pasteur discovered the disease that by killing the silkworms was destroying the silk-making industry of France. Later his whole effort was directed to the work of ascertaining the causes of disease and of producing antitoxins (anti-poisons) for their cure. His method was to take some of the disease-producing virus from a stricken animal, and pass it through a series of stages by permitting the bacteria to grow in mixtures of such foods as beef broth and gelatin, thus tending to reduce the poisonous effect of the bacteria. Some of this "attenuated" virus was injected into a well animal, and the disease in a mild form would result. But at the same time antitoxins would be produced which would guard the animal from future attacks of the disease. Pasteur's first success by this method was attained while experimenting with chicken cholera. Later he discovered the cause and the cure for splenic fever in cattle. In 1885 he discovered the cure for hydrophobia. The attenuated virus of hydrophobia is obtained by giving the disease to rabbits, and taking the serum of their blood containing the milder form of the disease, injecting it after certain preparation into the blood of the human being who has been bitten. The antitoxin thus injected is ready to combat and overcome the disease germs as they develop from the bite of the mad dog.

In the Pasteur Institute at Paris various scientific workers discovered methods of inoculating against diphtheria, the bubonic plague, and lockjaw.

Lister (1827–1912).——It seems almost incredible that in our day of the general use of antiseptics, such as carbolic acid, bichloride of mercury, hydrogen peroxide and iodine that up to the year 1867 there was no way of preventing death if a wound became infected with gangrene. In that year Sir Joseph Lister, a professor of surgery in the University of Glasgow experimented with the use of carbolic acid in the treatment of wounds. He was stimulated in this experimentation by the discoveries of Pasteur in the field of bacteriology. Lister's success was immediate, and with the perfection of methods of sterilization the name of Lister is recorded among the great benefactors of our race, along with Pasteur, and with Koch, the discoverer of the cause of tuberculosis.

Lamarck (1744–1829).——Some of the Greek philosophers believed that living things had not always been as they were in their day. But even the most enlightened scientists up to the beginning of the Nineteenth Century had not suggested a theory of evolution or change. Some, like Cuvier, believed that the species then existing had always existed. Although scientists had recognized the vastness of organic change that had taken place in Nature since the beginning of time, Jean Baptiste Lamarck was the first to suggest a consistent explanation and a theory of evolution.

Fig. 226. Jean Baptiste Lamarck.

Lamarck was a botanist, but at fifty years of age he took up the study of invertebrate animals as part of his work in the Jardin des Plantes, in Paris. As he endeavored to classify the species in the collection he noticed the variations in specimens from different localities and environments. He noticed also that animals living in certain surroundings, and having certain needs to meet, appeared to have parts and organs marvelously adapted to their needs.

For example, the giraffe can browse on the leaves of trees easily because it has a long neck; a duck can swim well, because it has webbed feet; a horse can run swiftly because it has slender legs and hard compact feet; cave animals and underground animals have sightless eyes, as the result of their becoming adapted to dark situations. In fact, the fitness of organs to their functions seemed to be universal. Lamarck was not content with noticing the facts. He undertook to *explain* them.

His explanation was that whatever need arises in the life of an animal, it is met by an effort on the part of the animal to adjust itself to the condition. In attempting to adjust itself the animal uses certain parts and perhaps neglects, or does not need to use, other parts. The parts used will develop by lengthening, or becoming stronger, or by changing form. The parts not used will become smaller and less significant. For example, Lamarck believed that the giraffe's neck began to become longer by stretching to reach leaves, the duck's feet became webbed by using them as paddles in the water, and that the moles and cave fishes became blind simply through not using their eyes.

Of course, Lamarck did not maintain that these changes took place swiftly or in a definite individual. He did maintain that the evolution of organs occurred by extremely slow stages through the effort to adapt being made in many succeeding generations, the changes accomplished in each generation being inherited by the next. Thus, Lamarck was the author of the idea that characters acquired in the life of the individual may be inherited and become characters of the species.

For over one hundred years pitched "biological battles" have been waged over this proposition made by Lamarck, and although the evidence for the proposition is meager, the theory has not yet been given up.

Like a great many other scientific men of an earlier day than ours Lamarck as a boy was put to studying for the Church. That was in those times considered the chief, or the only, professional career for a boy. But like some others, Lamarck did not prove to be adapted to that career, and finally broke with the parental home. He first went to the wars, where he showed the great physical and moral courage that became a notable part of his character in after life.

Lamarck studied at the Jardin des Plantes, and later became a professor there. When his theory of evolution was proposed he became the storm center of a great debate in which Cuvier and others attacked his theories with bitter-ness. Cuvier's influence was so great that Lamarck was generally neglected, and closed his life without receiving the homage warranted by his important beginning in the theory of evolution.

Darwin (1809–1882).——It has often been said that the most powerful book of modern times is Charles Darwin's *Origin of Species.* The influence of the book extended far beyond the realm of biology, and modified the thought and method of practically every branch of human interest and endeavor. After the publication of the book in 1859 the entire scientific world felt the stimulus of the new ideas, and science began to command the attention of the intelligent persons of all nations.

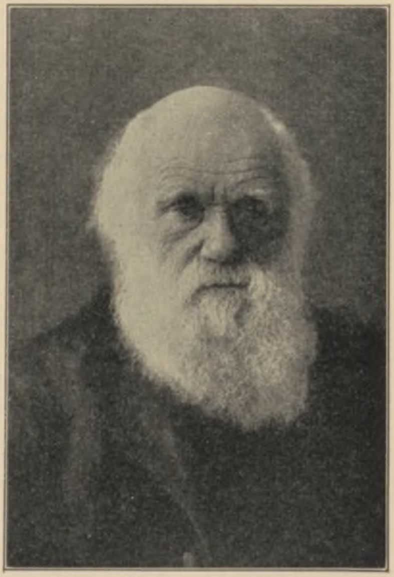


Fig. 227. Charles Darwin.

Darwin's theory of evolution as explained in the *Origin of Species* and in later writings rested on three principles, *first*, the facts of variation among plants and animals, *second*, inheritance, *third*, natural selection. The facts of variation had been noted by Lamarck who endeavored to explain them. Darwin collected and described vast stores of facts illustrating variations, but did not attempt to explain their cause. He believed that variations were inherited, and that to some extent the acquired characters are inherited.

Natural Selection was the entirely new feature in the development of the theory of evolution. By natural selection Darwin had in mind the process by which many variations occur in a given environment. Some of the variations will be weak or not useful in adapting the organism to its environment, others will be strong or "adaptive." For instance, in a litter of foxes some will be weak and be able to obtain food with less success than the stronger ones. The latter will get more food, and will become stronger. Therefore, the chances of their living to reproduce their kind will be better than the chances of the weaker animals. This results in the selection in nature of the strongest and the most active foxes. But there are many kinds of variations that may be selected in nature besides those of strength. Color is a feature which operates in a very interesting way. There is scarcely a species of animal from the highest to the lowest that does not profit from the similarity of its color to other things in certain situations. The color in most instances enables the possessor to escape some danger, but in certain instances it appears to aid the captor to approach its victim without being discovered.

Another type of adaptation that falls within the operation of natural selection is the kind that manifests degeneration, and still is adaptive. Examples of this kind are seen in the absence of soft appendages in earthworms, and in the absence of eyes. The tapeworm living in the intestine of the higher animals has neither eyes, nor mouth, nor intestine, nor appendages, and for these reasons is admirably adapted to its environment.

On the basis of Darwin's contributions to science other workers have gone on and contributed modifications of its principles. Darwin's principles have been attacked by scientific men because of the absence of an explanation of variation, and also because of the insufficiency of natural selection as a means of accounting for evolution,—a theory which no scientist now denies. In fact, so generally is the validity of the theory admitted that it is often called the law of evolution. The principal objection to certain phases of the theory as stated by Darwin will be given in later paragraphs.

The fact that Darwin himself admitted the incompleteness of his own statement of the theory is a sign of one of the finest of the traits of character of this the greatest of all biologists. Darwin was intellectually honest. He would not cover up or ignore a fact when it appeared to conflict with an opinion he had held. But he would seek to learn more about the truth, no matter where it led him. The picture most of us have seen of Darwin represents him as a stern old man with patriarchal beard. But he was one of the kindest and most generous of men, not only in his family life, but even with the enemies he made on account of his startling theories.

Some of these enemies were scientific men; others were leaders in the Church. The latter held out in opposition the longest, because they were convinced that the Darwinian theory threatened to undermine belief in religion. Nevertheless, with the progress of general understanding, the leaders of the Church for the greater part relented, and now teach evolution as a proved law of life, applying even to religion itself.

Darwin as a boy tried to study medicine, but found it very dull, and then went to Cambridge University to prepare for the ministry. But before taking his degree he became much interested in science.

At the age of twenty-two he was accepted as naturalist on H. M. S. Beagle, a war vessel that was about to make a cruise of five years' duration around the world. On this journey Darwin collected an enormous number of facts before the idea of change in the organic world became a conviction with him. In fact, like Lamarck, in the early part of his study he believed firmly in the unchangeableness of the species of plants and animals.

Soon after Darwin's return to England he bought an estate out of an abundant inheritance, and retired there to begin his eventful life of collecting more facts, experimenting and thinking. From the time Darwin first became convinced of the truth of evolution, in 1837, he studied twenty-two years until in 1859 he published the famous book, *The Origin of Species*.

Curiously enough when Darwin was about to publish his book, he received from the English traveler and biologist, Alfred Russell Wallace, an article which contained an exposition of exactly the same important idea of evolution, worked out in another part of the world. Friends of the two workers arranged to have abstracts of the idea as given by them presented before the Linnæan Society of London in 1858 at the same time.

Darwin was born in the same year as our martyred President, Abraham Lincoln, (1809) and died in 1882. During the last forty years of his life he worked under the handicap of ill-health, which was caused probably by eye-strain. A monument to the memory of Darwin has been erected in Westminster Abbey, London. His power in the field of all knowledge will be everlasting.

Agassiz (1807–1873).——Jean Louis Rodolph Agassiz is best known as a great teacher of zoölogy, especially as the teacher of many biologists of America, some of whom were still living and working at the time of the publication of this book. Everyone who has studied under Agassiz testifies to his inspiring leadership as a teacher and to the wonderful enthusiasm and productiveness of the man as a scientist. He was a great man and a warm friend in a circle of the great men of Boston and Cambridge, Mass., in the period of our Civil War. On the fiftieth anniversary of his birth he was given a dinner by these friends. One of them, the poet Longfellow, composed and read for the occasion "The Fiftieth Birthday of Agassiz," which may be found in the Birds of Passage series of poems. One stanza reads,

"And he wandered away and away
With Nature, the dear old nurse,
Who sang to him night and day
The rhymes of the universe."

Agassiz did not become a resident of our country until he was thirty-nine years of age. He was born in Switzerland. His first important scientific work was on fresh-water fishes. Later he studied fossil fishes and proposed a new classification for them. Although the amount of work he did on the fishes was prodigious, he carried on and completed monographs on the fossil echinoderms and on the fossil mollusks.

Fig. 228. Jean Louis Rodolph Agassiz.

When he was twenty-nine he branched out into a new field. He became interested in the phenomena of the movement of glaciers. In order to study glaciers continuously he built a hut on the Aar Glacier. He came to the conclusion that the whole of Switzerland was at one time like Greenland is now, covered with gigantic and deep rivers of ice which strewed boulders everywhere on the sides of the mountains. Later, in Scotland he discovered the undoubted evidence of a glacial epoch during which time a sheet of ice must have covered the north of Europe.

Agassiz's interest in visiting America was partly due to his desire to study the extent of glacial action here. In 1840 he came and delivered a series of lectures in Boston. The following year he was elected professor in Harvard University. He carried on extensive work in geology and zoölogy in America with the aid of many assistants. He made explorations to Brazil to study fishes, and built up the Museum of Comparative Zoölogy at Harvard, the best university museum in the country.

Near the end of his life, Agassiz founded a school of research on the Island of Penikese, in Buzzard's Bay, where the spirit of scientific investigation of marine life enthused many American biologists who were fortunate enough to come under the influence of the great teacher. One of the surprising facts of Agassiz's career is his opposition to the Darwinian theory. He was one of the last of the great leaders in biology to oppose it. Agassiz died in 1873 and was buried in Mount Auburn Cemetery, near Boston. His monument is a great boulder brought from the Aar Glacier near the spot where his hut stood.

Huxley (1825–1895).——Professor Thomas Henry Huxley, the English biologist, exerted an important influence on critical methods of investigation in the morphology or structure of animals as well as in their physiology. But, unlike most scientific men, he appeared often before the public to deliver addresses. Then his keen intellect, his brilliant wit, and his magnetic personality gave effective support to any scientific controversy or public cause he believed in. He was the knight-errant of evolution. In the period of general antagonism stirred up by the *Origin of Species*, Huxley battled formidably with opponents on the public platform and in public print.

Like Darwin, Huxley was a man of thorough intellectual honesty. While defending the theory of evolution on general grounds, he pointed out what he believed to be errors in the work of Darwin. For example, he did not believe that new species developed by the inheritance of small variations, but rather by the inheritance of large variations or "leaps." A great deal of support for this opinion has since developed.

Huxley was interested in many public movements. He was at one time a member of the London School Board, and at that time gave to the public some important criticism of the school studies. Huxley's influence on the teaching of biology in secondary schools is undoubtedly greater than that of any other man.

FIG. 229. THOMAS HENRY HUXLEY.

While Darwin was born of well-to-do parents, Huxley was the son of poor parents, and was not given the chance to go to school, and was not encouraged intellectually until he became a man. But by his own effort he got hold of scientific books and educated himself. At seventeen he began to study medicine at Charing Cross Hospital, London. After receiving his degree he went as surgeon on H. M. S. "Rattlesnake" to Torres Strait to survey. He was on this journey four years. During that time he collected and studied great quantities of material from the sea. For many years afterward he drew upon that rich store for facts new to science. Later he gave much time to the study of fossils. From these two sources his most important contributions to publications were made. Perhaps the best known of Huxley's public addresses is *Man's Place in Nature*, a very fascinating and illuminating essay.

Weismann (1834–1916).——August Weismann, the German biologist, gave the early part of his life to zoölogical investigations at the University of Freiburg. He studied and wrote about the development of the *Diptera*, known as the order of flies, and did a great deal of work on other groups of animals. Trouble with his eyes at times caused him to turn his attention to the problems of descent, especially that of heredity.

Fig. 230. August Weismann. (Photo from Keystone View Co.)

Weismann was a keen critic, a master of details, and a thinker with rare powers of organizing his facts and marshaling them into a consistent whole. But he was intensely speculative, and ranged into fields where his opponents maintained his suppositions could neither be proved nor disproved. Nevertheless, the career of Weismann has been extremely useful in helping to clear up some vexed questions in the Law of Evolution.

Weismann showed that the qualities transmitted from generation to generation in every species are carried by the minute bodies called chromosomes in the nuclei of the cells. In those animals and plants which reproduce by the sexual method the reproductive cells—the egg cells and the sperm cells—the chromosomes form the special "germ-plasm" which is the only material containing the characters for transmission. Furthermore, the reproductive cells are the only ones that pass from one generation to the next, and hence are the only ones that could carry the inheritance which continues forever. This fact gave rise to the expression, "the continuity of the germ-plasm."

Whereas Darwin believed that it was possible for characters or the effect of experience acquired by the individual during its life to be transmitted to the next generation, Weismann denied the possibility of anything of the kind taking place. As evidence of this he maintained that the experiences of the individual could reach only the *soma* or body cells, since they only are exposed to the effect of these experiences. He maintained that there is no way by which the effects in the soma cells may reach the reproductive cells. The group of biologists who are classed as Neo-Darwinians believe with Weismann that acquired characters cannot be inherited.

Weismann believed strongly in the principal of natural selection as stated by Darwin, except that he speculated further and maintained that there was a natural selection going on among the elements of the chromosomes of the reproductive cells themselves. He thought all variations took place there and that the best fitted to survive were selected and gave certain qualities to individuals that developed from the varying elements.

Weismann's last great work was *The Evolution Theory*, published in 1904. He died in 1916, in the period of the World War.

Mendel (1822–1884).——In the Middle Ages practically the only men of scientific attainments were attached to the priesthood of the Church. But in modern times, with the increasing specialization in learning, few men can give their attention to more than one field of endeavor. However, Gregor Mendel, an Austrian monk, found time to carry on experiments in heredity that have caused his name to be placed conspicuously on the roll of honor in biology.

In 1866 Mendel published papers which gave to the world some new and important discoveries. But the principles then discovered were overlooked by scientific men until

1900 when they were rediscovered by De Vries, the Dutch botanist. Bateson, the English zoölogist, then found the original publications of Mendel and made them known to the world. Mendel experimented with growing common peas.

The flowers of pea plants if left to their own development will pollinate and fertilize themselves. Mendel crossed one variety of form or color with another variety of form or color. When the seeds produced by this crossing matured they were planted the next year, and their progeny kept under observation for two or more generations.

Fig. 231. Gregor Mendel.

Mendel found that when a tall form of pea was crossed with a dwarf form all of the plants of the next generation, were tall. But if the flowers of the second generation were permitted to fertilize themselves, the seeds would produce in the next or third generation some tall plants and some dwarf ones. The character *tallness* was apparently the only one of the two present in the second generation, but further breeding showed *dwarfness* also to be present. Mendel called tallness in this experiment the *dominant* character, and dwarfness the *recessive* character.

In the third generation another curious fact was that the number of dwarf pea plants was just one-fourth of the entire number. When the dwarf ones were bred they remained dwarf through as many generations as they were carried. When the remaining three-fourths, the tall ones, were bred, one-third of them (one-fourth of all) separated out as tall plants, and gave rise to other tall ones continuously. In each generation there were one-half of the entire number that in the next generation gave rise to one-fourth dwarf and three-fourths tall.

This mathematical relation is due to the chances of the reproductive cells to unite. There are just the same number of chances of a "tall" reproductive cell uniting with another "tall" cell as there are of its uniting with a "dwarf" cell. These chances are expressed in the following algebraic formula:

TT + 2TD + DD
(1 + 2 + 1)

Mendel experimented on the inheritance of the smooth and wrinkled character in pea seeds, and also on the inheritance of color. The theoretical importance of Mendel's discoveries is that it shows that the reproductive or germ cells carry only one character of a particular kind; that is, they bear only the tallness or the dwarfness, and not both, although they bear other single characters of other kinds. The practical value of his work and of a great mass of work done on plants and animals since Mendel's time is that we now have a method by which new varieties can be produced. We also know when we may expect a variety to breed true, and why it breeds true.

Gray (1810–1888).——Asa Gray was born in Oneida County, New York. From early boyhood he was an incessant reader. At the age of sixteen he began the study of medicine. He took his medical degree in his home county before he was twenty-one.

In the period of his study of medicine he became interested in botany. He collected a great many plants, and "ran down" their names. Accounts of his life make no reference to Gray's practicing medicine. Instead, he soon became a professor of natural science, which in those days meant teaching every branch of science, in a small school in Utica, N. Y. He continued to collect botanical specimens. He taught and published his researches, some in botany, and some in mineralogy.

FIG. 232. ASA GRAY.

His method of work was to be careful and painstaking. He carried on an extensive correspondence with scientific men, and supplied some with new specimens. Many years later, in his days of distinction, he came upon specimens in European collections which he had prepared and sent to correspondents in early days.

At the age of twenty-six he was appointed Curator of the Lyceum of Natural History in New York. At twenty-eight he was appointed professor in the University of Michigan. At thirty-one he was elected to be professor of natural history at Harvard University, receiving a salary of $1,000 a year! At Harvard he established the well-known Botanic Garden, and began a long and distinguished career as the leading botanist of America. His several text-books became standard works everywhere, and his researches were classics in their field. He quickly caught the meaning of the new theories in evolution when Charles Darwin published the *Origin of Species* in 1859. His studies in plant life were available to Darwin in the published accounts, as well as in voluminous correspondence with the great English biologist.

In the elderly gentleman of Figure 232 it is difficult to recognize the alert and intense young man of an earlier period. His biographer says that in the street he was usually on a half run, as if impatient to reach his work again. When traveling by coach and climbing a hill, he would sometimes spring through an open window to secure a plant. He was quick and impetuous, and his prevailing spirit was of inexhaustible good nature.

De Vries (1848–).——Hugo de Vries, the Dutch botanist, an active and able experimenter still living at the time of the publication of this book, has made observations in the Botanic Garden in Amsterdam on the variations appearing in the evening primrose. He finds that new species seem to rise suddenly by the appearance of a new and considerable change in structure. These large changes he calls *mutations*. He believes that species have risen solely by the appearance of series of mutations. The mutations are fixed by natural selection. Thus De Vries believes in the principle of natural selection, but denies the validity of Darwin's idea that species arise by the gradual accumulation of minute variations. It will be remembered that Huxley used an expression, "jumps," which means the same thing as is implied by "mutation." The probability is that both large and small variations operate in the formation of species. But we shall know more about it when future biologists carry on experiments as carefully as has De Vries.

Galton (1822–1911).——Sir Francis Galton was another important contributor to our knowledge of inheritance. He was especially interested in the applications of laws of heredity to the human race. Galton was the grandson of the poet naturalist, Erasmus Darwin, and a cousin of Charles Darwin.

Galton combated the theory of the inheritance of acquired characters. His work was valuable because like Mendel he tried to reduce the study of heredity to a mathematical basis. The movement which he started in this line still continues, and has extended to the application of mathematical measurements to the distinction between species.

Fig. 233. Sir Francis Galton.
(© Keystone View Co., Inc., N. Y.)

The phase of Galton's work which is of the greatest social importance is in the new applied biological science to which he gave the name "Eugenics." This means the science of being "well born." This science is now extensively studied, and much legislation in Europe and America has resulted from the movement started so ably by Galton.

Our study of human inheritance has shown us that certain defects of body and mind are sure to be inherited, some as dominant, others as rescessive characters. The eugenists have convinced society that legal means should be taken to prevent persons suffering from certain foul diseases, and those of imbecile minds, from marrying. Our race must be protected from dangerous defects now existing. Otherwise, the whole race will tend to become degenerate.

If there were no other practical application of biology than eugenics, the value of the science of life to humanity would be evident to the minds of all thinking persons.

It is worth while to know that the science of biology is in a continuous process of development. Not all the essential facts have been discovered, and there are still important interpretations or explanations that will come with future thinking. Interest in the problems of life is very great among persons in general, of course, and deep enough for many persons to form the basis of the activities of a lifetime, even in our modern times, when the world is full of interests that never existed in former generations.

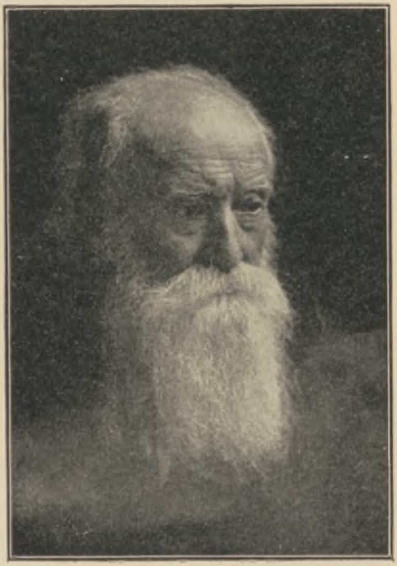


FIG. 234. JOHN BURROUGHS. (Courtesy American Museum of Natural History.)

Burroughs (1837-1921).—John Burroughs was a different kind of biologist from the others whose work has been described in this chapter. He studied at no university. He had no training under a specialist of any kind, and he left no record of technical work accomplished, such as the other biologists left. Yet, Burroughs has probably done more than all of them to inspire the young and the grown-ups also, with a deep and lasting love of nature. This inspiration was transmitted through simple, life-like and charming description of all things and conditions out-of-doors. Thorough familiarity with facts, and boyish enthusiasm about everything gave Burroughs a greater following, perhaps, than any writer on nature topics ever had.

John Burroughs was born in Roxbury, in the Western Catskill Mountains, in the State of New York. His father was a farmer, and the son also became a farmer, varying that career with teaching a country school during his young manhood. From early boyhood he liked the out-of-doors, the farm life, the hunting and the fishing.

At the age of twenty-three, he sent an essay he had written on a philosophic topic to the Atlantic Monthly. The editor, James Russell Lowell, at first thought it had been "cribbed" from Ralph Waldo Emerson, so closely did it resemble Emerson's style. But the article was genuine and was accepted. The somewhat formal style of writing was later put aside, and the simple style of familiar description taken up. With this he was immediately successful.

The "Rip Van Winkle Country" of the Catskills was known throughout to Burroughs. He had tramped over most of it, had fished, hunted and ridden through it so many times that to those who knew him in the long years of his leisurely but productive life, he was in reality as much a part of the character and charm of those low-lying, tree-covered mountains as was Washington Irving's hero himself in fiction.

Of course, everyone knows Rip Van Winkle. Not so many know the Catskills themselves. It may be that fewer still know well the writings of John Burroughs. But for those who have known all three, and in addition the personality of John Burroughs, there is a wealth of charm and spiritual satisfaction.

Near the close of his life Burroughs prepared this message to be published in his biography:

"My dear Young Friends:

The most precious things of life are near at hand, without money and without price. Each of you has the whole wealth of the universe at your very doors. All that I ever had, and still have may be yours by stretching forth your hand and taking it.

John Burroughs."

CHAPTER XL

THINGS AND CONDITIONS THAT HOLD US BACK

A Toppling Monarch.——The World War of 1914–1918 marked the beginning of the fall of monarchy in the world. None of the monarchs of history has ruled his subjects more tyrannically than has the longest-lived of them all, —King Alcohol. By a peculiar irony of fate that follows monarchs, and makes them disciplinarians of one another, the greatest human monarch on the eve of his own downfall decreed that *vodka* should no longer be made in the Russian Empire. That act of Emperor Nicholas was recognized the world over as the beginning of the end of the power of drink. The abolition of the manufacture of absinthe in France, and the governmental control of the manufacture of alcoholic beverages in England and America were blows at the liquor traffic which followed naturally.

When the abolition of the traffic became a political issue in the United States about the year 1880, the "Prohibitionists" were regarded as narrow-minded meddlers with "personal liberty." The Woman's Christian Temperance Union also came in for its share of social obloquy. Doubtless, there were "cranks" in both organizations, and so there were in the political party that forced the abolition of slavery before the country as a national issue in 1856.

Although the Prohibition Party had never polled a vote that either of the two great parties had reason to fear, nevertheless, the sentiment for prohibiting the manufacture and the sale of alcoholic beverages in the United States grew at a rapid rate. First Maine and Kansas, and then one Southern state after another passed prohibition amendments to their constitutions. By 1919, the required three-fourths of the states of the Union had approved the eighteenth amendment of the Constitution to prohibit the manufacture and the sale of intoxicating beverages in the United States for other than scientific and medicinal purposes.

Many of the largest public service corporations in the country have for some time refused to employ men who are addicted to the use of liquor. The interest of a railroad company in the habits of its employés does not rest on a moral basis, as might be the case with the interest of a city or a state in the welfare of its citizens. The concern of the company is purely economic. If it can establish a reputation for a small number of accidents in the running of trains and in construction operations, it will increase its business in competition with other companies. It has been shown in the experience of operating and construction companies of many kinds that men who are given to the use of liquor suffer from accidents, or are the cause of accidents more than are men who do not have this habit. The fact that accidents destroy property is an extra stimulus to reducing their frequency. Many companies that have been able to increase their efficiency in this way offer better wages than do other companies doing the same kind of work.

The interest of the nations at war in restricting the liquor traffic was connected closely with the efficiency and the dependability of the men in the trenches, and with the bearing of the manufacture of liquor on the food supply. Nations at peace find their chief interest in the bearing the traffic has on the prevalence of crime and poverty. Public service corporations are influenced by the desire for efficiency and for the development of their financial power. Two other branches of organization that have made up their minds on the effect of the consumption of alcoholic beverages on human beings are the life insurance companies and the physiologists, the scientific experimenters in nutrition. The interest of life insurance companies in the prevalence of the drink habit is connected with their desire to reduce to terms of scientific accuracy the chances of life and death of the persons they insure. The interest of the scientific experimenters in food values is connected with their desire to ascertain and to publish the truth.

An investigation made by a medico-actuarial committee studying the records of forty-three American life insurance companies ascertained that the mortality among "steady, moderate drinkers was 86 per cent greater than the average" for their several ages, and that of those who had a history of occasional alcoholic excesses, the mortality was "fifty per cent greater than the average" for their several ages. Those men who had taken two glasses of beer, or a glass of whisky, or their alcoholic equivalent each day, showed a mortality 18 per cent greater than the average. In all of these groups, the death rates from Bright's disease, pneumonia, and suicide were higher than the average. Following the discovery of facts like these, the life insurance companies establish groups of "risks" in which persons having a given set of habits or physical states are placed, and then are required to pay a higher rate for their insurance. Of late years some of the companies refuse to accept the applications for policies made by persons whose lives are uncertain because of their vicious habits.

The effect of alcohol on the human body has been studied scientifically by competent physiologists all over the world. About the year 1900 some American physiologists believed that alcohol could be called a food correctly and a proper stimulant to be used medically in certain cases. A great deal of investigation since that time has served to change that opinion, and to convince physiologists that alcohol is not a food in an accurate sense, and is not a stimulant at all, but is a dangerous narcotic. The number and the extent of the risks one takes in becoming addicted to the use of alcohol are so appalling that when our citizens become thoroughly informed about the subject, it is altogether likely that the doom of the traffic will be well-nigh complete, even "for medicinal purposes." The consummation of the end, however, must depend on the facts. They are as follows:

The carbon in alcohol is oxidized and releases some energy, but the amount is small and of no consequence. As was explained in Chapter XXXVI there are certain autonomic nerve

FIG. 235. GUINEA PIG.
(Courtesy of Professor W. E. Castle.)

centers which set organs into activity. Now, alcohol is one of the substances that paralyze the controlling nerve centers of the heart. In this way "the brake is taken off the heart," and that organ begins to "speed up" its movements, thus giving to the early scientific observers the impression that the action of the heart was really stimulated. It is also known that while the pulse beat is more rapid under the influence of alcohol the force of the beats is less, implying that the amount of blood sent through the arteries is not increased as was formerly supposed. These results obtained by experimenters in German universities have been verified by investigators working in the Nutrition Laboratory of the Carnegie Institution. The investigators agree that alcohol is a narcotic, a depressing drug, even in the smallest doses usually taken as a beverage.

It has been ascertained by the investigators in the Carnegie Institution and elsewhere that the time required to act on a stimulus or suggestion given a man is increased after a small dose of alcohol. Simple intellectual processes are retarded, and the memory is impaired.

Observations have been made on the resistance to disease of which persons given to the drink habit are capable, and it has been found that the paralyzing of the white blood corpuscles is one of the causes of their lowered power of resistance. Some of the special forms of infectious diseases which are more serious for drinkers than for others are pneumonia, tuberculosis, typhoid fever, blood poisoning, cholera, and hydrophobia.

Professor C. R. Stockard of the Cornell Medical College, New York, has carried out experiments on exposing guinea pigs to the fumes of alcohol for a certain period each day for years. Whatever conclusions he could draw would have a certain bearing on man, for the nature of the living substance, protoplasm, is much the same anywhere. Treated guinea pigs often showed an opaque appearance of the cornea, the tough, transparent coat of the eye. Some became blind during the treatment. But examination showed no abnormal condition of the internal organs. Nevertheless, the offspring of a parent that had been treated with alcohol showed seriously diseased conditions. The chief defects were manifested in the central nervous system. Many young animals had nervous tremors. The hind legs, the fore legs, or both legs on one side would be paralyzed. In some animals the eyes were blind. Or there would be present one eye only, or none at all, even the eyeball and the optic nerve being absent. The number of young guinea pigs tended to decrease. These defects persisted in at least three generations, although none after the first were exposed to the fumes of the alcohol. In fact, the great-grandchildren of the alcoholized parents "almost without exception are incapable of reproduction, and are in many ways subnormal and degenerate."

Obviously the effect on the protoplasm of guinea pigs is more serious than it is on the protoplasm of man, when the inheritance is considered. It may not be correct to say that the internal organs of guinea pigs are not directly affected by the alcohol as was stated above, until it is possible to compare the physiological and psychological effects on the guinea pigs with the effects as we know them in man. It may not be possible to make this comparison. In any event, the experiments on the guinea pigs are impressive.

There are some men of talent and understanding who freely acknowledge the validity of the principal charges in the indictment against King Alcohol. But they maintain also that in spite of all that has been shown, he has given the world much that is beautiful and wonderful in song and in literature. Besides, they say, the simplicity, charm and frankness of many personalities would be concealed from their friends forever, if it were not for alcohol.

In terms of the physiology of the nervous system under the influence of alcohol, we now understand that when "the brake is taken off the brain" the creative imagination of a genius may conceivably produce work that is unusual and truly wonderful. These are *possible* results. There are few evils that do not occasionally yield a beneficial result. But we have only to sum up the results all along the line, and consider whether in all the possible artistic and literary product of men of genius much of the same kind of product has not been actually *lost* through the paralyzing effect of alcohol. We must not forget that qualities of this kind that have been lost are never seen, and hence are not likely to be thought of.

It is well for us to consider why after men understand the serious results of using alcohol they still continue the custom. In a measure the answer is that a drug habit has been formed which the person finds difficult to break. Without question many men drink because they believe it paves the way for greater sociability, for having what is called a "good time," but chiefly because alcohol makes them forget the "hum-drum," or the worry, or the poverty of their lives.

Those who are fighting intelligently to destroy the liquor traffic should not forget that a strong point in the attack would be to aid also in the abolition of the conditions which exist as a constant menace to inducing men to drink. As was pointed out in the chapter on "Up from Savagery" we must endeavor to make it possible for every human being to have enough of the product of his labor to keep him in health and reasonable plenty. Besides, social conditions must be improved in every way, so that a man may find his home and the normal processes of living a comfort and a source of natural happiness. Furthermore, our system of education must be improved to give every person natural thoughts beyond the "hum-drum" of a stupid life of personalities. We must be taught to live outside our individual selves and to become a part of all nature, which is always interesting. It is absolutely wrong and destructive that a human being should be so surrounded by misery that he must take on a villainous habit in order to get away from himself and his environment.

With all the important work that has been done to destroy the King, it is most important that his former subjects should be provided with a new and finer substitute for their loyalty,—their own self-respect, and the welfare of their fellowmen.

The Drug Menace.——In addition to the burden of alcohol upon us, there is an evil which is even more insidious in its operations than is alcohol, and that is the other, more terrible habit-forming "drugs." The best known of these are the preparations and the derivatives of opium (morphine compounds). Less well-known habit-forming agents, introduced chiefly for medicinal purposes are *cocain*, *acetanelid*, *acetphenetidin*, *antipyrin*, *phenacetin*, *caffein*, *cannabis indica*, *chloral hydrate*, *saccharin*, *codein*, *dionin*, and *heroin*. The last named is one of the most terrible in its effects and its hold upon its victims.

It is estimated that there are over 1,000,000 drug addicts in the United States. Everyone of these persons lives in unnecessary and avoidable misery. Naturally, there are groups of individuals who are desirous of preying upon their fellowmen if the opportunity offers. These persons engage in the surreptitious sale and distribution of the drugs, in spite of laws forbidding the traffic. Many of the medicinal products containing the drugs are sold legally over the counters in drug stores. For this the drug stores are not primarily responsible. The people are responsible for permitting the manufacture of the patent medicines of that kind.

Sometimes physicians prescribe the drugs in cases seeming to require it. After recovery the patient may continue the use of the medicine on account of the apparent good effect. Thus the habit of using the drug is liable to be fastened on the patient, and he becomes one in reality practically throughout life. In the state of New York and in a few other states the law now requires physicians to make prescriptions for every filling of a bottle by the pharmacist, when habit-forming drugs are part of the ingredients. This helps to prevent the patient from continuing the use of the substance at his own pleasure.

Another way in which habits of this kind are formed is by the practice of giving "soothing syrups" to babies. By many mothers Mrs. Winslow's Soothing Syrup has been regarded as a great "blessing," but that was because the mothers did not know what the medicine was doing to their children. This preparation contains morphine sulphate in quantity sufficient to quiet a child through the narcotic action of the drug. No mother when she understands would deliberately give her child morphine. Other soothing syrups may be offered as substitutes for the old one that is nowadays condemned, but they also contain drugs of the same nature and effect, either morphine itself, or codein, or chloroform, or chloral hydrate, or cannabis indica, or heroin. Happily, with the new knowledge of the caring for babies the mother does not need to try to keep the baby quiet at all times. Sometimes crying is good exercise for it.

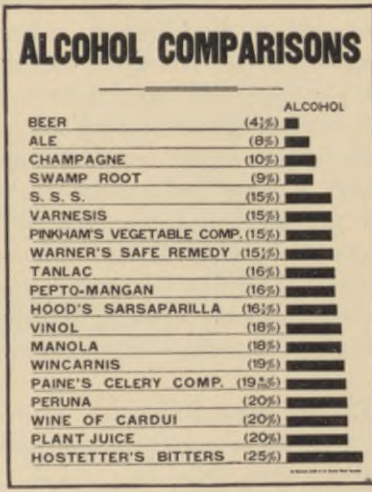


FIG. 236. ALCOHOL COMPARISONS. (Poster of the American Medical Association.)

Most persons who patronize the places where soft drinks are sold do not realize that danger lurks there. Many of the products there contain caffein, the narcotic found in coffee and in the kola nut, or extracts of cocoa leaves. This principle of cocoa leaves is cocain, one of the most insidious and dangerous of drugs. The advertised value of drinks containing these materials is that they give relief from fatigue. Many persons are addicted to the use of medicated soft drinks. These persons are properly classified as drug addicts. The step to their absolute dependence on the drugs would be a short one for them.

Many persons suffering from the chronic diseases of asthma, catarrh, tuberculosis, and epilepsy, and also from periodic colds and headaches purchase patent medicines that contain these habit-forming drugs. It is unfortunate that society has not yet been stirred to realize that patients suffering from disease naturally try to obtain relief from any and all sources that appear to be available. The bill for patent medicines is a large one, but the indictment against us for ignorance and the punishment for our social neglect are still more serious. We need to have more information spread among all classes of persons, and after that there should be a more definite determination on the part of organized society to eliminate the unnecessary evil of preying drug habits. In their stead let us try to establish greater confidence in the scientific cure and eradication of disease. Drugs not only create unnecessary misery, but they also hold us back from race accomplishments greater than we may be able to conceive.

The Smoking Nuisance.——Prior to the sixteenth century, the use of tobacco was confined to the American Indians. At about that time Jean Nicot, the French Ambassador at Lisbon, Portugal, introduced snuff-taking in the Court of Catherine de Medici. The habit of smoking soon began to spread rapidly throughout Europe. Whatever men may say about the taste for alcohol being natural because the existence of alcoholic liquors may be traced far back in history, they cannot say it of tobacco.

There has never been the powerful campaign made against the use of tobacco that has been made against alcohol, although in the early days of the introduction of tobacco in Europe the governments endeavored to oppose its use. Certain influences in America have organized to fight the habit of using tobacco, and certain states forbid the sale of cigarettes to boys under sixteen. But the use of tobacco is on the increase, especially in the form of cigarettes.

Tobacco contains a narcotic poison, called *nicotine* in honor of Jean Nicot. A number of other organic chemical compounds are found in tobacco, chiefly *pyridin*, and *furfural*. All these are very poisonous, and if they were taken even in

HE WON'T LAST LONG AFTER THE SUN GETS UP

FIG. 237. CONSUMPTION "CURES."
(Poster of American Medical Association.)

small quantities in their pure form would quickly prove fatal.

Many experimental observations have been made of the effect of tobacco on the human being. In 1912 an investigation was made on the effect of the smoking habit on the candidates for membership in the football squads in six colleges. In every case the percentage of those actually achieving positions on the team was much greater for the non-smokers. In the same investigation non-smokers stood higher in scholarship, and there were fewer of them who failed or had conditions charged against them.

In 1914 Dr. Bush carried on tests on college students who smoked. After smoking, the students showed a $10\frac{1}{2}$ per cent decrease in mental efficiency. He learned that the loss in efficiency was in imagery, perception, and association. Cigarette smoking seemed to be the cause of the most serious loss.

Some men claim that smoking clears the mind, enabling them to accomplish more mental work than they could otherwise; while others maintain that smoking soothes the mind, enabling them to put aside worries and nervousness. It should be noticed that these claims are exactly the same as are those made for alcohol. And the interpretation of the effects observed is the same. The physiological effect is narcotic as with alcohol. The "brake is taken off the brain," an expression employed by physiologists, although the feeling of some persons is that certain faculties of the mind have been stimulated to unusual activity. Others note the "soothing" effect, which is the distinctly drug activity of the tobacco. Men who are being "soothed" are being narcotized by the slow poison. The judgment of a man who is being affected by poison as to the comfort of a "good smoke" is hardly to be accepted. If an opium smoker told us that in his dreams he beheld certain wonderful things, more beautiful than he could see without the opium, we would hardly maintain that for this reason opium should be more widely used.

FIG. 238. CIGAR, CIGARETTE AND PIPE.

Rather than accept the judgment of the narcotic user, we ought to inquire concerning the actual effects of tobacco on the body. Some of these effects are a disturbance of the blood pressure, a more rapid heart action, shortness of breath, palpitation of the heart, pain in the region of the heart, and hardening of the arteries. It has also been noticed that users of tobacco do not recover from operations so readily as do others. Tobacco also lessens the power of the voluntary muscles, because of the depressing effect on the central nervous system.

One of the regular chemicals in the stockroom of the seaside laboratory of biology is nicotine. A drop of it in a dish of sea water containing specimens of delicate sea animals will paralyze their nervous systems immediately, and render them quiet for study. Yet many biologists are addicted to the use of tobacco. It is as if they stopped noticing effects when it came to considering themselves.

Perhaps few intelligent men would deny that the use of tobacco in excess is a dangerous habit. But the extent to which each user employs this artificial soothing agent is considered by himself not to be excessive. A material that must be guarded against to prevent excess should reasonably have some easily demonstrated benefit. But tobacco has absolutely none.

It has been maintained by good authorities that the prevalence of diseases of the heart and the circulation is increasing in this country. It is known that our per capita consumption of tobacco is increasing rapidly. In Great Britain the use of tobacco is decreasing, as is also the prevalence of diseases of the heart and the circulation. A close parallel between these two sets of facts is thus demonstrated.

Disease.——The theory of disease prevalent in savage races to-day is the same as was probably passed through by civilized man. It is that an evil spirit or demon enters the body, and there causes various ills. Medicine-men or wizards endeavored to induce the evil spirit to leave the body, either by sacrifices, or by conciliatory measures, or by forcing it out through the agency of powerful charms, by beating tom-toms, or by pummeling the body of the patient.

As civilization developed, there came into use the Hippocratic theory of disease, called after its founder Hippocrates, "the Father of Medicine." This theory was thoroughly believed in throughout the Middle Ages. According to it the human body contains four *humors*, blood, phlegm, yellow bile, and black bile. In health the belief was that these humors existed in proper proportions, and that in disease the porportions were improper.

As has been explained in the account of Pasteur, the germ theory of disease was formulated by Pasteur in connection with his studies of fermentation. This theory is accepted now by scientific workers all over the world, and the practice of medicine for the first time has become scientific.

Although the civilized nations have progressed far in the matter of combating disease, the desirable end of eliminating it does not seem so simple of accomplishment as it may have seemed to be about the beginning of the Twentieth Century. Then physicians and the health authorities were probably over-enthusiastic about the discovery of the cell origin of communicable diseases. It seemed not too much to expect that through organized sanitation in city and country and through the isolation of patients that the most important of the devastating diseases could be checked at once and finally exterminated.

Those who are not trained in medicine are liable to think that instead of the number of diseases being decreased, there are more of them than ever before. But this is only an apparent result. The study of disease has resulted in differentiating complaints into clearly defined diseases where general and vaguely understood physical ills formerly were treated. Besides, the development of commerce by exploration and travel has brought to the knowledge of men everywhere the characteristic diseases of other countries. And it has sometimes happened that the diseases themselves have been transported to other lands than the ones where they were indigenous.

However, no disease has been exterminated, nor is any likely to be in generations. It is true several have been greatly reduced in frequency and in their devastating effects, and this reduction is no doubt permanent. Diseases that are noticeably less frequent than they were before the discovery of the causes of communicable diseases are smallpox, typhoid fever, malaria, and bubonic plague. Diseases that are still all too common are tuberculosis, diphtheria, measles (a more dangerous disease than many imagine), scarlet fever, pneumonia, cancer, syphilis. Medical researches have reduced the fatality of these diseases but scarcely at all the frequency of their occurrence.

There are also a group of diseases known as the organic diseases which were never more frequent than they are today. Bacteria have nothing to do with their prevalence, except in ways sometimes more or less remote. These diseases affect the internal organs of the body, especially the nervous system, the circulatory system, the kidneys, the digestive system. As already noted in an earlier section of this chapter, the use of alcohol and tobacco have a direct bearing on the prevalence of these diseases. To a considerable extent also the general indulgence in an excessive amount of food tends to increase liability to these diseases.

Happily for humanity the solution of the problem of exterminating organic diseases lies largely in our own hands. That is to say, the will to stop the enormous waste of human energy going out because of organic disease is all that it is necessary to bring the undertaking into operation. But for the problem of stopping communicable diseases we need to fight long and intelligently to make the slightest impression.

In the first place, the fight against disease is one that involves the efficient coöperation not only of cities, but also of states and nations, for the bacteria of disease break down all political boundaries. It is to the everlasting honor of the medical profession that its scientific investigators have never held their discoveries within national limits. Scientists, medical foundations, and governments have cooperated and must continue to work together to save the members of the race from wasteful disease or early death.

The question may easily arise as to why the regulations of boards of health have not been able to keep down the communicable diseases. These rules are strict, and in general they are fairly well obeyed. When a communicable disease appears in a family the precautions in general, especially in the cities, are so effective that new cases seldom appear in the same family. But they appear elsewhere.

Health authorities are now convinced that the chief reason that it will be difficult for a long time to come to eradicate disease is on account of the prevalence of what are known as "carriers." These may be persons who have had the disease and continue to transport in their bodies the bacteria of the disease, or they may be persons who contract the disease in such form as not to become ill from it, or they may be persons in whose bodies the bacteria reside for a long time without making any impression. Investigation has shown that the number of carriers is far greater than is generally known. The nature of the case makes it difficult or seemingly impossible to detect all.

One of the most famous cases of carrier is that of a woman known as "Typhoid Mary." This woman was a cook, and she followed the common custom of changing places frequently. She had typhoid fever about the year 1907. Wherever she cooked some one or more members of the family became ill in about two weeks with typhoid fever. An investigator becoming suspicious of her connection with the numerous outbreaks of the disease followed her wanderings from New York to Maine and back to New Jersey, finally succeeding in locating her and securing material from her intestinal tract that proved the existence of typhoid bacteria still in her body. She was forcibly detained in a hospital for a long time, and was finally discharged while still a carrier. Although this woman was probably not cleanly in her habits, the danger of permitting even cleanly persons who are carriers to prepare food, or in restaurants to wait upon their well customers is very great. It is often occasion for wonder that physicians and nurses so constantly in touch with disease seldom are known to carry disease to others, while persons in less exposed positions, like Typhoid Mary, may exist as menaces to the health of a community. Sanitation or cleanliness is at the bottom of the difference. The physician or nurse is trained to be careful, to wash the hands, to change the clothing, and to keep themselves in good health as a matter of professional preparedness. Probably Typhoid Mary seldom washed her hands. If our education created the instinctive habit of cleanliness in the race, the ravages of disease would doubtless be far less extensive than they are.

Another place for general education on the score of health is the extension into all ranks of society of the truth about the causes of disease and the scientific methods of treatment. The causes of communicable diseases are undoubtedly micro-organisms of plant or animal origin, and yet there are great numbers of persons who profess to believe that "germs" do not exist except in the minds of the doctors. The unfortunate fact is that the human mind has not developed to the extent of recognizing truth naturally. A bundle of prejudices clutter up the pathways of the brain. Long education and the development of a racial habit of "thinking straight" are the main dependence of those who hope for success along this line.

The recognition of the causes of disease entails a scientific search for the remedy, no matter what its nature. The main object in the scientific treatment of disease, let us realize, is the cure and prevention of disease in human beings. Many sentimental persons balk at this point, especially when they see that the discovery of the cure of disease may lead to the destruction of life among some types of lower animals. They are unwilling to trust the scientific method, which is economical of life by virtue of its very motive. Instead, many of these well-intentioned persons work to pass laws that hinder the saving of human life by assisting in the movement to stop experimentation with the lower animals.

Now and then we hear them say that the inoculation of soldiers with typhoid vaccine even results in the death of large numbers of soldiers, in spite of what should be common knowledge that typhoid in soldiers' camps nowadays is extremely rare, while before vaccination for typhoid was discovered great numbers of soldiers in camps died of the disease. In spite of the fact also that smallpox has been well-nigh eliminated through the system of organized vaccination, many persons oppose vaccination, and strive to discredit a scientific discovery so obviously beneficial to mankind.

Smallpox vaccine, diphtheria serum, and the attenuated virus of hydrophobia respectively involve pain to cattle, to horses, and to rabbits. Shall we on that account decide to give up the cure of these diseases in human beings? This should be the test of the worth of the logical position held by those who call themselves "anti-vivisectionists."

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