PRACTICAL BIOLOGY

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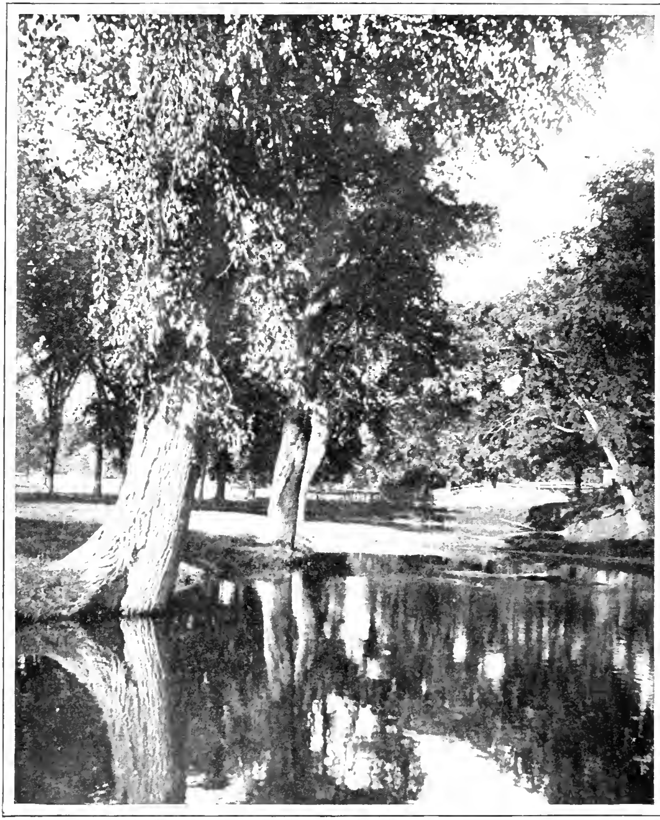

Elms at the Water's Brink.

PRACTICAL BIOLOGY

BY

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PREFACE

Practical Biology offers a simple, workable, attractive, flexible, and teachable course in Biology.

Simplicity is a feature of the book. The language is simple, not technical, and the style is easy, flowing, and colloquial. The pupil is assisted by many mechanical helps. Small cuts or larger pictures illustrate each new topic and there are many charts and maps.

The practical aspects of Biology are emphasized. A study is made of the economic value of plants and animals, and of the characteristics which make them beneficial or harmful to mankind.

The attractive illustrations, many of which were made especially for the book, are a feature of the Biology. In addition to the cuts and pictures which illustrate the text, there are portraits of the leading biologists of the world, with brief accounts of their lives and of their contributions to the subject.

The flexibility of the book enables teachers to begin with the study of animals or with the study of plants.

A number of features help to make *Practical Biology* teachable. (*a*) The paragraphs are short, and there are summaries and questions at the end of each chapter. (*b*) Well-known types like the grasshopper and the bean plant are studied first, and the treatment passes from the known to the unknown. (*c*) The pronunciation and derivation of technical names are given in the text the first time the names occur. (*d*) There is an introduction defining the common scientific terms used in the study of Biology. (*e*) Optional field work and students' reports are provided for. (*f*) Laboratory work is contained in the book, so that a special manual is unnecessary. (*g*) The index is unusually complete.

The treatment of human biology emphasizes hygiene and sanitation and contains graphic diagrams illustrating the sections on health and disease. This treatment will be found especially practical. The treatment of alcohol and narcotics is adequate, but sane.

For teachers in New York State a feature of the book is its close relation to the Regents' Syllabus, which it covers exactly. It is equally suited to courses laid down for various other states, notably Massachusetts and Ohio.

The book has a number of appendices, one of which has to do with bird study. Another contains the sanitary code of the State of New York.

The work is so arranged that the course, though simple, is thoroughly scientific. Science is organized knowledge, and the simple student reports in the form of tables lead the pupil to make a correct and logical classification of his facts, thus laying the foundation for scientific study.

W. M. S.
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INTRODUCTION

DEFINITIONS OF COMMON BIOLOGICAL TERMS

Biology is the science which discusses living things — plants, the lower animals, and man. These living things move, breathe, feel, and get their food in varied ways.

Man, for instance, does not move as a jellyfish moves, nor does he breathe as a tree breathes. He has not the same sensations as a frog, nor does he get his food as do the flowers; though he and all other living things have these functions[1] in common. Each living thing has its parts especially adapted to its peculiar needs. Claws serve a cat admirably for climbing and for catching mice; a frog has web feet to aid in swimming; while hands are better suited to the kind of things that a man has to do.

Energy. — Everything that plants and animals do requires *energy*. Without energy in some form they cannot move or grow. Energy is produced in various ways. In a steam engine fuel is consumed or *oxidized* to make energy. In man the food taken into the body is converted into energy by a slow kind of burning which we call *oxidation*.

Life Processes. — From the study of physiology we are fairly familiar with foods, or *nutrients*, as they are sometimes called. Some of these are starch, sugar, fats, oils, and mineral matter. The life of a plant or of an animal is directly dependent upon its food. But food is not the

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[1] **Function has a scientific use in biology, where it is used to describe the common living activities of animals and plants.**

only important thing to consider in studying its life. The life of each plant or animal may be studied under eight headings, known as *life processes.* These are ***sensation*** or ***irritability***, ***locomotion***, ***food getting***, ***digestion***, ***assimilation***, ***respiration***, ***excretion***, and ***reproduction.***

1. *Sensation* (*irritability*) is that life process by means of which an organism comes to know of things outside of itself. Through sensation (irritability) it becomes aware of its food. By the help of the senses the higher animals are able to see and hear one another, are conscious of heat, cold, light, sound, and many other things, all of which are called ***stimuli.***

2. *Locomotion* is the life process by which animals move, and is closely related to sensation. It is the means by which animals secure food. In the higher animals stimuli are sent through the nervous system to the various muscles, which contract and so cause the animal to move.

3. *Food getting* needs no definition. Man gets his food from many sources. He eats animals, minerals, and vegetables. Lower animals live by hunting or grazing, and plants get their food through their leaves and roots.

4. *Digestion* is the life process which prepares the food to pass to all parts of the body. It takes place in all animals and plants, but we are most familar with it in man. Man chews his food in the mouth, thus softening it and mixing it with saliva ready for the stomach. Digestion is continued in the stomach and completed in the intestine.

As soon as the food is digested, some of it passes through a thin membrane in the wall of the intestine into the blood vessels and thus is ready to furnish energy in the body. This passage of the dissolved food through a membrane is called ***osmosis*** (ŏs-mō′sis).

5. *Assimilation* is the building of the digested food

into living animal and plant parts. In animals the blood vessels, into which the digested food passes, carry it to all parts of the body, and as it circulates, each part takes the food needed and builds it into living material.

FIGURE 1. — SIMPLE OSMOMETER SHOWING OSMOSIS.

The water in the glass passes through the egg-membrane and forces the egg-white up in the glass tube; while the egg-white does not pass out into the surrounding water.

6. *Respiration* is the life process that uses oxygen taken from the air or water and forms a waste product known as *carbon dioxide*. This life process should not be confused with breathing, which is limited to animals with lungs or air-tubes. In such animals the breathing is simply a mechanical process in which the air is brought into the lungs or air-tubes. This allows the oxygen to pass by diffusion into the blood, where it is carried to all parts of the body, or it may pass directly to the living cells. See section 6, page 14.

7. *Excretion* is the life process in which waste products, like perspiration, are made and cast off by the body. On page 1 we saw that energy was produced by oxidation. After this the waste is thrown off by excretion, as the ashes are thrown out of a steam engine.

8. *Reproduction* is the life process by means of which each generation of plants and animals is brought forth. There are two kinds, asexual (a′sex-u-al) and sexual. Figure 47 on page 49 shows a simple animal, the amœba (a-mē′ba), dividing into two young amœbæ by asexual methods. The same kind of reproduction in a simple plant, the yeast, is illustrated in Figure 374, page 355.

Sexual reproduction is the name given to a process in which two special cells, called the egg and the sperm, unite to form one cell, the fertilized egg cell. The fertilized egg grows into the new organism. In some plants the fertilized egg forms part of a seed which later develops into the plant.

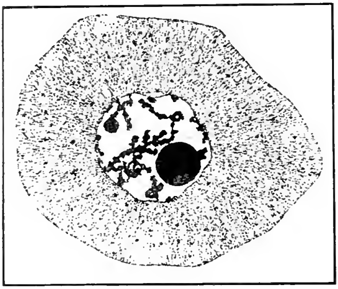


FIGURE 2. — PLANT CELL.

These eight *life processes* are seen in all forms of living things, but it is often hard to study them. For instance, the locomotion of a clam is harder to study than that of a cat, and the respiration of a plant than that of a man.

The Parts of Bodies. — These life processes tell us what the parts of bodies do, but they tell us nothing about these parts themselves. There are four words which are used in biology to describe these parts. They are: *cell*, *tissue*, *organ*, and *organ system*.

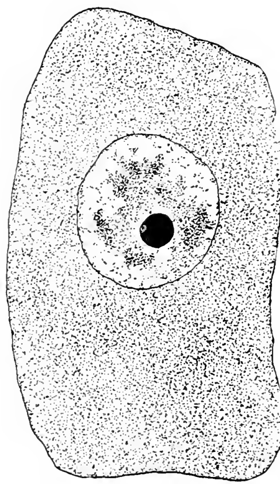


FIGURE 3. — ANIMAL CELL.

1. *The Cell.* — When the biologist takes apart the plant or animal as you used to take down your block houses, he finds that he can separate the parts until he comes to a unit so small that a microscope is necessary to see it. These microscopic parts are called *cells* and are alike in the following respects: each one has a clear

outer portion called the *cell wall* which incloses a mass of substance known as *protoplasm* (prō′tō-plaz'm : Greek, *protos*, first; *plasma*, form). The protoplasm is made up of a substance called *cytoplasm* (sī′tō-plaz'm : Greek, *kytos*, hollow place; *plasma*, form), in which is held a saclike body, the *nucleus* (nū′klē-us : Latin, *nucleo*, to become hard). The nucleus usually contains one or more separate bodies called *nucleoli* (nū′klē-ō-lī). A cell is therefore defined as a *mass of protoplasm composed of cytoplasm and nucleus* (Figures 2 and 3).

2. *Tissue.* — The cells are of many shapes and sizes, and in the bodies of all but microscopic plants and animals are united to help the plant or animal carry on its life processes. This union of cells to do a certain work is called a *tissue*, and the usual definition is: *a tissue is a group of similar cells that do a similar work* (Figure 4).

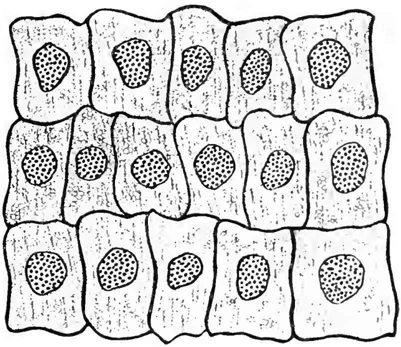


FIGURE 4. — TISSUE.

Compare these cells with Figures 2 and 3.

3. *Organs.* — In all of the higher animals the tissues are united into skin, arms, stomach, and so on, or in plants into leaf, branch, etc. Such structures are called *organs; an organ is defined as a group of tissues that do a given work in the animal or plant.*

4. *The Organ System.* — When different organs combine to carry on such a general life process as digestion, all of the parts that assist in this process are described as an *organ system*, as the system of digestive organs (Figures 178 and 179, pages 163 and 165).

These four expressions, *cell*, *tissue*, *organ*, and *organ system*, describe the materials of plants and animals which carry on the eight *life processes* referred to above. We shall read more and more about them as our study of biology progresses.

Classification of Living Things. — Our study of biology cannot progress far before we see the need of classifying animals and plants. Animals are generally grouped in two divisions: *invertebrates* (animals without backbone) and *vertebrates* (animals with backbone). Plants are also divided into two groups: *cryptogams* (flowerless and seedless plants) and *phanerogams* (flowering or seed-bearing plants). Below is given a detailed reference table of these classifications.

I. Invertebrates. Animals without a backbone.
  1. Protozoa. 8000 different kinds.
    a. Rhizopoda. Example, the amœba.
    b. Ciliata. Example, the paramœcium.
  2. Porifera. Sponges, 2500 different kinds. Example, the bath sponge and grantia.
  3. Cœlenterata. Hydra, corals, and jellyfish. 4500 different kinds.
    a. Hydrozoa. Example, the hydra, obelia, pennaria.
    b. Scyphozoa. The large jellyfishes.
    c. Actinozoa. The corals.
  4. Echinoderms. Starfishes and sea urchins. 4000 different kinds.
  5. Worms and wormlike animals. Examples, flat worms, tape worms, earthworms. 11,000 different kinds.
  6. Mollusca. The clams and snails. 61,000 different kinds.
    a. Pelecypoda. Example, clams.
    b. Gastropoda. Example, snails.
    c. Cephalopoda. Example, squids, devilfish.
  7. Arthropoda. Crabs and insects. 400,000 different kinds.
    a. Crustacea. Example, crayfish and crabs. 10,000 different kinds.
    b. Insecta. Example, grasshopper, flies, butterflies, bees. 390,000 different kinds.

II. Vertebrates. Animals with a backbone.
  1. Fishes. Examples, trout, perch, bass, cod. 13,000 different kinds.

2. Amphibia. Example, frog, salamander. 14,000 different kinds.
3. Reptilia. Example, snakes, turtles, alligators. 35,000 different kinds.
4. Birds. Example, sparrow, eagle, hawk, crow. 13,000 different kinds.
5. Mammals. Example, horse, cow, sheep, monkey, man. 35,000 different kinds.

The plants, like the animals, are arranged in general groups (*phyla*) which, beginning with the simplest, are as follows:

I. Cryptogams. Flowerless or seedless plants.
 1. Thallophytes.
  a. Bacteria. 1300 different kinds.
  b. Algæ. Example, pleuroccocus, spirogyra. 1300 different kinds.
  c. Fungi. Example, molds, puff-balls, toadstools. 64,400 different kinds.
 2. Bryophytes.
  a. Liverworts. 4000 different kinds.
  b. Mosses. 12,600 different kinds.
 3. Pteridophytes. 4500 different kinds of ferns.

II. Phanerogams. Flowering or seed-bearing plants.
 1. Gymnosperms. Example, pine, spruce. 540 different kinds.
 2. Angiosperms. Flowering plants proper.
  a. Monocotyledons. Example, corn. 23,700 different kinds.
  b. Dicotyledons. Example, bean. 108,800 different kinds.

Scientific Terms. — Scientists in America, France, Germany, Russia, and elsewhere are continually studying different plants and animals. For their convenience the Latin names are usually adopted in advanced scientific works. Thus the *English* or *house sparrow* is called *Passer domesticus*, and the *American elm*, *Ulmus americana*, so that scientists of different countries may always use the same term. But in this book we shall use the common American names of the plants and animals studied.

Scientific terms include also the names of certain substances frequently referred to in science books like this

Biology. Before going farther it is well to get a clear idea of what the common chemical terms mean.

1. *Oxygen* is a gas which makes up a large part of the air. It is the element in the air which sustains life in animals and plants. Without it they cannot live. When given an undue amount of it, they develop at an abnormal rate. It forms about seventy per cent of the bodies of plants and animals.

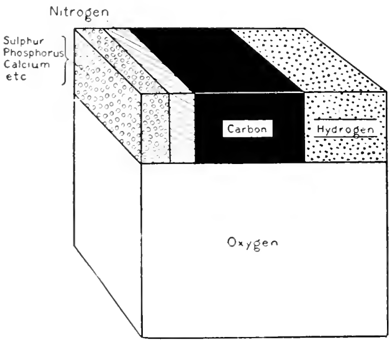


FIGURE 5. — DIAGRAM.
Showing proportion of chemical elements in living things.

The most striking property of oxygen is the ease with which it unites with other substances. Practically all cases of burning are caused by oxygen uniting with paper, wood, coal, or some other material. If a piece of glowing charcoal is placed in a jar of oxygen, it bursts into flame. This is the test for oxygen.

2. *Carbon* is, next to oxygen, one of the most important elements in biology. It is usually black and solid and is best seen as the charred remains of any material that has been overheated but not burned up, as when toast or meat is "burned." Carbon forms about fourteen per cent of the body of plants and animals.

3. *Hydrogen* gas is the lightest of all substances. For this reason it is used in balloons and Zeppelins. It forms a little less than ten per cent of the body of plants and animals.

4. *Nitrogen* is a gas which — unlike oxygen and hydrogen — does not burn. It dilutes the oxygen of the air and

so makes it less active. Nitrogen forms less than three per cent of the body of plants and animals.

5. *Calcium*, *sulphur*, *phosphorus*, *iron*, and *potassium* are the other important elements found in living things. None of these elements forms as much as one per cent of the body of plants or animals.

Chemical Compounds. — All these chemical elements combine with each other to form definite substances called *chemical compounds*, which we can see and handle. Oxygen and nitrogen mixed together make up about ninety-nine per cent of the atmosphere; hydrogen and oxygen unite to form water; carbon, hydrogen, and oxygen unite to form starch and sugar.

The union of oxygen with any other substance produces heat or energy. This uniting is called *oxidation*. When oxygen unites with carbon in our bodies, *carbonic acid gas* (carbon dioxide) is formed and heat is produced. The production of heat is one of the most important of the changes that take place in living things.

Physical and Chemical Change. — If a solid piece of ice is melted, it becomes liquid water. If the liquid water is boiled, it becomes steam, vapor, or gas. If the steam is condensed, it becomes water, which in turn may again be frozen into ice. Any change in a substance which does not alter the material of which it is composed is called a *physical change*.

On the other hand, when oxygen unites with wood, the wood burns, giving off heat and smoke, and ash remains. But this ash cannot be united with heat and smoke to form the original wood. Such a change as is seen in the burning of wood is called a *chemical change*.

Organic and Inorganic Matter. — It is customary to separate chemical compounds which are made in living things from those which are made outside the bodies of plants and animals. All matter such as wood, sugar, and meat, which is made in living things, is called *organic* matter. All matter like stones and water, which is made outside of living things, is called *inorganic*.

Environment. — Plants and animals have accustomed themselves to live in different parts of the world. Their behavior and habits under these varying conditions form a most interesting part of the study of biology. The surroundings of plants and animals, that is, the different conditions, the air, water, climate, and soil in which they live, are called their *environment*.

PRACTICAL BIOLOGY

PART I

ANIMAL BIOLOGY

CHAPTER I

THE GRASSHOPPER, A REPRESENTATIVE ANIMAL

1. **Live Animals.**—We all know that animals are alive, just as men and plants are alive, and we naturally want to know *how* they live, what parts of their bodies they use in eating and breathing, and how they escape their enemies. After we have learned about the lower animals, we can compare them with plants and with man, and it will be interesting to learn in what ways all living things are alike.

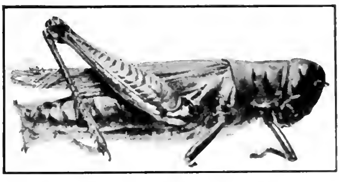


FIGURE 6.—FEMALE GRASSHOPPER.

When the study of Biology begins with animals, all that is necessary is to select an animal that can be conveniently found and watched; and then to try to learn where it lives, what it does, how it produces its young, and what relation it has to mankind. Material for study is easily obtained wherever you happen to live, whether in the city, the country town, or on the prairies. A nearby park or vacant lot, the fields, the woods, or the plains, whichever you can reach most easily, will supply you with a collection of insects, if you look carefully.

All insects will be found doing something. Some will be flying from flower to flower, and you can watch to see what they are doing; others will be busy on the leaves or the stems, and a few minutes of observation will show you whether they are friends or foes of the plant upon which you find them. The most interesting way to study insects is to watch them in their home life, but when this cannot be done, they can be well studied in the laboratory. Even in a large city a surprisingly large number of kinds of insects can be collected by a class and brought alive to the laboratory.

2. The Grasshopper. — The study of animals begins in this book with the grasshopper. When during the late summer we walk into the fields or along paths lined with grass, we are often surprised at the number of grasshoppers which jump away as we approach. They are of various sizes and kinds. Some are small and without wings, while others have small but well-formed wings. The difference in the wings and in the shape of the body tells us that there are various kinds of grasshoppers.

FIELD STUDY

To study living insects. Collect insects such as grasshoppers, crickets, beetles, bees, wasps, flies, moths, butterflies, etc. Place some under tumblers and complete your report as follows:

	Where Found	Number of Legs	Number of Wings	Size of Wings	Size of Third Leg	Mouth Parts			
						Strong	Weak	Separate	Fused
House fly .	On food in the home	6	2	Small					
Grasshopper	On grass in the field	6	4	Medium					
Moth . .	On flowers in the park	6	4	Large					

3. Life Processes of the Grasshopper. — The young grasshopper must escape being eaten, must find food, must have oxygen to breathe, must develop into an adult, and must do its part in providing for another generation of grasshoppers. If the grasshopper fails in any one of the first three of these necessities, it is unable to live, and consequently the last and most important work, that of providing for the next generation, is not possible.

LABORATORY STUDY

Examine a live grasshopper. What are its means of locomotion? Compare its jump with its length. If in the same proportion, how far could a man six feet tall jump? How does the grasshopper obtain food? What protection from enemies does it gain from its color? Notice the division of the body into three regions; *head*, *thorax* (thō'răks) which has wings, and *abdomen* (ăb-dō'mĕn). When the living grasshopper is held between the thumb and finger, it "spits molasses." This is the partially digested food from its crop.

4. Protection — When we look closely at the grasshopper, we find that it is provided with many character-

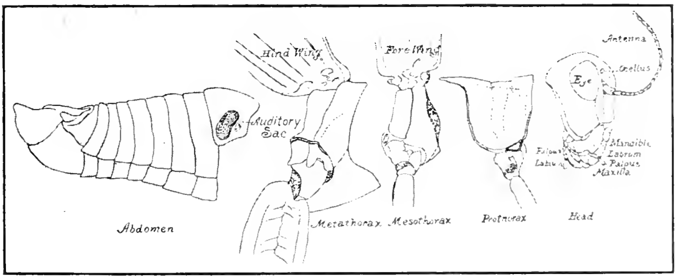


FIGURE 7. — DIAGRAM.

Showing the main parts of the grasshopper.

istics which prevent its being caught and eaten. The most important of these are its color and markings. When a grasshopper jumps into the grass and remains quiet, its color so closely resembles the grass and the sticks that many of its enemies overlook it. This is an example of what is called *protective coloration.* The grasshopper is further protected by a pair of large eyes and by simple ears which are located on the side of the body. By means of these sense organs, it becomes aware of the presence of enemies. The quickness of grasshoppers in jumping also helps them to escape being eaten.

5. **Food Getting.** — The grasshopper has little difficulty in finding its food. It eats leaves, and particularly the leaves of grass. It does not need a keen sense of smell, as does the bee which must search for flowers. However, the grasshopper has special smelling organs located in its antennæ (ăn-tĕn′ē), those long feelers which grow out from the head like soft horns.

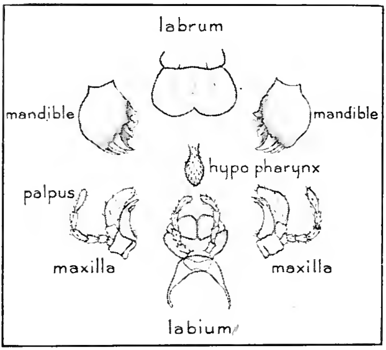


FIGURE 8. — MOUTH PARTS OF THE GRASSHOPPER.

The mouth parts which cut and chew the food consist of an upper lip and two teeth (mandibles, măn′dĭ-b'ls). The teeth are moved by powerful muscles which nearly fill the head. These mandibles work from side to side, instead of up and down as our teeth do. They are so effective that sometimes when grasshoppers become numerous they strip the grass of all its leaves, and even destroy growing fields of grain.

6. **Breathing.** — All animals have some way of getting oxygen to every portion of their bodies and of getting rid of carbon dioxide. The grasshopper has no lungs such as

ours, nor does it breathe through its mouth. On each side of the body are found a number of regularly arranged, small openings, *spiracles* (spĭr'ȧ-k'ls), which lead into branching tubes, *tracheæ* (trā'kē-ē). These tubes carry air to all parts of the body in order that the cells may be able to take the oxygen from the air and give carbon dioxide to it. The cell process in which oxygen is used and carbon dioxide formed is called *respiration*. See section 6, page 3.

7. Reproduction and Life History. — In the autumn, the female grasshopper lays her eggs in a hole which she makes in the ground. The eggs remain in the hole until the following spring, when they hatch into wingless grasshoppers. Their bodies are covered by a firm skin, called the *exoskeleton*, which does not increase in size as the grasshoppers grow, so this skin must be shed to allow room for growth.

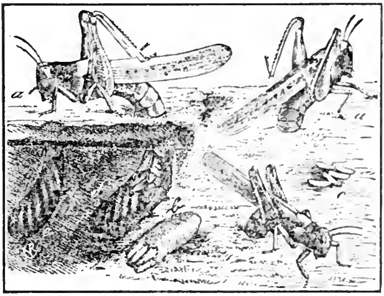


FIGURE 9.

a, GRASSHOPPER LAYING EGGS; *b*, EGG-CAPSULE; *c*, EGGS.

Young grasshoppers, like young children, grow rapidly; therefore the grasshoppers have to shed their skeleton often and grow a new and larger one. The scientific term for this shedding of the old skeleton and the growing of a new is *molt* (mōlt). In the early spring and summer, the young grasshopper molts again and again, each time growing a little more like the adult grasshopper. This process of growth takes three or four months. After the last molt, it has wings and can fly, and so is a full-grown grasshopper.

LABORATORY STUDY

Work out the divisions of the body of the grasshopper: head, thorax, and abdomen; the position of eyes. How are the antennæ related to the eyes? How many distinct mouth parts are there? The teeth or jaws are the most useful in getting food. How do the jaws work? Sketch the head to show these parts with the mouth open.

Notice the attachment of the head to the thorax. The head fits into the thorax. The loose anterior (front) portion of the thorax is the prothorax (forward thorax). The first pair of legs is attached to it. Sketch the prothorax to show it and its legs. The portion of the thorax back of the prothorax is divided into two regions: the mesothorax (middle thorax) and the metathorax (back thorax). The line between them is not clear. Sketch these parts together with the legs and the wings. The jumping legs are attached to the metathorax; the outer wings to the mesothorax; the inner wings to the metathorax. The inner wings are used in flying. The leg of the grasshopper consists of: (1) a small section close to the body (the coxa); a long muscular part free from spines (femur); a slender spiny part (tibia); and the three segments of the foot (tarsus). The last segment of the foot is furnished with hooks which help the grasshopper in climbing, while the spines on the tibia prevent slipping as the grasshopper jumps. The large muscles in the femur of the last pair of legs, the spines on the tibia, and the hooks on the tarsus, are special adaptations which help the grasshopper in various ways.

Notice the tapering abdomen, composed of ten segments (rings) or parts of segments. Notice the depression and membrane in the first segment. This is the auditory organ, but it is not a true ear. Sketch the abdomen to show its features. The spiracles are located on the sides of the abdomen.

8. **Metamorphosis.** — All animals which pass through a marked change in external appearance as they become full grown are said to undergo a *metamorphosis* (mĕt-a-môr′-fō-sĭs: Greek, *meta*, change; *morphe*, form). These changes are more marked in such insects as the ants and bees than in the grasshopper. For this reason we speak of two forms of metamorphosis — complete and incomplete.

9. **Incomplete Metamorphosis.** — The newly hatched grasshopper, while very small, looks enough like a wingless grasshopper to be identified as belonging to the grass-

hopper family. Its form does not change materially from the time it is hatched until it is full sized. Thus the grasshoppers become adult by a growing process termed *incomplete metamorphosis*, showing no marked change in form (Figure 10).

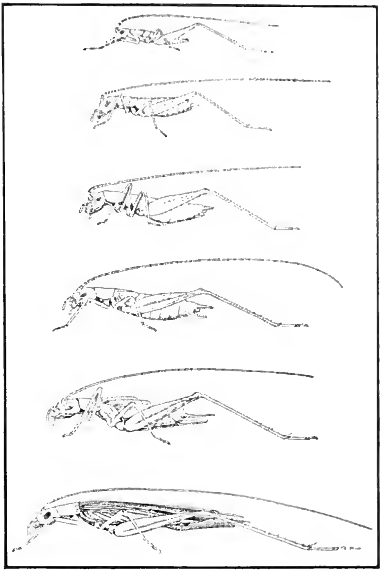


FIGURE 10. — INCOMPLETE METAMORPHOSIS OF THE TREE CRICKET.

The tree cricket belongs to the same family of insects as the grasshopper.

10. Complete Metamorphosis. — Certain other insects, for example the codling moth, hatch into caterpillars from the eggs that the female lays in the apple. These caterpillars are known as larvæ (lär′vē : Latin, *larva*, mask). The larvæ of the codling moth are the "worms in the apple." These larvæ are not recognized from their external appearance as young codling

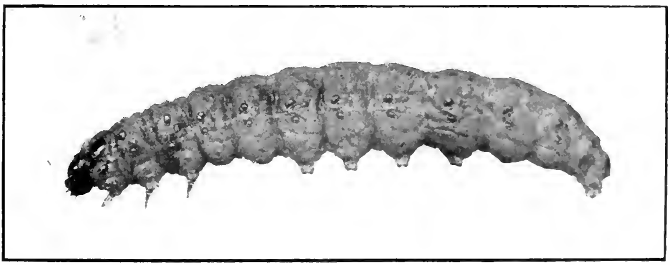


FIGURE 11. — CODLING MOTH LARVA.

moths, yet that is what they are. As the larva eats a great deal, it grows rapidly, molting again and again until it becomes a full-grown caterpillar. It then eats its way out of the apple where it has been living its larval life for several weeks.

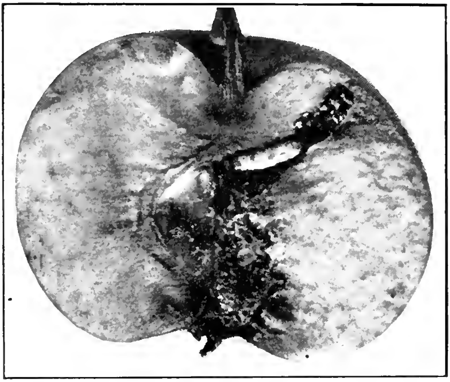


FIGURE 12.—"THE WORM IN THE APPLE."

In some protected spot, under the bark scales, the full-grown caterpillar then weaves a silken covering (the *cocoon*, kō-kōōn′) about itself. In this cocoon it molts again. When this last molt occurs, the

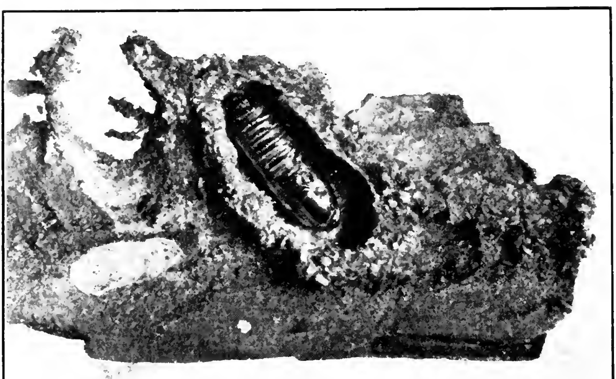


FIGURE 13.—CODLING MOTH PUPA.

caterpillar loses its legs and mouth parts, and is now known as a *pupa* (pū′pa). The pupa does not eat, but continues to breathe. Thus we speak of this stage in the growth of the codling moth as the "resting stage." This resting stage of the codling moth pupa[1] is very short. Then a final molt takes place and the fully formed codling moth crawls from the cocoon (Figures 11–14).

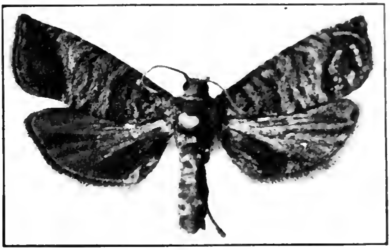


FIGURE 14. — CODLING MOTH.

This series of changes through which the codling moth passes from egg into caterpillar, then into pupa, and finally into full-grown moth, is termed *complete metamorphosis*. Ants, bees, butterflies, beetles, and certain other insects, all undergo complete metamorphosis.

There are a number of different terms used to describe the larval stage of insects:

Larvæ {
- caterpillars are the larvæ of butterflies and moths.
- grubs are the larvæ of beetles.
- " wigglers " are the larvæ of mosquitoes.
- maggots are the larvæ of flies.
- currant worms are caterpillars.
- measuring worms are caterpillars.

11. Structure and Classification of the Grasshopper. — In order to understand the grasshopper more fully it is necessary to find its place in the classification of animals. All animals that are known have been grouped into classes for convenience in study. The grasshopper belongs to the large class of animals called *Insecta* (ĭn-sĕk′ta: Latin, *in*, in; *seco*, cut).

The *insects*, as a class, have their bodies divided into

[1] Sometimes the codling moth passes into the pupa stage in the fall, thus living through the winter in the "resting stage."

three regions — head, thorax, and abdomen. See Figure 7. All have three pairs of legs, and most of them two pairs of wings. They breathe by means of air tubes (*tracheæ*). In becoming adult, all pass through metamorphosis, either complete or incomplete. The insect group is subdivided into ten smaller groups or orders.

FIGURE 15. — MONARCH BUTTERFLY.

Showing how it carries pollen from one clover blossom to another.

The grasshopper belongs to the order known as *Orthoptera*[1] (ôr-thŏp′tẽr-a : Greek, *orthos*, straight; *pteron*, wing). In the Orthoptera we find six common families: grasshoppers, crickets, katydids, cockroaches, walking sticks, and praying mantids.

12. Economic Insects. — By economic insects, we mean those insects which, by their activities, are either helpful or harmful to man. If an insect has no economic importance, we mean that it does not harm us by eating things useful to us, nor does it help us in any way.

The struggle to live is a problem for all animals, for

[1] grasshoppers, katydids, crickets	(straight wings)	Orthoptera
butterflies and moths	(scaly wings)	Lepidoptera
beetles	(shield wings)	Coleoptera
bugs	(half wings)	Hemiptera
bees, wasps, ichneumons, gall flies	(membrane wings)	Hymenoptera
flies and mosquitoes	(two wings)	Diptera
dragon flies	(teeth)	Odonata
May flies	(short lived)	Ephemeridæ
stone flies	(net wings)	Plecoptera
fleas	(wingless)	Aptera
	often called siphon-mouthed	Siphonaptera

man as well as for the grasshopper. All insects must eat, and some eat the same things we wish to eat. Such insects we call harmful. Others aid the growth of plants by carrying the pollen dust from one flower to another;

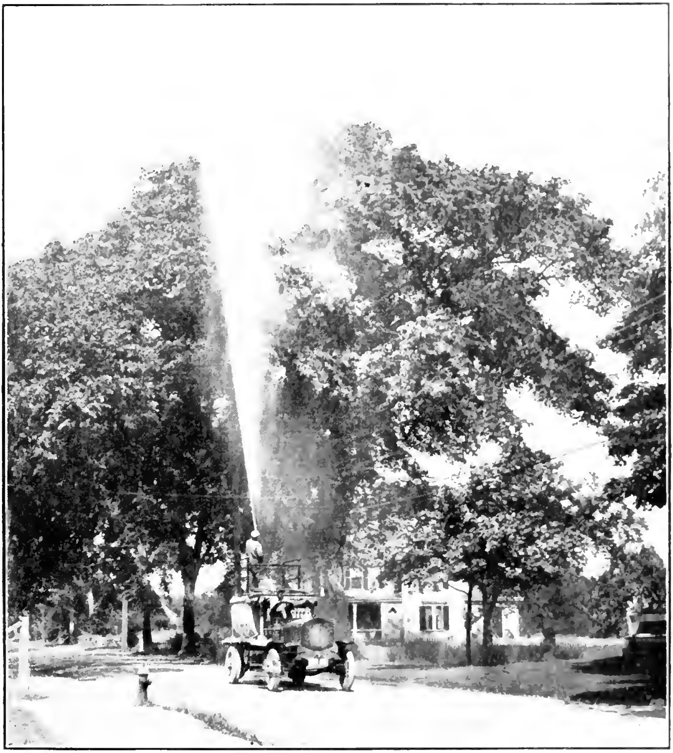


FIGURE 16. — MODERN SPRAYING OUTFIT.
Used to destroy harmful insects.

others make honey. Such insects are useful. Certain other insects, like the fly, carry the germs of disease. These insects are particularly harmful, for they cause sickness and death.

Certain beetles eat dead flesh or bury dead animals by tunneling under them. Such insects are helpful. We should study insects in order to find out which are our friends and which our enemies. It would not do to kill all kinds of insects, for in many cases we should harm ourselves.

13. Economic Phases of the Grasshopper. — The grasshopper eats the leaves of plants, and if there are many grasshoppers, they cause a serious loss of crops. The plague of locusts mentioned in the Bible refers to grasshoppers. In some of the Western States years ago the grasshoppers came in great swarms year after year and destroyed annually crops estimated to be worth $200,000,000. But ordinarily, owing to the activities of their natural enemies, the number of grasshoppers does not become alarming.

Among the natural enemies of these insects that do much toward reducing their number are the birds. Some of the greatest destroyers of grasshoppers are the quail, bluebird, sparrow hawk, butcher bird, crow, red-winged blackbird, and kingbird. The crows, because of their large size and great numbers, probably kill the most grasshoppers.

Other members of the order of Orthoptera, that are more or less harmful, are the cockroaches, the nuisances of the pantry, and the crickets that eat the roots of plants. There are also tree crickets which frequently lay their eggs in raspberry cane and kill the cane above the place where the egg is laid.

14. What has an Animal like the Grasshopper Accomplished by Living? — (1) It has used plants as food to build a complex body. (2) It has produced more grasshoppers. (3) It has used some stored-up food which might have been useful to cattle or sheep. (4) It has set free waste carbon dioxide which can be used by green plants to assist them in making food. (5) When it dies and decomposes, its chemical substances are returned to the soil and air to be used again by other living things.

QUESTIONS

What are the most important things that the grasshopper must do to live?

How is the grasshopper protected? How does the grasshopper breathe? How get its food?

How does the grasshopper begin life?

Define metamorphosis. How many kinds of metamorphosis are there? Which kind does the grasshopper show?

Is the grasshopper a friend or an enemy to man? Why?

CHAPTER II

OTHER COMMON INSECTS

In the preceding chapter we studied the grasshopper, a typical member of the Orthoptera. We shall now take up several other orders of insects, with most of which we are already familiar.

15. **Hemiptera.** — Another common order of insects is the *Hemiptera* (hĕ-mĭp′tẽr-a: Greek, *hemi*, half; *pteron*,

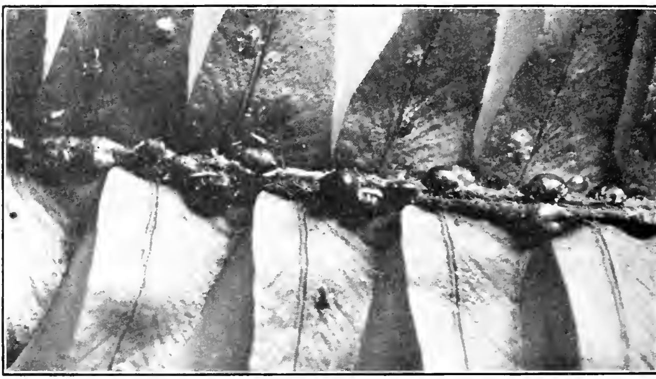


FIGURE 17. — SCALE INSECTS ON FERN.

wing). To this order belong such common insects as the cicadas, plant lice, the woolly aphis, and the bane of the orchard, the San José (sān hō-sā′) scale. Some of these are very harmful. When the San José scale is allowed to feed freely, whole orchards may be destroyed. Plant lice injure apple, cherry, and peach trees, and the cabbage plant. The several kinds of scale insects which harm orchards may be killed by spraying the trees with a solution of lime and sulphur.

16. Cicada. — One of the most interesting insects of the Hemiptera is the seventeen year cicada (si-kā'da), commonly called the "seventeen year locust." The name is given to it because the nymphs (nĭm'fs, the immature stage) remain in the ground, actively feeding on roots, for seventeen years. There is another kind of cicada that remains in the ground for thirteen years.

FIGURE 18. — MEALY BUG. One of the scale insects.

Every thirteen or seventeen years, generally in the month of May, the nymphs crawl out of the ground, climb trees or fences, and molt into adult cicadas. The adult females lay their eggs in tender shoots of trees, and this causes the shoots to die. The young cicadas, after hatching in the shoot of the tree, go into the ground and begin their long period of larval existence which lasts thirteen or seventeen years. These cicadas are usually found in limited areas, but in these areas are very numerous.

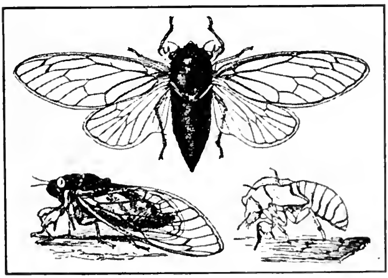


FIGURE 19. — CICADA, ADULT AND NYMPH.

The cicadas which we hear every summer are another kind, whose nymph lives in the ground for two years. As there are two broods of this species that appear in alternate years, the number does not seem to vary from year to year. The birds do much towards destroying them. The kingbird, sparrow hawk, butcher bird, and great-crested flycatcher are their most common enemies.

FIGURE 20. — MAY BEETLE.
Note difference in first and second pairs of wings.

17. Coleoptera. — The Coleoptera (co-le-ŏp′-tẽr-a: Greek *coleos*, shield; *pteron*, wing) are the beetles. The first pair of wings is horny and meets in a straight line down the back. The second pair of wings consists of thin membranes. The mouth parts are for biting. Among the harmful beetles are many wood borers, the May beetles, potato beetles, asparagus beetles, and weevils. Some of the beneficial beetles are the ladybug, which feeds on destructive and harmful insects, and the carrion beetle, that feeds on dead animals.

FIGURE 21. — EGGS OF LADYBUG.

The ladybugs are decidedly beneficial. Their larvæ run over leaves and feed on other insects. Even as adults they continue this good work. Hop growers appreciate the value of the ladybug larvæ on their vines, as the ladybugs destroy the harmful hop lice.

Through the investigations of the United States Department of Agriculture a certain kind of ladybug (Vedalia) was found in Australia, which is the natural enemy of an insect pest (cottony cushion scale) that was destroying the orange trees grown in California. This scale is a plant insect which was imported into the United States on young trees. Being freed from their natural enemies (Vedalia) which were not imported, they had increased rapidly. The prompt importation of Vedalia put an end to their increase, and they are now of no great economic importance.

FIGURE 22. — HOLES MADE BY WOODPECKERS.

The bird enemies of the beetle are numerous. Among the most important are the ring-necked pheasant recently introduced, the rose-breasted grosbeak, and the quail, which feed particularly on the potato beetles. The English sparrow, cuckoo, and kingbird feed on the weevils. Robins, blackbirds, and crows eat the white grubs, the larval stage of the May beetles. The woodpeckers destroy great numbers of borers by digging holes in the trees where the borers are tunneling.

18. Lepidoptera. — The Lepidoptera (lep-i-dŏp′tẽr-a: Greek, *lepidas*, scaly; *pteron*, wing) include the familiar moths and butterflies. Some of the members of this order,

FIGURE 23.—REDHEADED WOODPECKER.

such as the adult peach-tree borer, look more like wasps than like moths. There are more harmful insects in the Lepidoptera than in any other order. Among the particularly destructive members are the insects which are commonly called codling moths, gypsy moths, browntail moths, tent caterpillars, cut-worms, army worms, and canker worms.

But not all the Lepidoptera[1] are harmful. Many of the most beautiful moths and butterflies develop from larvæ that do no particular harm. Their natural enemies, such as birds and *ichneumons* (see section 21, page 39), keep their numbers reduced. Among the more strikingly colored butterflies are the black swallowtail, the larvæ of which feed on celery, parsley, and carrots; and the monarch or milkweed butterfly.

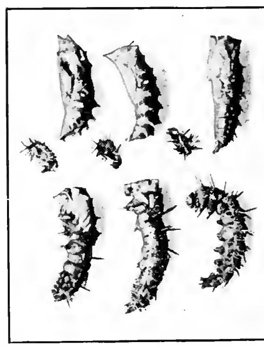


FIGURE 24.—LARVA OF MOURNING CLOAK MOTH.

Gradually transforming into a pupa. The cast-off skeletons of the larva appear in the middle row.

LABORATORY STUDY

The adult monarch butterfly has the body divided into head, thorax, and abdomen. The legs are smaller than in the grasshopper, while the wings are larger. The butterfly is, therefore, poorly adapted for jumping, but better adapted for flying than the grasshopper. Draw the entire animal. Draw wings and legs.

Gently rub the finger on the wing, and as the dust comes off, the wing

[1] The Chinese silkworm is a valuable member of this order.

will look more like the wing of a fly or bee. The lines that run lengthwise of the wing are the veins. Draw the wing.

The mouth parts of the butterfly are united into a single long tube which is the coiled tongue-like structure, called the proboscis (prō-bŏs′ĭs). Unroll it and see how its length compares with the length of the body. The butterfly uses the proboscis to suck nectar from flowers.

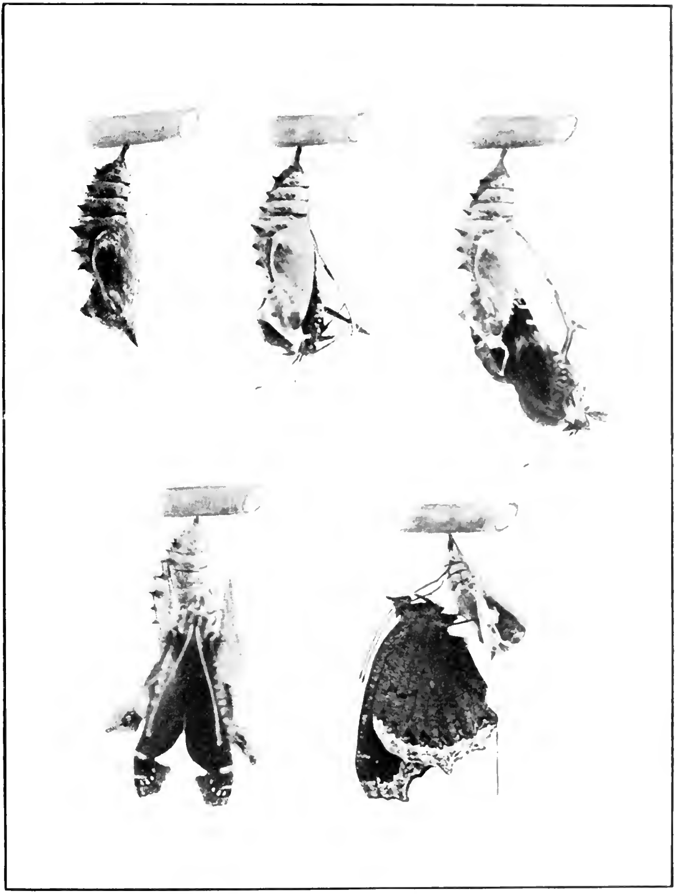


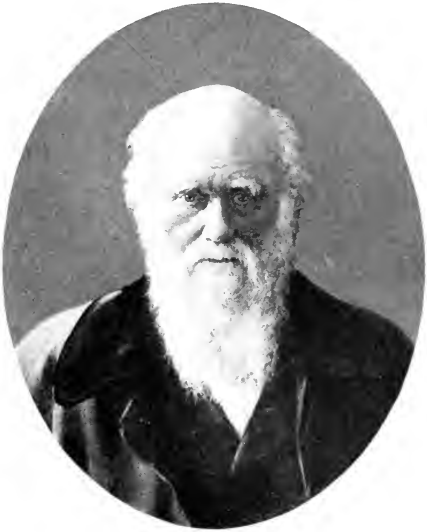
FIGURE 25. — TRANSFORMATION OF PUPA OF MOURNING CLOAK BUTTERFLY INTO ADULT.

As the butterfly goes from flower to flower after nectar, its head brushes against the parts of the flower that grow the pollen dust. The pollen is thus carried from one flower to another, and this helps the flower to grow better seeds.

Enemies of the Lepidoptera. — The numerous enemies of the Lepidoptera prevent them from becoming a scourge. Chief among these enemies are the *ichneumons*, members of the order Hymenoptera (Figure 40). Ichneumon (ĭk-nū′mŏn) adults lay their eggs on the bodies of many caterpillars. When these eggs hatch into small larvæ ichneumons, the larvæ eat their way into the body of the large caterpillar, where they live feeding upon its body juices. These ichneumon larvæ are called *para-*

FIGURE 26. — CECROPIA MOTH. Larva, pupa, cocoon, and adult.

FIGURE 27. — YOUNG TOBACCO WORM. Bearing cocoons of parasite.



Charles Robert Darwin (1809–1882), the celebrated English naturalist, was the founder of the Darwinian theory of evolution.

After taking part in the scientific expedition of the *Beagle* around the world, Darwin settled in 1842 in the secluded village of Down in Kent, where he devoted himself to a life of study and scientific research. In 1859 he published his chief work, "The Origin of Species," which was translated into many languages and became the subject of more discussion than any volume of the age. A second great work, "The Descent of Man," appeared in 1871, and Darwin continued to produce important scientific works throughout his life.

sites because they derive their food from the caterpillar. The caterpillar which contains these ichneumon parasites is called a *host*.

The ichneumon parasitic larvæ grow rapidly and before the caterpillar dies they reach the stage at which they turn into pupæ. When they are ready to pupate, they eat their way out of the body of the caterpillar and spin a cocoon which in some cases remains attached to the body of the caterpillar (Figure 27). These parasitic larvæ so weaken the caterpillar that it dies. We shall learn more of these ichneumons later.

FIGURE 28. — LARVÆ OF A LEAF MINER.
At work in an elm leaf.

Next to ichneumons, the birds are probably the most active enemies of the Lepidoptera. Many birds live entirely upon caterpillars and we find birds that seek them as food in all stages of their development and growth. The eggs laid on the twigs and trunks of trees are eaten by chickadees, nuthatches, brown creepers, and woodpeckers. The larvæ are eaten by many birds, notably by cuckoos, bluebirds, wrens, blackbirds, orioles, blue jays, crows, and house sparrows. The cocoons and pupæ are sought by the chickadees, woodpeckers, nuthatches, and brown creepers. The adult insects are preyed upon by house sparrows, chipping sparrows, and the whole group of flycatchers, including the kingbirds and phœbes.

Figure 29. — Cedar Bird.
Feeding its young a flying insect. One of our most beneficial birds.

19. Codling Moth. — The most destructive of the lepidopterous insects is the codling moth, already mentioned as an example of metamorphosis. The larvæ become adult in April at about the time the early apple trees blossom. The eggs are laid on the young apples and the larvæ begin to eat the growing apple, which, as a result, in many cases drops to the ground. In any event the quality of the apple is injured.

In most parts of our country, there are two distinct broods of the codling moth, the life history of which has only recently been clearly understood. The eggs of the second brood are laid generally in August when the fruit is pretty well grown. The same damage is done as to the early apples, but as each mature female lays a hundred or more eggs and as the most important apple crop is the late one, the chief damage is at this time.

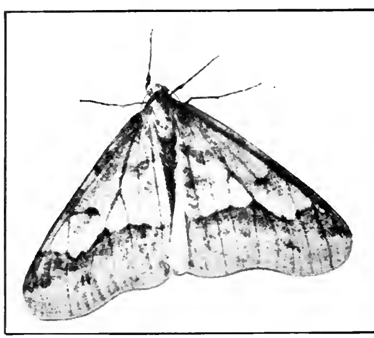


Figure 30. — A Geometrid Moth.

FIGURE 31. — PROTECTIVE COLORATION.

It was estimated that in 1898 the injury done by the codling moth to the apple and pear industry in New York State alone amounted to $3,000,000. By applying a spray containing some poison just after the blossoms have fallen, the codling moths may be destroyed. The spray should not be used while the blossoms are fresh, because then the helpful bees which visit them are killed, and no harm is done to the destructive codling moths that come later.[1]

FIGURE 32. — YELLOW SWALLOWTAIL. Gathering honey from lilacs.

FIELD, LABORATORY, OR HOME STUDY OF MOTHS AND BUTTERFLIES

These insects are easily collected and are interesting to study. From late in the spring until October you can find larvæ and pupæ. Some of the leaves upon which the larvæ are feeding should be collected. The larvæ should be placed in jars provided with soil and some leaves. Arrange the cocoons and pupæ which you find as suggested in the following table.

[1] The life history of the peach-tree borer and monarch butterfly may be assigned in this connection.

Cocoon			Pupa			
Spun with silk only	Spun with a leaf	Spun with hair	Without cocoon	Suspended from one end	Suspended from one loop	Parasitized

Tent caterpillars spin cocoons and form small brown moths. Celery "worms" hang in a loop and form a black, swallowtail butterfly which feeds on the nectar of lilacs and the rhododendrons of city parks.

The black spiny caterpillars of the willows and elms hang free from the knot of silk and form the mourning cloak butterfly.

Tomato "worms" burrow into the ground and form a large-bodied, small-winged moth, a sphinx moth.

20. Hymenoptera — The Honeybee. — In contrast to the Lepidoptera, which, as has been said, are probably the most

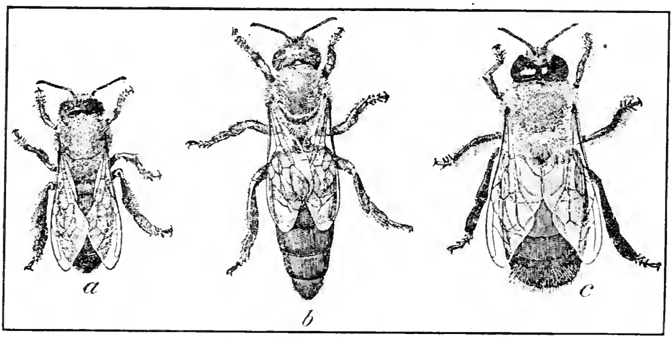


FIGURE 33. — *a*, HONEY BEE WORKER; *b*, QUEEN; *c*, DRONE. Twice natural size.

destructive order, we find the Hymenoptera (hȳ-mĕn-ŏp′-tẽr-a: Greek, *hymenos*, membrane or thin skin; *pteron*, wing) that are of the greatest value to man. This order includes the bees, wasps, ants, ichneumons, and the like.

The honeybee and the bumble bee are the most important of the bees. The honeybee is valuable for its honey and wax, and as a distributor of the pollen which is necessary for the growth of new plants. The bumble bee is valuable mainly as a distributor of pollen.

FIGURE 34. — THREE QUEEN CELLS.
Natural size.

Honeybees afford a splendid example of community life among insects. In the wild state they live in trees and caves. All wild honeybees in this country have escaped from hives or apiaries (bee farms).

In a honeybee colony there are three classes of bees, — the perfect females or queens, the males or drones, and the imperfect females or workers. There are generally one queen, a few hundred drones, and twenty to fifty thousand workers.

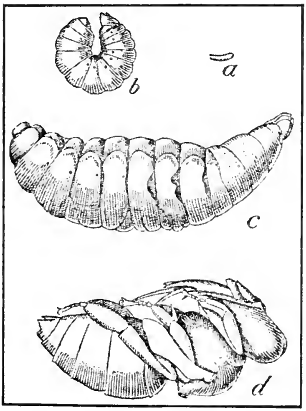


FIGURE 35. — *a*, HONEY BEE EGG; *b*, YOUNG LARVA; *c*, OLD LARVA; *d*, PUPA.
Three times natural size.

The queen alone can lay eggs. She can lay an unfertilized egg which hatches into a drone, or she can lay an egg which is fertilized. This fertilized egg hatches into a queen or a worker, according to the food and the size of the cell which are provided by the workers. Thus the decision as to whether the young bee shall be a queen or a worker rests with the workers themselves. They also have the power to supersede the queen, or to raise a new queen in case of the sudden death of the old one. These powers are rightly intrusted to the workers — the great majority.

The eggs are placed by the queen in cells, and, after hatching, are fed by the young workers, called nurses. The larva is fairly bathed in food. In a few days the larva is full grown, and then pupates. The workers now cap over the cell with wax, and in about twenty-one days the young bee cuts away the cap and crawls out — an adult provided with four wings, mouth parts, antennæ, and the six legs of the honeybee.

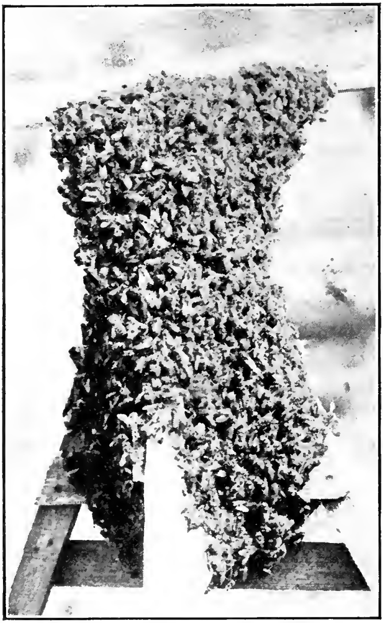


Figure 36. — Honey Bees Clustering at Swarming Time.

Workers are provided with the sting which is a weapon of both defense and offense. The queen has a small sting, and the drones have none. When bees sting large animals, like men, horses, and dogs, their sting is pulled out and with it parts of the internal organs, thus causing the death of the bee. When bees sting other insects, or even one another, their sting is not lost.

Sometimes swarms which have few bees and little honey are attacked by bees from other colonies. It is a pitched battle until the "robber bees" are beaten back, or the defenders are themselves killed. The sting is used in these battles.

Bees are instinctively sanitary. If a large bumble bee enters the hive, the bees kill the intruder and usually, finding him too large to be taken out, embalm him by injecting the sting repeatedly into his body. The result of this operation is to make the bumble bee harmless to the colony. Sometimes they cover the body of a small, dead animal with a case made of *propolis* (prŏp′ō-lĭs), a substance the bees gather from certain buds. This serves to protect the colony from the effects of the decomposition of the body.

FIGURE 37. — CAPTURING A SWARM.

At irregular intervals during the early spring and summer, bees have the peculiar habit of *swarming*. Several reasons for swarming are given by bee-keepers, but no one pretends to be certain that he really knows the cause. It is a sort of revolt of the bees against their condition. Two of the commonest reasons given to explain swarming are the lack of room for the growing colony, and lack of food.

When bees swarm, they usually light on the limb of a tree and form a dense cluster. Here they hang from fifteen minutes to an hour before leaving for the woods. In a few cases bees have remained in this "cluster" state overnight, but usually they are lost unless they are collected inside of half an hour. The swarm consists of a large number of adult bees, workers and drones, and usually a single queen.

Various devices against swarming have been invented, but the most effective is to clip the wings of the queen in order that she may be kept at home, because the other

FIGURE 38. — MODEL APIARY.

bees usually follow her. This is done after the queen has taken her "wedding-flight." Her wings are clipped close to the body, but only on one side. The bees that then swarm soon come back and are easily controlled. While the bees are still in the air, a clean, empty hive is placed where the old one was. Beekeepers, during the swarming period, always have a number of empty hives in position ready for the swarm to occupy.

The returning bees enter the new hive in search of the queen. As they are rushing in, the queen with clipped wings is released, and she, in turn, joins the procession and enters with the others. Having found the queen and plenty of room, the colony is usually content to remain. Sometimes swarming becomes a mania with certain colonies, and it is difficult to get them to settle down contentedly in a hive and make honey. Runaway swarms have to be watched with great patience. Bees that have been raised for many bee generations in man-made hives sometimes leave suddenly and seek out a hollow tree in the forests.

FIGURE 39. — CUTTING COMBS FROM BOX HIVE.

The length of the bee's life varies. The drones are usually killed at the end of their first season. Queens live for five or six or even ten years. Workers live three or four weeks in the working season and several months in the fall or winter.

The honey and wax produced annually in the United States are valued at $22,000,000.

21. Ichneumons. — Another interesting division of the Hymenoptera are the ichneumons. We have already seen (page 30) how they help to keep the Lepidoptera from becoming a scourge. They also furnish other interesting examples of parasitism. As an illustration we may use one of the larger ones known as *Thalessa*. With long, thread-like drills this parasitic insect bores holes in trees, and lays an egg at the bottom of the hole. The egg is usually laid near the burrow of one of the larger tree borers, the *Tremex*.

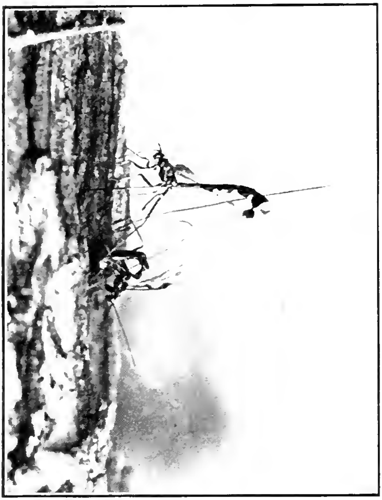


FIGURE 40. — ICHNEUMON FLIES.
Laying eggs in a tree.

The larva of the Thalessa makes its way along the burrow of the Tremex borer and fastens itself to the body of the borer, where it feeds upon the borer and thus kills it. In time the adult Thalessa emerges, ready in turn to do its part in laying eggs which will destroy more of these enemies of the tree. But if the Thalessa parasites kill the Tremex borer before it has eaten its way through the hard wood, then all die together, because the Thalessa cannot cut an opening for itself.

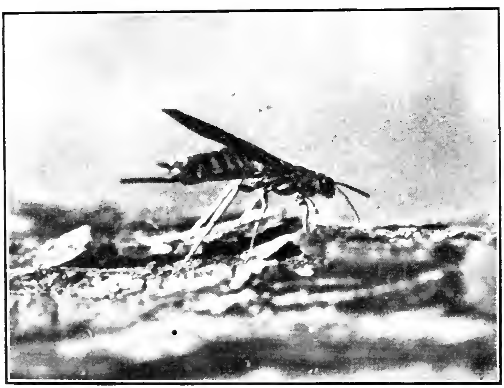


FIGURE 41. — ADULT HORN-TAILED SAW-FLY.
Just after laying eggs in a tree. The larvæ of this insect do much damage to lumber.

22. Ants. — The ants are insects which live in large families. Each family has many workers, and a number of queens and males. Certain kinds have in addition their soldiers which have strong mouth parts (mandibles). The soldiers do the fighting for the family. Some ants are winged and others are wingless.

Many ants have the curious habit of protecting the plant lice, because these lice give off a sweet fluid of which the ants are fond. In some cases the ants carry the plant lice from the wilted leaf to a fresh one, or confine them in the ants' nest and bring them fresh leaves. When they wish to feed on the sweet fluid, the ants quietly stroke the body of the plant lice with their antennæ.

23. Diptera. — The Diptera (dĭp′tẽr-a: Greek, *dia*, two; *pteron*, wing) include such harmful insects as the mosquito, housefly, botfly, and cheese skipper; also the beneficial bee fly, wasp fly, and tachina fly.

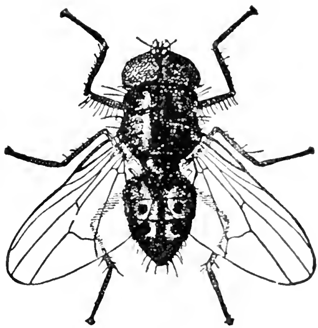


FIGURE 42. — FLY.

The most important member of this group is the mosquito. The common mosquito lays its eggs in the water in small clusters which look like minute rafts. These eggs hatch into larvæ, called "wigglers." Any stagnant pool or rainwater barrel furnishes a favorable place for mosquitoes to breed.

In the United States there are three distinct kinds of mosquitoes. (1) The common mosquito is known by the technical name of *Culex* (kū′lĕks). It is not known that the Culex carries in its body any disease germs harmful to men, therefore it is regarded as harmless, although a source of great annoyance to those who frequent the woods

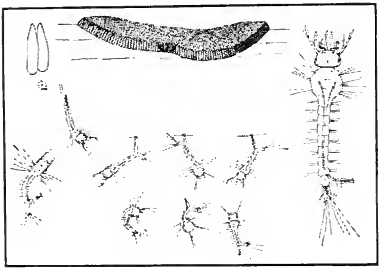


FIGURE 43. — EGGS AND LARVÆ OF CULEX.

The commonest mosquito.

or seashore during the summer. (2) *Anopheles* (ȧ-nŏf′e-lēz) is the scientific name of a second kind of mosquito, which is also generally distributed, but is not so numerous as the Culex. The Anopheles often carries in its body the germs that cause the disease called *malaria.* (3) *Stegomyia* (stĕg-o-mī′yȧ) is a mosquito common in the southern part of the United States. It is the insect which carries the germs of yellow fever from one person to another.

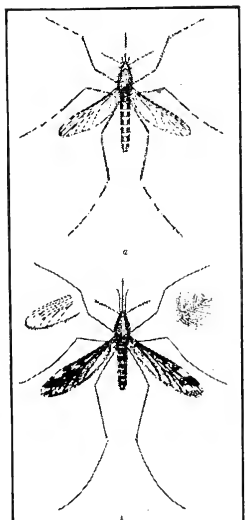


FIGURE 44. — *a,* ADULT CULEX; *b,* ADULT ANOPHELES.

It is fortunate that the mosquitoes have so many enemies. The "wigglers" are preyed upon by the larvæ of the dragon flies, by small fish, and by water beetles; while the adults are eaten by nighthawks, martins, bats, and dragon flies. Certain diseases caused by plants attack the adults and kill them in great numbers. The number of mosquitoes can be greatly reduced by destroying their natural breeding places in old rain barrels, watering troughs, boxes that may hold water, pails, eaves troughs, and sink holes. The larger breeding places are sluggish streams and swamps. Draining these is the most effective method of preventing mosquitoes from laying their eggs in that locality. When this is not possible, the surface of the water may be covered with kerosene, which kills the larvæ by preventing them from getting oxygen from the air. Frequent applications of oil greatly reduce the number of mosquitoes.

SUMMARY

The insects include a large number of animals, the smallest of which can be seen only through a microscope, while the largest, certain butterflies, measure nine inches across their wings. Some insects are parasitic and lead dependent lives. Insects feeding on plants which we wish to eat are called harmful. Others, like the honey-bees and silkworms, which make products that we use, are beneficial. Insects such as ticks and lice, that injure our domestic animals, are called harmful. Then there are the beautifully colored moths and butterflies whose larvæ never become numerous enough to do much damage; we say that they are beneficial because we get pleasure from their beauty.

The whole question of what is beneficial or harmful depends on the relation of the insect to man. Insects living on an uninhabited island could not be thus classified. In the earlier stages of our civilization, many insects now regarded as harmful were not so classified, because man had not learned to use the plants upon which they fed. The important relation which insects bear to disease has, in recent years, caused us to classify several insects as harmful which were not so considered earlier.

Insects, like man, are constantly undergoing a struggle to escape their enemies and to secure food and a place to live. It is interesting in this biological study to try to view ourselves in the same unprejudiced way in which we study the lower animals; it helps us better to understand ourselves, and to go forth better equipped to wage our contest and win our fight.

QUESTIONS

Explain the difference between beneficial and injurious insects.

Which are some of our most beneficial insects? How do they help us?

How did they help to save the orange industry of California?

How do fruit growers spray their trees? Why?

What can you do to prevent harmful insects from spreading?

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CHAPTER III

THE SIMPLEST ANIMALS — PROTOZOA

24. Definitions. — In our study of the grasshopper and its insect relatives we considered their behavior and life processes. If we had studied the minute structure of any of these insects, the grasshopper, for example, and had used a microscope to aid us, we should have found that every organ was made up of numerous small parts joined together in a definite manner. These small parts are called *cells*.

Any book on biology uses the word *cell* again and again. The name was first used by Robert Hooke over two hundred years ago, when, with his crude microscope, he examined a piece of bark and found it to be made up of little rooms which looked like the cells of the honeycomb. These spaces he named *cells*. When better microscopes were made, the living parts of the cell were discovered, and it was found that Hooke had seen only the walls of dead cells.

All plants and animals are composed of cells. A cell may exist alone, carrying on all the life processes itself, or it may exist in connection with a great many other cells, as in all large animals and plants. In every case each cell is produced from another cell.

There are certain animals that are never more than one-celled even when they are full grown. These animals are called *Protozoa* (prō-tō-zō'a: Greek, *protos*, first; *zoön*, animal).

25. **The Protozoan Cell.** — *The protozoan cell is a single mass of living matter, called* **protoplasm**. In a general way it carries on the same life processes as the grasshopper, or any other animal. When this living cell comes in contact with heat, cold, electricity, chemicals, or other stimuli, it moves, and we say that it is *irritable*. The term *irritability*, used with a scientific meaning, is defined as the *power of being aware of a stimulus*. When this living cell is brought into contact with cold, for example, it makes a definite movement. It is aware of the cold stimulus.

The living cell grows by using food. It takes in oxygen from the water or from the air, according to where it happens to live. It gives off waste substances. It can grow or reproduce other cells of the same kind.

Many protozoan cells have no limiting wall between the living substance and the water in which they live. Yet the protoplasm and the water do not mix, though we do not understand why. Other Protozoa living in the ocean are surrounded by extremely thin skeletons of lime, and when the animals die their skeletons sink to the bottom and become massed in a sort of rock. The famous chalk cliffs of England were formed in this way.

26. **Habitat.** — The *habitat* of any animal is the place where it lives. The Protozoa are small, usually microscopic, animals common in stagnant pools and in swamp water. They are also common in salt water. In fact, Protozoa are likely to be found in nearly all ponds of water that contain food for them. Often, in the summer time, our attention is called to the activities of Protozoa when the water from lakes or reservoirs has a fishy taste. This peculiar taste may be due either to animals or plants, or to both. When it is due to animals, it is caused by a disagreeable oil formed by a certain kind of Protozoa.

By far the greater number of Protozoa are harmless, and many are helpful to us in that they serve as food for fishes. Others, however, may become parasitic in our bodies, and thus cause such diseases as malaria, yellow fever, or sleeping sickness.

27. **Amœba.** — The name *amœba* (a-mē′ba) is given to several different Protozoa, but all of them represent the simplest form of life known to us. For this reason they are always studied in biology. In order to describe correctly the structure of even so simple an animal as the amœba a few new words are necessary.

28. **Structure of Amœba.** — It is difficult for inexperienced students to see the living amœba through the microscope, because the whole cell has a faint, grayish appearance, and in a strong light is transparent. But if this grayish appearance of protoplasm is once seen, it is always remembered.

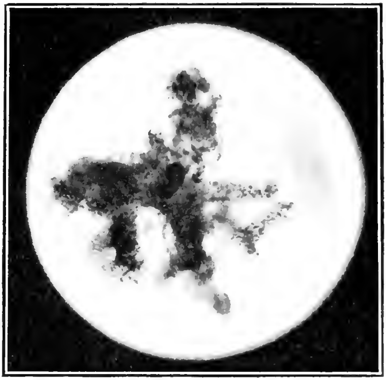

FIGURE 45. — MICROPHOTOGRAPH OF AN AMŒBA.

The living amœba is continually changing shape and pushing out from the surface of its body blunt, finger-like projections of the protoplasm called *pseudopodia* (sū-dō-pō′dĭ-a: Greek, *pseudo*, false; *pod*, root of *pous*, foot), which give an irregular outline to the body (Figure 45). Sometimes the pseudopodia branch out, and therefore the scientific name *Rhizopoda* (rī-zop′ō-dă: Greek, *rhizos*, root; *pod*, root of *pous*, foot) is the technical name for all amœba-like Protozoa.

The amœba sends out a pseudopodium, and gradually the rest of the body flows, by a rolling movement, in the same direction. This creeping-rolling motion of the protoplasm enables the amœba to move through the water.

When the pseudopodium comes in contact with a minute plant upon which the amœba feeds, the protoplasm of the pseudopodium surrounds the plant and takes it into the cell. The microscopic plant thus eaten by the amœba is inclosed, with a small amount of water, in a tiny globe called the *food vacuole* (văk′ū-ōl). The food vacuole is to be thought of as a stomach in which digestion can take place, for the plant is digested in it. The nutritious parts are absorbed into the protoplasm, the undigested parts are cast from the cell, and the food vacuole disappears.

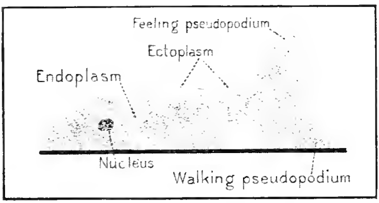

FIGURE 46. — DIAGRAM OF AN AMŒBA.

There is no well-defined cell wall; therefore the amœba is an illustration of a living, naked cell. Near the center of the cell is a spherical mass of denser protoplasm called the *nucleus*. In many amœbæ the nucleus is not easily seen except by means of specially stained preparations. The rest of the protoplasm in the cell is called *cytoplasm* (sī′tō-plazm). This does not appear the same in all parts of the amœba. On the outside, there is a thin, almost transparent layer, called *ectoplasm* (ek′tō-plazm: Greek, *ecto*, outside; *plasma*, form). The larger part of the cytoplasm is filled with numerous small granules and contains several vacuoles. This inner mass of cytoplasm is called *endoplasm* (en′dō-plazm: Greek, *endo*, within; *plasma*, form). The vacuoles in the endoplasm may contain food, water, or waste products. The food and water vacuoles are temporary structures, but the vacuole which collects the liquid waste is always present. When this vacuole reaches full size, it suddenly contracts and throws the waste into the water. This excretory vacuole is therefore called the *contractile vacuole*.[1]

29. **Respiration.** — The amœba respires. From the air dissolved in the water, it obtains by diffusion the oxygen necessary to its life, and it gives off carbon dioxide from the cell.

30. **Reproduction and Encystment.** — The chief method of reproduction in the amœba is simple (Figure 47). The living cell divides into two equal parts, forming two new cells. This process is known as *fission* (fĭsh′ŭn: Latin, *fissus*, cleft).

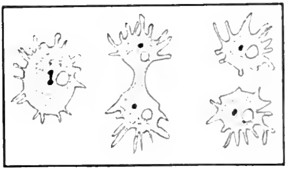

FIGURE 47. — AMŒBA REPRODUCING BY FISSION.

When the food or water becomes unsuited to supply the needs of the cell, in order to live the amœba often secretes (makes for itself) a thick wall completely surrounding the protoplasm. This process is termed *encystment* (en-sĭst′ment: Greek, *en*, in; *kystis*, bladder). After the wall has been formed, the amœba is able, for a long period, to resist cold, the drying up of the pond, or the lack of food.

[1] No suggestion can be made which will always enable the teacher to secure amœbæ. They are more frequently found in the slime and mud of stagnant water than anywhere else. Paramœcia and other infusoria can usually be secured in abundance by placing a handful of hay or leaves in a jar and covering them with the ordinary water used in the laboratory. This is called a *protozoan culture*, and should be started about four weeks before the material is wanted for class study. The length of time that the culture should stand can be lessened by adding a little beef-extract and by keeping the jar near a radiator. Water sufficient to keep the hay or leaves covered must be added from time to time. When a good culture of paramœcia is once secured, the jar should be kept from year to year, simply adding water to the dried hay left in the jar when infusoria are desired.

31. Paramœcium. — One of the most common forms of Protozoa is the slipper-shaped *paramœcium* (para-mē′-shĭ-um), which is more active than the amœba. It is abundant in stagnant water and in the hay infusions prepared in the laboratory. (See Laboratory Suggestions.)

LABORATORY STUDY

There are certain kinds of Protozoa that are usually found in protozoan cultures. The most abundant form is the paramœcium. Make repeated examinations of drops of water from the protozoan culture, until you are able to find the paramœcium. Notice its shape, rate of movement, behavior on meeting obstacles, and the like. Report on what you can make out. Compare the paramœcium with any other protozoan you can find, as to shape, rate of movement, size, color, etc. If available, examine slides which show the nucleus of a protozoan. Make sketches that illustrate the above features.

32. Structure of Paramœcium. — The paramœcium, like the amœba, is a single cell, but it has both a large nucleus and a small one. It has an endoplasm, an ectoplasm, and a *cuticle* (kū′ti-kl), or cell wall. Through the cuticle, there extend great numbers of *cilia* (sĭl′i-a), or threads of living protoplasm. The ectoplasm contains many thread-like darts known as *trichocysts* (trĭk′o-sists). These can be discharged. On one side is a fold or depression (the gullet) in which food is collected by the waving motion of the cilia. Within the cell are found food and water vacuoles

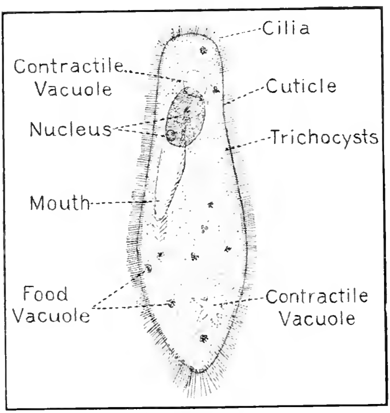

FIGURE 48. — DIAGRAM OF PARAMŒCIUM.

as in the amœba; but there are two contractile vacuoles, one at either end, and the food and water vacuoles are more numerous than in amœba.

33. Locomotion and Defense. — The animal moves by the action of the cilia, the direction being due to the angle at which the cilia are held. It can be observed that the animals move backward and forward, and that they also rotate on the long axis. Paramœcia defend themselves by discharging the trichocysts. This discharge occurs either as a result of certain strong artificial stimuli, such as electric currents or chemicals, or naturally because of collision with certain other Protozoa. If attacked by some animal which feeds upon them, they discharge the trichocysts in the region of the attack (Figure 49).

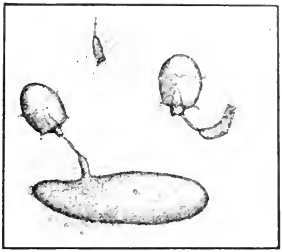

FIGURE 49. — PARAMŒCIUM. Being attacked by another Protozoan that feeds upon it. The trichocysts are discharged, and they force the foe away.

34. Reproduction, Respiration. — Paramœcia reproduce by fission, *i.e.*, an animal divides, producing two; these divide and produce two more. The process of fission goes on indefinitely (Figure 50). Like the amœba these forms can encyst when conditions of life become unfavorable. They can then be blown about in dust.

FIGURE 50. — PARAMŒCIUM REPRODUCING BY FISSION.

As in amœbæ, the oxygen which is necessary to respiration is obtained from the water. Excretory waste is cast from the body by the contractile vacuoles, which force it through the ectoplasm. Gases escape from the entire surface.

35. Economic Importance. — Paramœcia consume considerable quantities of bacteria, but whether more harmful than helpful ones cannot be told. Therefore their economic value is uncertain.

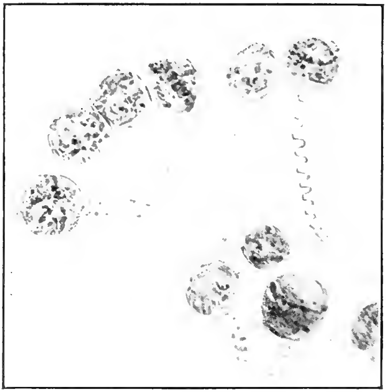

FIGURE 51. — VORTICELLA.

36. Other Protozoa. — If one examines stagnant water, a large number of other kinds of Protozoa will be found. The more common forms are much like the paramœcium and have many cilia on the body. Several of these large, ciliated Protozoa feed on the smaller Protozoa. Some of the common forms are shown in Figures 51–53.

All of these various Protozoa can be grouped into classes,

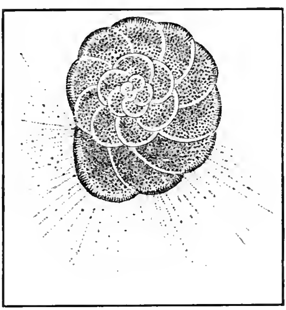

FIGURE 52. — ONE OF THE FORAMINFERA.

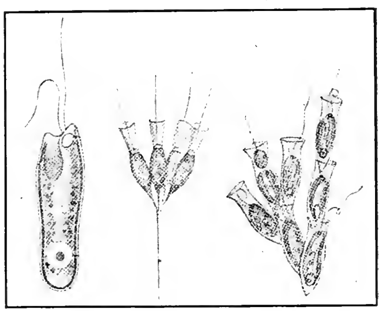

FIGURE 53. — SOME FLAGELLATE PROTOZOA.

each with certain distinct characteristics. For instance, all Protozoa that have pseudopodia are called *Rhizopoda*. In this group, the cells may be naked or may possess a hard mineral covering; a second group of Protozoa are provided with one or more long, wavering threads called *flagella* (flā-jel′la: Latin, *flagellum*, whip), and have the name *Flagellata;* the flagella are longer than cilia and exhibit more complicated movement. A third class, known as *Infusoria* (in-fū-sō′ri-a), includes most of the common Protozoa found in protozoan cultures. Most of this class are provided with cilia.

LABORATORY STUDY OF PROTOZOA

Take a drop of water from an infusion rich in Protozoa; place on a slide and examine with a 16 mm. or $\frac{2}{3}$ objective. Answer the questions suggested by the report.

Number of Kinds Observed	How Many Kinds —				How Many Kinds Have —	
	are free swimming?	are attached by threads?	have even motion?	have zigzag motion?	constant form?	varying forms?

37. **Protozoa and Alcohol.** — Scientists have studied the relation of alcohol to the life processes of Protozoa. Normally, such Protozoa as paramœcia divide a regular number of times each day. When a small amount of alcohol is placed in water containing paramœcia, the normal rate of fission is diminished. Professor Woodruff has shown by an extended and critical study that alcohol tends to prevent paramœcia from dividing as many times as they would under normal conditions. This means that alcohol hinders the growth of paramœcia.

SUMMARY

Protozoa are the simplest group of animals. They are found mostly in water, yet some are parasitic in higher animals. They are small and usually consist of only one cell. They reproduce mostly by fission. Some produce in man and beast diseases, such as malaria and the sleeping sickness of Africa. But the great majority of Protozoa are not harmful.

QUESTIONS

Compare the body of a protozoan with the body of a grasshopper. In what are they alike? In what different?

How do the amœba and paramœcium compare?

Explain how the Protozoa eat, digest food, produce more Protozoa, and protect themselves.

How do these vital processes compare with the similar vital processes in the grasshopper?

In what ways are Protozoa injurious to man? Are they parasitic?

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Osborne, Economic Zoölogy, Chapter II.

CHAPTER IV

THE SIMPLER METAZOA

38. **Metazoa.** — The Protozoa just studied are single, free, living cells, while the grasshopper is made up of thousands of cells. The grasshopper is called a *metazoan* (mĕt-a-zō′an : Greek, *meta*, after ; *zoön*, animal) because there are many cells in its body. The Protozoa and the Metazoa are alike in that both take in food, breathe, give off waste matter, and reproduce their kind.

There are a number of organisms concerning which scientists disagree as to whether they are plants or animals. In zoölogy, these forms are known as Colonial Protozoa or simple Metazoa. We shall study two of these (Gonium and Volvox) and then examine the sponges, which all scientists agree are Metazoa.

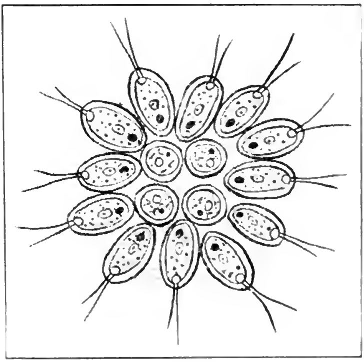

FIGURE 54. — GONIUM.

39. **Gonium.** — Gonium is an animal made up of sixteen separate cells held together by a mucilage-like secretion of the cells. Each cell works independently in getting food, breathing, giving off waste, and in reproduction. The colony moves by lashing the water with long protoplasmic

threads (flagella), two of which project from each cell. The advantage in rate of movement resulting from the union of cells is illustrated in rowing. Eight men in a large rowing shell can go faster than one man in a single, small shell. In reproduction, the sixteen cells fall apart, and each one grows into a new colony.

40. Volvox. — *Volvox* is a colony of hundreds of tiny green cells embedded in a hollow gelatinous sphere. Each cell has two flagella. For a time all the cells are alike and share equally in the work of the colony. But in reproduction only a few cells take part. In the simplest method, a few cells grow large and escape into the hollow sphere. There, they divide and grow into new colonies. Finally, the mother colony breaks, and the daughter colonies escape.

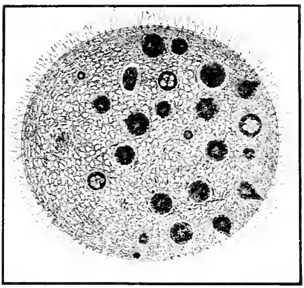

FIGURE 55. — VOLVOX.

The more complex method is like the reproduction of higher animals. Certain cells in the colony grow large and escape into the hollow sphere. They are the *egg cells.* Other cells of the colony enlarge and divide into large numbers of slender, free-swimming cells called *sperm cells.* The sperm cells escape into the hollow sphere and swim about. One sperm enters an egg cell and unites with it, forming a single cell, the *fertilized egg cell*, which can develop a new colony.

41. Division of Labor. — In gonium, the cells are alike in form and function, but in volvox, we find that a few cells have been changed in form in order better to perform the special work of reproduction. This is the first step in the division of labor.

This is well shown in the higher animals, where certain cells are grouped together for a given work. The digestive system contains cells which work to make solutions of the food eaten. These solutions nourish the whole body, not the cells of the digestive tract alone. Certain other cells are modified in such a way for secreting and holding lime that they form bones by which the whole body is benefited.

Some cells are grouped to form muscles to be used in securing food and in enabling animals to escape from their enemies. Other cells are for the purpose of conveying and interpreting impressions, so that the animal may hear the approach of an enemy, or detect the presence of food. It is largely the carrying out of this "division of labor" that tells us the rank of an animal or a plant in biological classification.

In the business world we know of division of labor. Years ago the cobbler made all the parts of a shoe. In our large shoe factories to-day we find no one man making an entire shoe. One man runs the machine that cuts the leather and does no other part of the work. He may have been a cutter twenty years, and he works rapidly and accurately. Another man runs the machine which sews uppers to the soles. He, too, is a rapid and skillful worker. Other men have their special lines of work to do. In the end they produce more shoes and better shoes than this same number of men could, if they were all cobblers and each finished his product. So in the world of business we find the same plan of division of labor that we are studying in biology.

42. Sponges. — Sponges are simple metazoa. In them we find division of labor carried out in a more complex way than in gonium and volvox. Simple sponges have a body in the form of a hollow cylinder. Water enters through the sides of the body and passes out through a hole in the top. A simple sponge, called *Grantia*, grows in salt water attached to docks or other objects submerged along the seashore. On examination, it will be observed that grantia is less simple than volvox.

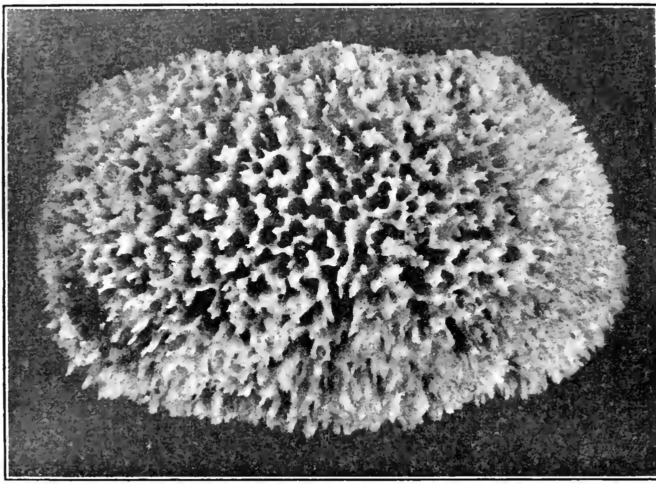

FIGURE 56. — BATH SPONGE.
A skeleton.

43. **Structure.** — Grantia is composed of three layers of cells which show division of labor. The inner layer is called the *endoderm* (en′dō-derm). It consists of cells provided with flagella which, by their movement, produce a current of water through the central cavity. The water enters through the holes in the sides (inhalent pores) and is forced out through the opening at the top (exhalent pore). The water contains food particles which the cells of the endoderm have the power to take in and digest. The food solution is passed to the other cells in the sponge body by the process of *osmosis.*

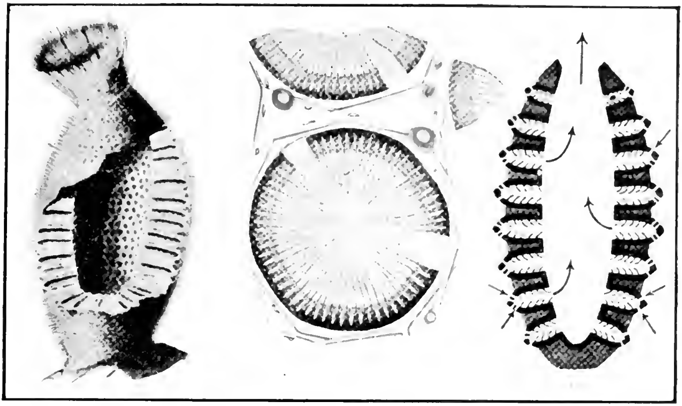

FIGURE 57. — DIAGRAM.
To show parts of sponge.

This is a physical process in which gases or liquids of unequal densities, separated by a plant or animal membrane, tend to mix and become alike, the liquids or gases passing through the membrane.

Thus the food digested is passed on and nourishes the cells of the middle and outer layers. The cells of the middle region form *spicules* (spĭc′ūls) of lime (Figure 58) that project through the other layers and strengthen the whole body. The outer layer or *ectoderm* (ek′tō-derm) serves as a protective layer and with the help of the spicules gives definite shape to the body.

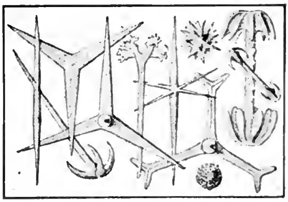

FIGURE 58.

LABORATORY STUDY

The sponge which we ordinarily handle is simply the skeleton, and is easily kept from year to year. Examine several kinds of sponge skeletons and compare their shape, size, and the nature of the skeleton. How much water will the pores of the sponge hold? Microscopic sections of Grantia are necessary if you are to make out the inhalent pores, the central cavity, and spicules.

44. Reproduction. — At certain times of the year the sponge reproduces by means of two kinds of cells (eggs and sperms) developed in the middle layer. A sponge may develop both eggs and sperms, but usually develops only one kind at a time. Cells from the middle layer move in between cells of the endoderm and grow large and round. These are the eggs (female cells). Other cells move into the endoderm layer and divide into many small ciliated cells (the sperm or male cells). The sperms are set free and escape into the water of the central cavity and out from the body of the parent sponge. A sperm enters the body of another sponge and when it finds an egg, fuses with it, thus forming the fertilized egg. The fertilized egg then begins to grow, and after a definite period breaks away from the parent, moves about for a time, and then settles down, attaches itself, and grows into a mature sponge. The immature sponge has the power of locomotion, but the mature form loses this power. Nevertheless the sponge is an animal.

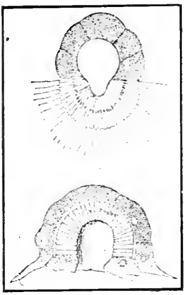

FIGURE 59. — TWO STAGES IN THE DEVELOPMENT OF THE SPONGE.

Reproduction that comes about through the fusion of an egg and a sperm is called *sexual reproduction*. The other method of reproduction, called *asexual reproduction*, also occurs among sponges. By this method, sponges form little buds or branches which develop into new sponges.

45. Spongilla. — *Spongilla* (spŭnj-ĭl′la) is a fresh-water sponge. At the approach of cold weather, certain reproductive bodies are formed, known as winter-cells, and these escape from the sponge. They settle down to the bottom of the pond or stream and remain dormant until the approach of warm weather, when they grow into new sponges. They have a thick protecting coat which enables them to resist unfavorable conditions.

46. Economic Importance. — The spicules of the different sponges form a large part of their so-called skeletons. These spicules are, in some cases, composed of lime and form the limy sponges. In others, they are of silica and form the glassy sponges. The more important sponges have a skeleton made up of a hornlike substance which is flexible. This is the sponge of commerce.

Great quantities of sponges are gathered from the sea by divers and by dredges. The living tissues are allowed to decay, and the skeletons are then washed and dried. Some are bleached to form the white sponges. The sponges of best quality come from the Mediterranean Sea and the Red Sea.

Sometimes fresh-water sponges grow in the water mains of cities and towns, causing the pipes to become clogged.

47. Relation to Other Animals. — No animal is known to eat the sponge. Sponges themselves feed on minute particles of food, which are carried in by the currents of water produced by the cilia of the endoderm. Some marine animals use the porous body of the sponge as a retreat.

Certain sponges live in close relationship to higher forms of animals. One kind is always found growing on the legs of crabs. The movement of the crab carries the sponge to water richer in oxygen and food, and the crab is hidden from its enemies by its sponge covering. Each animal gains by this inter-relationship. Where two such animals as the crab and sponge live in this way the relationship is known as *symbiosis* (sўm-bī-o′sĭs : Greek, *syn*, with ; *bios*, life).

SUMMARY

The transition from simple Protozoa, through the Colonial Protozoa, to the Metazoa is simple and direct. In gonium and volvox, the beginning of division of labor is noticed; that is, one part of the body becomes dependent on another part for certain definite things. For example, one cell is devoted to securing food, while another produces eggs or sperms. The sponges are simple Metazoa in which the division of labor has taken the form of producing three layers, — the ectoderm, or outer layer; the endoderm, or inner layer; and a loosely formed middle layer. Grantia is a simple sac-shaped sponge which reproduces both sexually and asexually. The general manner of development by the sexual process is essentially the same in all the higher animals, including man. The bath sponges are the only ones of economic importance.

QUESTIONS

What can the single-celled protozoan do? Compare with the Colonial Protozoa, gonium and volvox. Explain the meaning of division of labor in an animal. In what respects do sponges differ? Of what use are they? Why are not all sponges useful?

REFERENCES

Hegner, Introduction to Zoölogy, Chapter VI.
Jordan and Kellogg, Animal Life, Chapter II.
Osborne, Economic Zoölogy, Chapter III.

CHAPTER V

CŒLENTERATES. HYDRA-LIKE ANIMALS

48. **Cœlenterates.** — The *Cœlenterates* (sē-len′te-rāts: Greek, *koilos*, hollow; *enteron*, intestine) are simple metazoa, a little higher in development than the sponges. In the group are hydras (hī′dras), hydroids (hī′droids), jelly-fishes, sea-anemone (a-nem′o-nē), sea-fans, and corals.

49. **Structure of Hydra.** — The *hydra* is an interesting fresh water animal about a quarter of an inch in length. Its body is shaped like a little cylindrical bag with only one opening, the mouth, which is surrounded by a few, usually six, delicate, thread-like arms called *tentacles* (ten′ta-kls). The body is composed of three layers, the outer layer, *ectoderm;* the middle layer, the *mesoglea* (mes-ō-glē′a: Greek, *mesos*, middle;

FIGURE 60. — MICROPHOTOGRAPHS OF HYDRA.

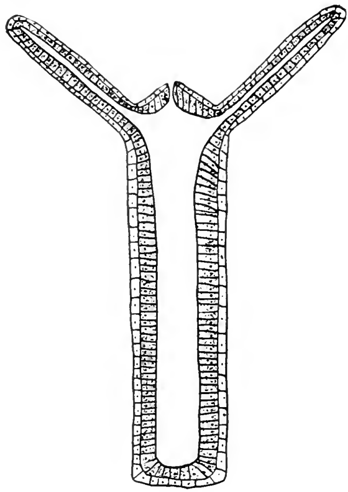

FIGURE 61. — DIAGRAM OF BODY OF HYDRA.

gloios, glutinous substance); and the inner layer, *endoderm*.

Each layer does some particular work for which the others are not fitted. For example, the outer layer contains cells which are especially sensitive to stimuli and many modified muscle cells that enable the animal to move about. The inner layer contains cells provided with flagella which catch the food particles for the inner cells to digest. The muscular action of the outer layer moves the entire animal. The sensitive cells enable the animal to recognize its prey. The food digested by the inner layer is used by all the cells of the body. Thus we see an advance in the division of labor over that shown in the sponge. We shall observe a still greater increase in division of labor as we study higher animals.

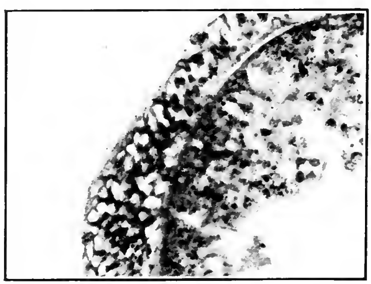

FIGURE 62. — MICROPHOTOGRAPH OF BODY WALL OF HYDRA.

Tentacles are hollow, finger-like branches connected with the body cavity. They are provided with stinging cells which help the hydra to capture living water fleas, and the like. These stinging cells have darts which are automatically discharged when the tentacles come in contact with little animals. The darts stun the prey and render escape impossible. The tentacles surround the food and carry it to the mouth, which opens directly into the food cavity. The action of the tentacles in doing this work suggests the idea that each tentacle has some way of realizing the efforts of the others.

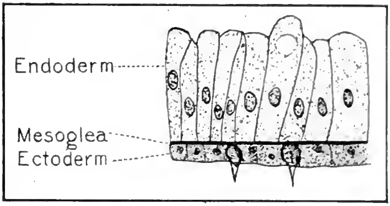

FIGURE 63. — DIAGRAM.
To explain cell layers in Figure 62.

We should keep in mind that in the metazoan the united cells are in connection with each other through the cell walls. This is true even if we are not able to trace the connections with the microscope. In the higher animals we shall find that connections between cells are made by means of nerve cells. The development of a nervous system only carries out division of labor to a greater degree.

50. Respiration and Excretion. — By osmosis, oxygen is absorbed from the water by the cells of the ectoderm. The water that enters the mouth carries oxygen, and by osmosis it is absorbed by the cells of the endoderm. At the same time the carbon dioxide from the cells is thrown off into the water.

51. Reproduction. — The hydra reproduces both sexually and asexually. In sexual reproduction eggs and sperms are produced by the ectoderm cells. The sperm cells escape into the water and, like sperm cells of all other animals, have the power of locomotion. The fusion of the egg cell and a sperm cell starts growth which results in the division of the egg cell into many other cells.

Hydras also reproduce asexually by budding. The buds soon separate from the parent and begin an independent life. Like the developing sponge, the developing hydra grows until it finally becomes a fully formed hydra.

LABORATORY STUDY

The living brown or green hydras can usually be found in the spring or fall in most fresh water ponds. They are easily collected by gathering the floating leaves and overhanging grass that is immersed in the water. Place this collection in a glass jar in the laboratory. In a couple of days the hydras will have moved from the grass to the sides of the jar. They can be examined by a small magnifying glass in the jar or be transferred to a watch glass and observed under the low power of the microscope. Watch the hydra contract, when jarred or touched. Note that the tentacles become very short. Try feeding with a small bit of raw meat. Make out the transparent ectoderm and the darker endoderm. Are there any buds? What happens to the buds when the parents contract?

52. **Hydroids.** — Hydroids are marine, hydra-like animals which are united in groups forming a tree-like colony (Figures 64–66). They are often mistaken for plants.

FIGURE 64. — MICROPHOTOGRAPH OF THE HYDROID OBELIA.

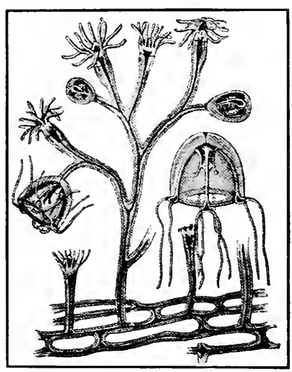

FIGURE 65. — DIAGRAM OF THE HYDROID BOUGAINVILLEA.

When the young hydroid first begins to grow, it looks like the fresh water hydra (Figure 60).

As the hydroid grows, branches form and on the end of each branch, tentacles and a mouth appear.

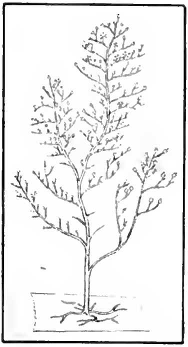

FIGURE 66.—A HYDROID COLONY THAT LOOKS LIKE A PLANT.

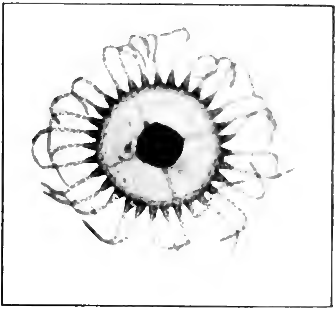

FIGURE 67.—A HYDROID MEDUSA.

Each branch is able to capture food and, after it takes what it needs, the surplus is distributed to other parts. This is easily brought about, as a common digestive cavity connects all of the branches. The hydroid is termed a colony because all of the branches are united and help each other in getting enough food for all.

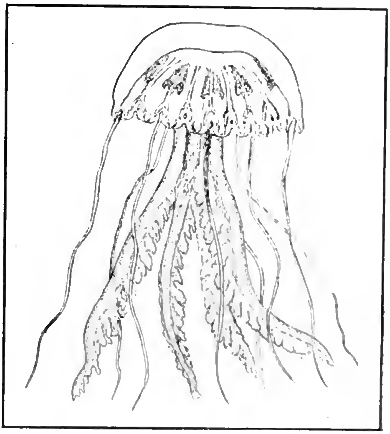

FIGURE 68.—THE MEDUSA KNOWN AS PELAGIA.

Some of the hydroids form curious buds which develop into *medusæ* (mē-dū′sė). See Figure 67. As soon as the

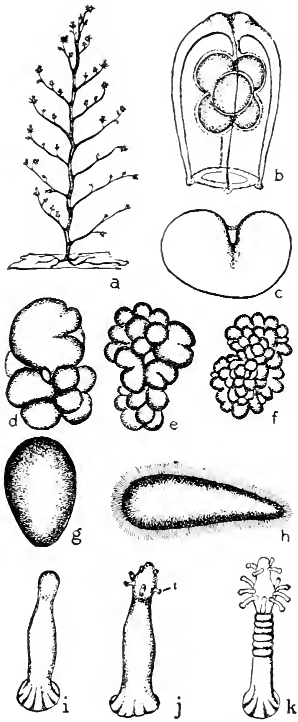

FIGURE 69.—PENNARIA TIARELLA.

a, The hydroid colony; *b*, one of the female medusæ, much enlarged; *c*, the egg of the medusæ beginning to segment after it has been fertilized; *d*, *e*, *f*, further segmentation stages; *g*, the blastula stage; *h*, the free swimming larva (planula); *i*, *j*, and *k* show the gradual transformation of the larva into a hydra-like colony. Branches grow on the stage shown in *k* until a colony like *a* results. This is the form that alternation of generations takes in this hydroid. (Arranged from a monograph on Pennaria by C. W. Hargitt.)

medusæ are set free from the hydroids, they swim about and capture their own food. Each medusa is provided with either *ovaries* (ō′vȧ-rĭz), organs which grow egg cells, or *spermaries* (spẽr′mȧ-rĭz), organs which grow sperm cells. When the eggs and sperms mature, they are discharged into the water. A single sperm cell must fuse with an egg cell before the egg can begin to grow. This union of these two cells is called *fertilization*. The egg grows into an *embryo* (ĕm′-brĭ-ō), an immature stage differing in different animals, and this gradually changes into a small hydroid. The several steps in this complicated series of changes are illustrated in Figure 69. The hydroids and medusæ show a form of reproduction called alternation of generations, that is, they reproduce alternately sexually and then asexually.

53. Sea-anemone.—Sea-anemones are animals allied to the hydra. The interior of the body cavity is subdivided by many partitions which increase the digesting and absorbing surface. The sea-anemone reproduces by eggs and sperms.

The resulting embryo is free at first, but later becomes fixed to some object and develops into the sea-anemone. There is no medusa stage.

54. Coral. — Geographies tell us of the many coral islands and reefs built up by the coral animals. These animals are cœlenterates, most of them closely allied to the sea-anemone, but the coral animal secretes about the body and along the partitions *calcareous* (kăl-kā′rē-us, limy) skeletons which form the stone-like masses of the coral rock. The upper portion of the coral rocks is alive with these coral animals. The lower portion is made up of skeletons only. Succeeding generations build upon the work of their ancestors.

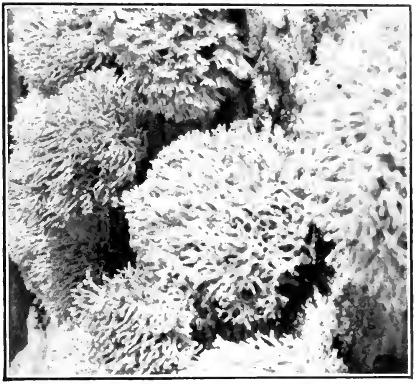

FIGURE 70. — SOME COMMON CORALS.

Corals reproduce much as trees grow branches, but at certain periods eggs and sperms are produced as in the sea-anemone. Then the embryo settles down, secretes its own skeleton, and this is added to the work of other corals.

Sea-fans and sea-plumes are cœlenterates which have the forms suggested by their names. A dried specimen of either looks as if a branch had been dipped in a solution and coated. The interior is of a horny substance. The exterior is covered with a limy secretion.

55. Economic Importance. — The corals alone of the cœlenterates are of economic importance; they add to many islands, protect others from being washed away, and in some cases form entirely new islands.

SUMMARY

The hydra-like animals represent an advance in the division of labor. The layers of their bodies are more definite and do their work better than in the sponges. Hydroids and the corals illustrate the formation of a colony. In some of the colonies the division of labor is more extensive than in others. The economic importance of the corals has been, and continues to be, very great.

QUESTIONS

Explain fully how the hydra gets its food and how some of this food finally nourishes the ectoderm cells. Compare the hydra and the hydroid. In what are they alike? In what are they different? How does the hydra reproduce? How does the hydra get its oxygen? Explain how the coral animal has been able to form islands.

REFERENCES

Darwin, Structure and Distribution of Coral Reefs.
Hegner, Introduction to Zoölogy, Chapter VIII.

CHAPTER VI

THE STARFISH FAMILY. (Optional)

56. The Starfish Group. — This group of animals includes the well-known starfish, the sea-urchins, sea-lilies, and several soft-bodied forms such as the sea-cucumber. The technical name for these different animals is *echinoderm* (ē-kĭn′ō-dĕrm: Greek, *echinus*, spine; *derm*, skin), meaning spiny-skinned animals. Most of these animals have a skeleton. Unlike that of man it is on the outside and is composed of calcareous plates. In some forms, like the starfish, the plates are embedded in the skin, while in the sea urchin the plates fit edge to edge, forming a shell. The plates support many spines which project out over the body giving the spiny appearance characteristic of the group. Both the skeleton and soft parts are arranged in a radial manner. The presence of spines and the radial arrangement are two characters by means of which one can recognize most of the echinoderms.

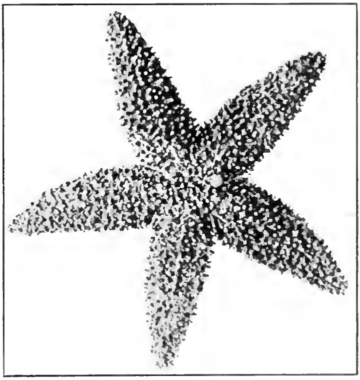

FIGURE 71. — STARFISH.

57. The Starfish. — Starfishes are found in salt water. They are composed of a central region, called a disk, from which extend five arms or rays. On the disk is a porous circular plate. It is known as the *madreporic* plate (măd-rē-pŏr′ĭk: Greek, *mater*, mother; *poros*, soft). It

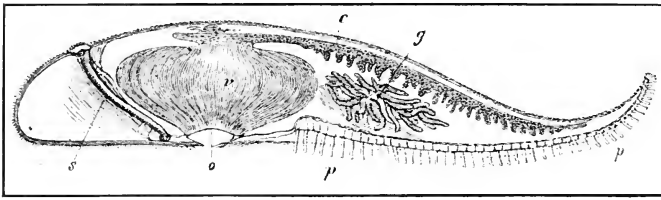

FIGURE 72. — DIAGRAM OF BODY OF STARFISH.

c, liver; *v*, stomach; *o* mouth; *g*, reproductive glands; *p*, tube feet; *s*, stone canal.

serves to take water into a series of vessels by means of which the animal moves and holds on to rocks and shells at the sea bottom

58. **Internal Structure.** — If the upper portion of the animal is removed carefully, the internal structure can be examined. Each ray is nearly filled with masses of yellowish green substance. This is a gland which forms the digestive fluids used in the stomach. The wrinkled mass in the region beneath the disk is the stomach. The mouth is just below the stomach on the lower or *oral* side of the body. At the angles of the arms and extending into each ray are the reproductive glands, which vary in

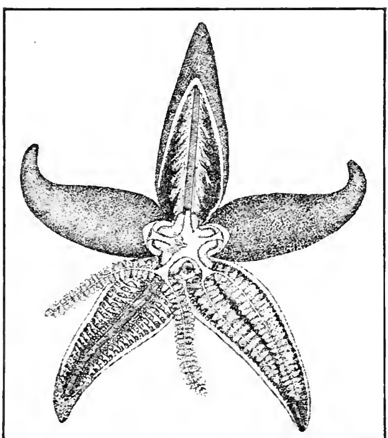

FIGURE 73. — ANATOMY OF THE STARFISH.

size at different ages and seasons. According to the sex of the individual these glands produce either eggs or sperms, which are discharged into the water.

LABORATORY STUDY

Dried specimens of starfish serve well for general study. These may be compared with specimens which have been preserved in alcohol or formalin. Work out the several parts such as disk, arms, madreporic plate, spines, groove of the feet, and position and form of the mouth. If skeletons of sea urchins are available, they are interesting for comparison.

59. **Life History.** — The eggs and sperms fuse outside the body. In their development into adults they pass through a series of striking changes. The young or larval forms do not resemble the adults at all. This development through a series of marked changes is as striking as that seen in the insects and is likewise called a metamorphosis.

60. **Food Taking.** — The starfish takes its food in an unusual manner. Most animals move the food to the mouth, swallow it or engulf it, and digest it within the body cavity. In the case of the starfish we find that the stomach is projected through the mouth and made to surround its food. In this position it digests and assimilates the food and then withdraws its stomach through the mouth and moves on slowly to some other place. A common food of the starfish is the clam. The arms or rays surround the clam, and the "hinge ligament" which holds the shell together is tired out, thus causing the protecting clam-shells to separate. The stomach is then pushed out, enveloping the clam. The digestive fluid is secreted and the dissolved clam is absorbed as food.

61. **Locomotion.** — The animal moves chiefly by means of the tube-like feet found in the groove on the under surface of the rays. These so-called feet make little sucking disks.

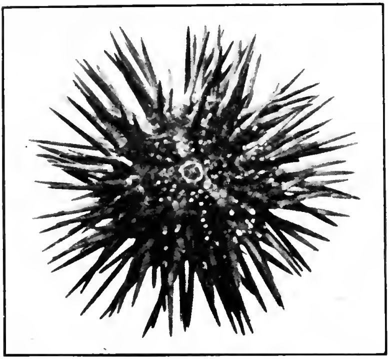

FIGURE 74. — PURPLE SEA URCHIN.

62. Respiration. — Oxygen is taken from the water and carbon dioxide given off through little thin-walled, gill-like processes which cover the upper surface of the disk and arms. These gill-like processes project through holes in the exoskeleton.

63. Other Echinoderms. — The sea urchins are thickly covered with spines and have tube feet which, in many cases, may be greatly extended. When the spines are removed, an exoskeleton is revealed, which readily shows the radial arrangement characteristic of the echinoderm group.

64. Economic Importance of the Group. — Of echinoderms the starfish alone has an economic bearing. It is harmful. Living as it does in the region of the oyster and clam beds and feeding almost exclusively on them, the starfish annually destroys thousands of dollars' worth of clams and oysters. By removing the seaweed where the immature starfish gather and by dragging the oyster and clam beds great numbers of starfish are destroyed.

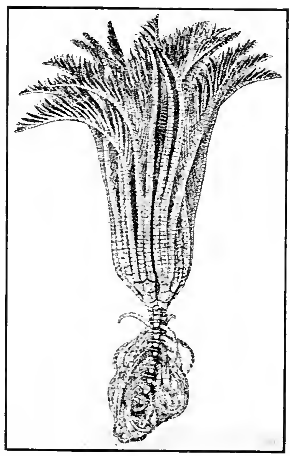

FIGURE 75. — SEA LILY.

In former times the fishermen used to break starfish to pieces on the side of the boat and throw them back into the water. It is now known that by so doing they were but increasing the number of starfish, for starfish have the power to re-grow the parts broken off. Each complete arm could reproduce an entire starfish. This power to restore lost parts is known as *regeneration* (rē-jĕn-ẽr-ā'shun). Many of the lower animals have this power to a marked degree, and all animals have it to some degree.

SUMMARY

The starfish group of animals is known by the presence of spines in the skin and a radial arrangement of the organs. Their chief economic relation to man consists in their great destructiveness to the oyster and clam beds.

QUESTIONS

Why are starfish so-called? How can they be distinguished from other animals? How do they move? Where do they live? On what do they feed? How do they breathe?

REFERENCES

Brooks, The Oyster.
Osborne, Economic Zoölogy, Chapter VIII.
Poulton, All About the Oyster.

CHAPTER VII

THE WORM GROUP

65. **The Worm Group.** — Here are found several distinct groups of animals that in advanced text-books of zoölogy are treated separately. The word "worm" is an old term which properly describes such animals as the earthworm, sea worm, leech, tapeworm, flat worm, and a few others. The word "worm" cannot be correctly used for such larvæ of insects as the "apple tree worm" or "currant worm."

The worm group is divided into two classes — those whose body is composed of numerous *segments* (sĕg′mĕnts) or rings, such as the earthworm, the sea worm, and the leech; and those whose body is not segmented, such as the tapeworm and flat worm. The first class comprises the true worms, which are known as *Annelida* (ă-nĕl′ĭ-dȧ). The second class, the unsegmented worms, have no single technical name, and are not believed by scientists to be true worms. They comprise a number of worm-like animals which have hardly any features in common. Here are found the fresh water planarians, the parasitic tapeworms, liver flukes, and numerous round worms, of which the hair worm is an example.

The planarian worm is one of the simplest of these unsegmented worms. It is found under stones submerged in stagnant water and in streams. It is frequently brought into the laboratory and lives easily in aquaria.

The liver fluke is a parasitic flat worm which each year causes the death of many sheep by injuring their livers.[1] Like some other parasitic animals the liver fluke requires two hosts to complete its development. The hosts of the fluke are the sheep and certain snails. The adult liver flukes form eggs and sperms in the liver of the sheep. The fertilized eggs partially develop in the sheep; then as embryos they pass down the bile duct into the intestine and then out of the body.

FIGURE 76. — A PLANARIAN WORM.

The *ciliated* (sil′i-a-ted) larva then makes its way into water or along dew-covered grass. If it comes in contact with a water snail in the water or a land snail on the grass, it enters the body of its second host, otherwise it dies. Once inside the body of the snail it completes a complicated development. By a bud-like process many young flukes are formed which finally emerge from the snail and make their way to the grass stems on which they encyst themselves. If this grass is eaten by a sheep, the digestive fluids set free the young fluke which goes up the bile ducts to the liver, where it grows to maturity.

66. Trichina. — Another unsegmented worm that is of economic importance is the Trichina (trĭ-kī′nȧ), now generally called Trichinella (trĭ′kī-nĕl′lȧ). This worm lives in the intestine of mammals and from the intestine migrates into the muscles of its host. In the muscle it becomes encysted and remains until the flesh is eaten by some other mammal. When pork, infected with this parasite and insufficiently cooked, is eaten by man the

[1] The Animal Parasites of Sheep. Dr. Cooper Curtice. Bureau Animal Industry, United States Department of Agriculture, 1890.

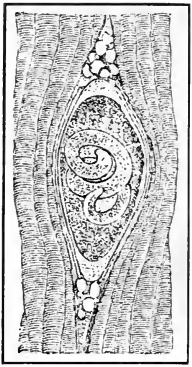

FIGURE 77.—TRICHINELLA.

cysts are dissolved by the digestive fluids and the worms are freed.

These worms then develop eggs and sperms which after uniting mature into young worms and migrate through the intestine into the muscles. The activity of the worms at this stage causes a serious inflammation of the tissues and a disease known as trichinosis (trĭk-ĭn-ō′sis), which is often fatal. Hogs contract trichinosis by eating refuse that contains the encysted worms.

Government inspectors examine pork which is to be exported or sold in large quantities to see that it is free from these parasites. The smaller sales of pork by local dealers are not inspected and the only way to be sure of the harmlessness of the meat is to cook it thoroughly.

Hair Worm. — The only importance that can be attached to these worms is the myth about their origin. In almost every school will be found students who believe that horse hairs placed in water will develop into "hair snakes." It would be a pity if a student still believed this after a course in biology.

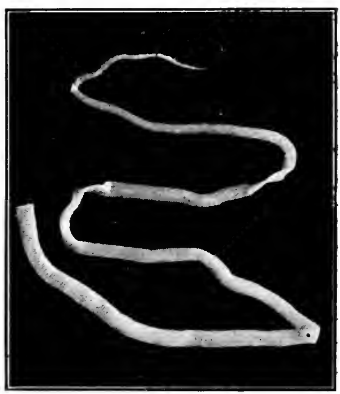

FIGURE 78.—A COMMON TAPEWORM.

Let us see how such a belief can originate and often be thought to be proved. The hair snakes live for a time in water and often in the watering troughs where horse hairs are also found. Boys, and men too, sometimes put horse hairs in water and then after a few weeks examine the water and find these hair snakes. They conclude, since they put in the hairs and later found the "hair snakes," that the hairs grew to form the snakes or small round worms. If they had been as careful to look before any hairs were put in, they would have seen these "hair snakes" swimming about. A better test is to take a bottle of water, put in the

FIGURE 79. — HAIR WORM IN BODY OF GRASSHOPPER.

hairs, and watch for developments. Such a test would show that no hairs turn into hair snakes.

Hair snakes have a complete life history as clearly defined as other worms. They lay eggs which fuse with sperms and form larvæ. These larvæ live as parasites in the bodies of insects and fishes and when mature make their way out of the bodies of their hosts. It would be natural, then, to find them in pools where horses drink and these parasitized fishes live, or in watering troughs into which grasshoppers may have jumped, as they so often do.

We know at present no way in which lifeless matter can be made to live. A hair cannot become a worm and a crooked stick cannot grow into a snake. New life comes from the old. We sometimes read in the papers that some one has produced life from chemicals, but it is not believed at the present time to be possible.

67. **The Earthworm** is the simplest and best animal to illustrate the annelid group of true worms.

When one examines a living earthworm, the head end can be determined as the one which first moves forward. Actually there is no head nor are there special sense organs. The muscles in the front end are stronger and the body rounder than in the back end. The back, or *dorsal* (dôr′s'l) part, of the worm is exposed to the light and is darker in color than the rest. This surface is rounder than the opposite (under) one which is in constant touch with the dirt when the worm is crawling. The flat surface upon which the worm crawls is the *ventral* (vĕn′tral) surface.

The body of the earthworm is made up of a number of segments (rings) which are marked off by shallow grooves. Some of the segments in the front end are larger than those that make up the back end, but all are similar in shape. The number of segments depends mostly upon the age of the earthworm, and is from 60 to 150 in full-grown worms.

68. **Locomotion.** — The earthworm crawls by means of short, stiff bristles used as legs, the *setæ* (sē′tē: Latin, *seta*, bristle), which are found in all of the segments except the first two or three. These setæ are arranged in four rows, two in each row. To understand how the setæ are used in the locomotion of the earthworm it is necessary to know that the body wall contains two muscular layers. In the outer layer the muscles running around the body are called circular muscles. The inner layer, consisting of a number of bands running in the direction of the length of the body, are called longitudinal muscles. The contraction of the circular muscles

lengthens the body and the contraction of the longitudinal muscles shortens it. The setæ are connected with the longitudinal muscles. By pointing the setæ backward and bracing them against the ground, the worm can push itself forward. By pointing the setæ forward the worm can instantly change the direction of its movement.

LABORATORY STUDY

One of the annelids should be studied with some care, as an illustration of an invertebrate animal. How do you determine the anterior and posterior ends? Dorsal and ventral surfaces? The number of segments? Compare several worms. The back region of the worm shows the most variation because new segments are being added. Where are the setæ? How does the earthworm move? Place it on a glass. The front region of the body is most sensitive to touch. Test it.

69. Internal Structure of Earthworms. — This is shown diagrammatically in Figure 80. The internal structure consists of an outer tube, the body wall, and an inner tube, the digestive tube. The space between the body wall and digestive tube is known as the body cavity or *cœlome* (sē′lŭm: Greek, *koilos*, hollow). Thin sheets of membrane pass from each furrow between the segments to the digestive tube.

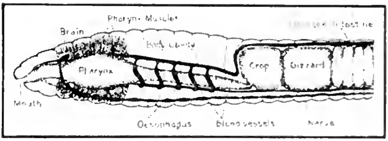

FIGURE 80. — DIAGRAM.

The organs of earthworm from the side.

Beginning at the front end the digestive tube is given certain names for each distinct region, as follows: the *mouth cavity;* the *pharynx* (făr′ĭnks), with its thick muscular walls; the *esophagus* (ē-sŏf′ȧ-gŭs), thin-walled and small; the *crop*, a wide pouch; the *gizzard*, where food is ground; and the *stomach-intestine*, a large, thin-walled tract extending through the last two thirds of the length of the worm.

The earthworm has an easily recognized nervous system which is found beneath the digestive tube. It consists of a continuous, minute, white thread with slight swellings in each segment. From these swellings, which are called *ganglia* (găn′glĭ-ȧ: Greek, *ganglion*, swelling or tumor), short branches extend to the digestive tube and other organs. These branches are known as nerves. Toward the front end the nerve-thread parts and becomes double. Each part passes around the front end of the pharynx and enlarges to form two ganglia, the largest found in the earthworm. More nerves grow from these two large ganglia than from any of the others and so the term "brain" is given to these two ganglia found in the dorsal surface of the pharynx (Figure 81).

FIGURE 81.—EARTHWORM.
Front end of nervous system.

The organs of the earthworm are supplied with blood which is carried in a large dorsal blood vessel, a ventral blood vessel, and numerous branches. The blood is pumped by the contracting of the dorsal vessel and by the five pairs of tubes which pass from the dorsal to the ventral vessel around the esophagus. These five tubes are named *aortic* (ȧ-ôr′tĭk) arches.

LABORATORY STUDY OF INTERNAL STRUCTURE

Work out the internal structure of the earthworm. In dissecting, cut the skin along the dorsal surface, being careful to cut the many membranes that hold the digestive tube in place. Work out the size and position of the mouth cavity, pharynx, esophagus, crop, gizzard, and stomach-intestine. The white reproductive organs are located beside the esophagus. Locate the "brain," the ventral chain of ganglia. The dorsal blood vessels and aortic arches should be located. Make a sketch locating the organs in their respective segments.

70. Life History. — In the starfish group the sexes are distinct. The sexes in the annelids are distinct in some forms and in others the same individuals have both ovaries and spermaries. However, the sperms that unite with eggs always come from another worm. During the season when the ovaries and spermaries are forming eggs and sperms, certain segments, usually six in number, beginning with the twenty-eighth segment, and known as the *clitellum* (klĭ-tĕl′lŭm), pour out a gelatinous secretion which hardens into a collar-like sac around the worm.

This sac is worked forward and as it passes the openings of the reproductive organs, eggs and the sperms from another worm are pushed into it. The sac continues to move forward and finally leaves the worm as a closed capsule. This capsule contains eggs, sperms, and fluid food. After the fusion of the eggs and sperms, the resulting embryonic worms begin to feed upon the fluid food in the capsule; later they feed upon each other until but one may remain eventually to bore or eat its way to the earth outside. From now on the food of the young worm is the soil.

The earthworm is an example of an animal which has both ovaries and spermaries.

71. Respiration. — Oxygen passes through the skin directly into the blood, which then carries the oxygen to the various cells of the body. The outer surface must be kept moist to permit the skin to act as a lung.

72. Excretion. — In each segment is found a pair of organs known as *nephridia* (nē-frĭd′ĭ-ȧ), which look like little threads. These remove the liquid waste and carry it to the outside of the body. It is believed that carbon dioxide passes off through the skin, much as oxygen passes in. This taking in and giving off of these gases is accomplished by osmosis.

73. **Food-taking.** — The food of the earthworm is chiefly the soil in which it burrows. By means of ar upper lip, which is a specialized anterior segment, and the muscular walls of the pharynx, it takes the earth into its body and the muscles of the digestive tube advance the food along its course. The soluble and therefore digestible parts are absorbed, and the remainder (the greater portion) is passed along to the outside. Earthworms are not critical in the selection of their food, although they are not entirely without a sense of taste.

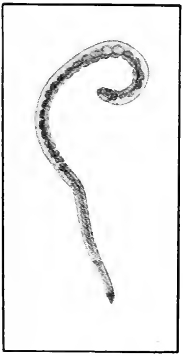
FIGURE 82. — DERO. A common fresh-water annelid.

74. **Economic Importance.** — The value of the earthworms to agriculture is too great to be overestimated. In burrowing their way through the soil they leave passageways for water and air to enter, thus assisting plants to grow. They bring the fertile, swallowed soil to the surface. When the large numbers of the earthworms are considered, it is obvious that they are the great natural cultivators of the soil.

75 **Other Annelids.** — The sand worm or *Nereis* (nē′rē-ĭs), a marine or salt water form, is another segmented annelid. It is more highly specialized than the earthworm, for it has biting mouth parts, tentacles, and eyes. It is an active swimmer at times. The development of the sand worm exhibits metamorphosis, while the earthworm hatches directly into a worm without metamorphosis.

SUMMARY

In the worm group are included the unsegmented worms, such as tapeworms, liver flukes, and hair worms; and the segmented or true worms such as the earthworms, sea worms, and leeches. All of these worms have more perfectly organized parts than the sponges and hydroids. The body of the earthworm shows the first steps in the formation of definite front, back, and ventral regions. The digestive tube is also specialized into pharynx, esophagus, crop, gizzard, and stomach-intestine; and the name *brain* may be given to a slightly enlarged portion of the anterior end of the nerve cord. Small worms of various kinds are numerous in stagnant water. Some live as parasites in man and other animals, causing much suffering and loss of life. The earthworm as a cultivator of the soil has been of inestimable value to man.

QUESTIONS

What kind of animals are called worms? Is it proper to call "currant worms" worms? Why not? What are they? How do you recognize the anterior, posterior, dorsal, and ventral regions? Compare the grasshopper or some other insect with the worm. Explain how the earthworm moves; makes its burrow. Compare the digestive tube with the digestive sac of the hydra.

REFERENCES

Darwin, Earthworms and Vegetable Mould.
Jordan, Kellogg, and Heath, Animal Studies, Chapter VI.
Sedgwick and Wilson, General Biology.

CHAPTER VIII

CRUSTACEANS AND RELATED FORMS

76. Crustaceans. — The *Crustaceans* (krŭs-tā′shŭns: Latin, *crusta*, crust) are so-called because of their hard outer covering. They belong in the same group of animals as the insects and are more highly developed than the worms. The body consists of a limited number of segments, each of which usually bears a pair of jointed appendages. The appendages are variously modified; some aid in swimming, others in securing food, and others are used in walking. The jointed appendage is the characteristic expressed in the technical name *Arthropoda* (är-thrŏp′o-da: Greek, *arthros*, joint; *pod*, root of *pous*, foot) given to the group to which all these animals belong.

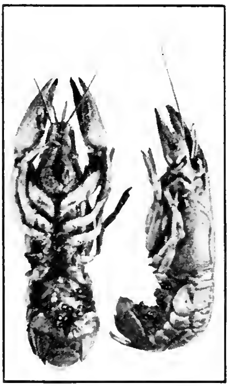

FIGURE 83. — CRAYFISH BEARING EGGS.

77. Crayfish. — As a typical crustacean we have the common crayfish, or "crab" as it is known away from the seashore. The crayfish has nineteen pairs of appendages adapted to different kinds of work. It lives in fresh-water ponds and streams where there is sufficient lime for its use in building up its outside covering (exoskeleton).

The animal is divided into two regions, the *head-thorax* region and the *abdomen*. The segments of the abdomen are clearly defined, but those of the head-thorax are so fused that they cannot be made out. The appendages of

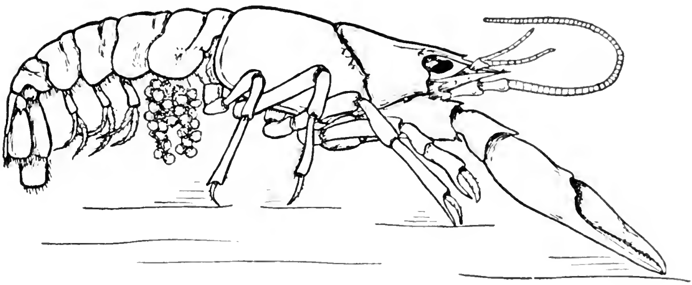

FIGURE 84. — CRAYFISH.

the head-thorax region are the most important to the animal. Certain of these are fin-like and by their constant waving motion serve to carry food to the mouth. Others are elongated and serve for walking. One pair, the pinchers, are used for seizing and holding.

FIGURE 85. — MOLTED EXOSKELETON OF LOBSTER.

The last abdominal segment and the appendages next to the last are broad and fin-like and together form a tail fin (caudal fin) for use in thrusting the animal backward, when it is alarmed.

78. Life History. — The sexes are distinct. The males may be distinguished from the females by the larger tubular appendages on the first and second segments of the abdomen. The eggs of the female are carried for some time by the appendages of the abdomen, where they pass through their early stages of development. The young crayfish is unlike the adult in form, and approaches maturity only after passing through many changes (Figure 84).

79. **Molting.** — One of the interesting features in the study of the crayfish is the shedding of the external skeleton. Being covered by a firm exoskeleton it is necessary that this be removed occasionally, in order that the animal may grow. Molting, in the case of the crayfish, is a serious and dangerous operation, as it is followed by a period during which the crayfish is without means of offense or defense. The crayfish usually hides until a new exoskeleton is partially formed. In the molting process the covering of the eyes and part of the lining of the digestive tract, as well as the whole exoskeleton, are shed. The crayfish molts every year of its life and several times during the first year (Figure 85).

LABORATORY STUDY

Place several crayfish in jars or aquaria and observe their behavior. Fill out the following report:

Do they Move the Antennæ?	Do they Walk Forward?	Do they Walk Backward?	Do they Use Caudal Fin?	Do they Move Eyes?	What Organs Make a Current in Water?

Laboratory study on the appendages. Examine more fully than in the above and report the work of each pair of appendages. Compare one of the abdominal appendages with those used in walking and feeling. What is the work of the large pinchers? How many fin-like appendages are found in the mouth region? Notice that one of the mouth appendages has a flat part that extends in front of the gills. This part of the appendage is called the gill scoop or bailer.

80. Food and Food-getting. — The food of the crayfish is both plant and animal, living and dead. One of the simple water plants, *Chara* (kā′rȧ), furnishes the crayfish with lime for its skeletons. Shells of snails and their own shed skins also help to supply lime. Crayfish seize food with their pinchers and move it towards the mouth. Small food particles are also carried towards the mouth by currents of water produced by the mouth parts and the abdominal appendages. Particles of food are torn loose by the teeth or mandibles.

81. Digestive System. — The mouth is just back of the teeth, and connects with the stomach by a short esophagus.

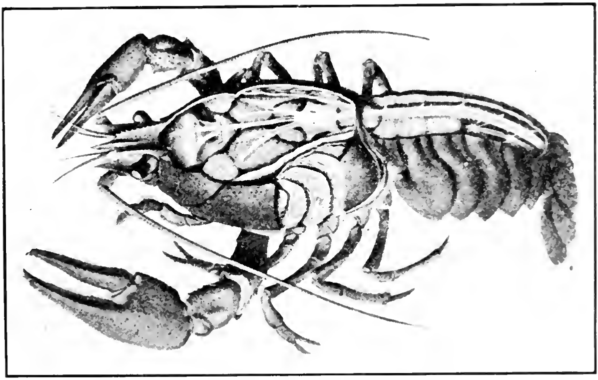

FIGURE 86. — ORGANS OF CRAYFISH.

The stomach is divided into front and back parts. The front part possesses a grinding structure known as the *gastric mill*, which serves to shred and crush the food and make it ready for digestion in the back part. The liver, or digestive gland, pours a fluid into the stomach, which prepares the food for absorption by the walls of the stomach and intestines. The intestine begins at the back end of the stomach and extends to the last segment.

82. **Respiration.** — Crayfish obtain oxygen from the water by means of gills which are well covered by the overhanging skeleton of the head-thorax region, but are really outside of the body. Most of the gills are plume-like in shape and are attached to the appendages, but some of them are attached to the thorax. Water is made to circulate through the gill chamber by means of the gill scoop or bailer. The finely branched gill affords a large amount of surface for the absorption of oxygen.

83. **Circulatory System.** — The crayfish has a well-developed heart from which extend several arteries that carry blood to the various parts of the body. The blood returns to the heart through veins and through several irregular ducts called *sinuses* (sī′-nŭs-ĕs). As the blood flows through the body it loses oxygen and receives carbon dioxide. Fresh oxygen is absorbed by means of the gills which, at the same time, pass off carbon dioxide from the blood into the water.

84. **The Nervous System.** — In the crayfish this is made up of a brain, ventral nerve chain, and many nerves. The eyes are borne on a pair of short movable stalks. The special senses are well developed, and the sense of taste is keener than that of most lower animals.

85. **Excretion.** — The organs for excretion of waste are the *green glands* that are found at the base of the antennæ. Blood going to these glands loses some of the waste which it has gained in its course through the body. The method of purification of the blood in these glands is much the same as in the kidneys of the higher animals.

86. **Other Crustaceans.** — Shrimps, lobsters, and crabs are crustaceans of much economic importance, because of their food value. The trade in these animals amounts to millions of dollars each year. In order that these important food animals may not become exterminated by careless and

excessive fishing, the state and national governments have attempted to control the numbers taken and have also established hatcheries in which the eggs are hatched and the young protected during the earliest stages of their development.

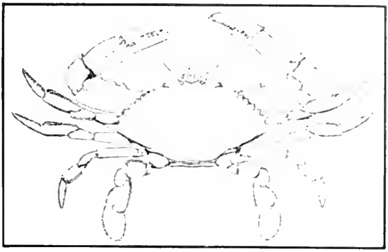

FIGURE 87. — SOFT-SHELL CRAB.

Crustaceans of less economic importance are the barnacles which cling to rocks, wharves, and steamships; the hermit crabs that live in the shells of *mollusks* (mŏl′lŭsks); and the smaller fresh-water crustaceans such as the *Cyclops* (sī′klŏps), *Daphnia* (dăf′nĭ-ȧ), and *Cypris* (sī′prĭs) which are barely visible to the unaided eye.

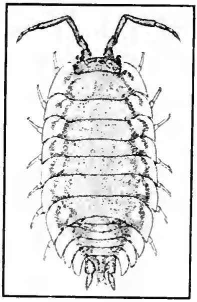

FIGURE 88. — PILL BUG.

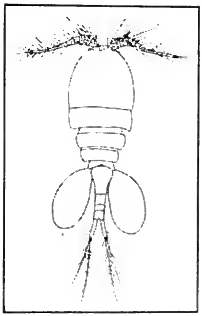

FIGURE 89. — CYCLOPS.

87. Arachnids. — The spiders, scorpions (skôr′pĭ-ŭns), ticks, and mites are arthropods that are grouped together under the name *Arachnida* (ȧ-răk′nĭ-da: Greek, *arachne*, spider). The spiders and scorpions have eight walking appendages. The forward pinchers of the scorpions are mouth-parts, and not walking appendages. The harvest-man (daddy-long-legs) is a harmless arachnid which does good by destroying injurious insects. The spiders catch insects either by pouncing upon them or by entangling them in their webs. Scorpions sting severely, but the wound, although painful, is rarely fatal. Some ticks and mites are parasitic on man and beast.

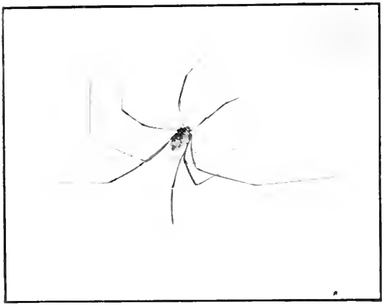

FIGURE 90. — DADDY-LONG-LEGS.

88. **Myriapods.** — Another group of arthropods is the *Myriapoda* (mĭr′ĭ-ȧ-po-da: Greek, *myrias*, many), a group which includes animals of many legs such as the centipedes

FIGURE 91. — SPIDER.

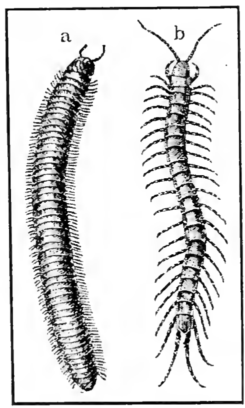

FIGURE 92.
a. Thousand-legged worm; *b*, Centipede.

(sĕn′tĭ-pēdz) and "thousand-legged worms." The centipedes are provided with poison glands, and their bite is fatal to some of the smaller animals and painful to man. The thousand-legged worms are harmless.

Note. Insects have been studied also in Chapters I and II, but it should be remembered that they are arthropods.

SUMMARY

An animal belongs to the arthropods if it has more than two pairs of appendages which have several joints in them. They also have an external skeleton which is shed at irregular intervals in order to allow the animal to increase in size. The body of the crayfish shows that part of the segments have fused to form the head-thorax region. The members of this group vary much in size and habits. Lobsters and crabs are valuable for food and for this reason should not be caught when they are small.

QUESTIONS

What kind of animals belong to the crustaceans? How can you distinguish one from a worm? From a hydroid? Explain why insects are arthropods. Which groups of arthropods are beneficial? Which are harmful? What do you mean when you say that an insect is beneficial or harmful?

REFERENCES

See Chapter II.

CHAPTER IX

THE MOLLUSKS

89. **The Mollusks.** — This group includes such animals as clams, oysters, snails, slugs, squids (skwĭds), and octopi (ŏk′tō-pī). These forms differ from the crustaceans in having a soft, unsegmented body and, in most cases, a shell as their exoskeleton. The squids have a shell that is internal, and the shell is absent in some of the snails.

90. **Clams.** — The fresh water clam is a convenient type of mollusk to study. It is found in canals and in many streams and lakes. This clam has two shells or valves and, when moving naturally, the hinge is uppermost, while the opened valves allow the foot to be extended into the mud. The foot is a thick, muscular mass, not at all foot-like in appearance, but it enables the clam to move, although slowly and at an uneven rate.

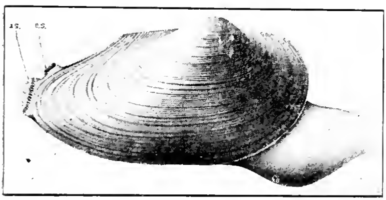

FIGURE 93. — CLAM SHOWING FOOT. Water enters through *i.s., inhalent siphon,* and leaves the body of the clam through *e.s., exhalent siphon.*

91. **Structure.** — The structure of the fresh water clam shows how it has adapted itself to its peculiar method of life. The shell is lined with a membrane called the *mantle.* The mantle secretes the shell-material and adds to its size year by year. At the back, the edges of the mantle are united at three points,

thus forming two openings known as *siphons* (sī′fŏns). Through one of these siphons water enters, carrying food and oxygen. Through the other the water passes out, carrying the waste from the body.

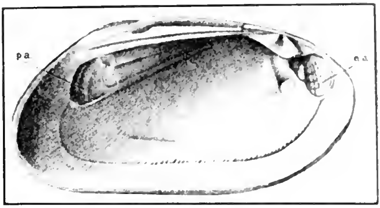

FIGURE 94. — RIGHT SHELL OF CLAM.

Showing mantle and muscles. *a.a*, anterior adductor muscle; *p.a*, posterior adductor muscle.

Between the mantle and the body proper are gills, which hang free in the shell cavity. The gills are filled with holes through which the water passes.

The foot is attached directly to the body proper and is the part of the clam hard to chew when it is eaten. The foot and body form a solid mass that nearly fills the space between the shells.

The two valves of the clam shell are held together by means of strong muscles, attached to each shell. One of these is located in front of the body and is known as the *anterior* (*front*) *adductor* (ăd-dŭk′tẽr) muscle: the second is just back of the body and is the *posterior* (*back*) *adductor* muscle. When these two muscles contract, the two valves are held tightly together. Before the live clam can be examined these two muscles have to be cut, as it closes its valves when handled. When the clam is dead, these muscles relax and the hinge forces the valves apart. It is not safe to eat clams and oysters that have died in their shells.

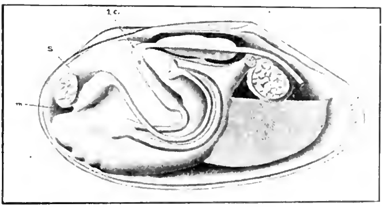

FIGURE 95. — DIGESTIVE TUBE OF CLAM.

m, mouth; *s*, stomach; *i.c*, intestine.

When the two adductor muscles are cut free from the valves, a round or oval surface is seen which is marked off from the rest of the interior of the shell. These areas are called muscle scars (Figure 94).

When the empty clam shell is examined, it is found that the hinge, sometimes called the hinge ligament, is elastic. This is shown by compressing the two valves and seeing how promptly they open when the pressure is taken off. Where the two valves come in contact just beneath the hinge ligament, a blunt projection of one shell fits into a depression in the other. These are called the hinge teeth.

LABORATORY STUDY

Live clams can be secured in the market during the school year. The dissection of the clam is too difficult, but the arrangement of the organs in the mantle cavity can be studied. The position of the adductor muscles, foot, gills, palps, heart, etc., should be observed. Examine a small portion of a gill under the microscope for cilia. A variety of shells of clams should be studied in which hinge, muscle scars, and hinge teeth are examined. Compare clam and snail shells.

92. **Locomotion.** — The movements of the fresh water mollusks are extremely slow. In the clam the foot is forced out of the shell by the blood, which flows into it and causes the foot to be greatly enlarged. Muscles attached to the shell and front of the foot contract and pull the shell forward over the extended foot.

93. **Food.** — The food of the clam consists of microscopic plants and animals that are caught in a sticky fluid (*mucus*) on the gills, as the water passes through them. The food, together with the mucus, is moved into the mouth by means of cilia. The mouth is simply an opening into the body and the cilia are on triangular flaps or lips (palps) on either side of the mouth. From the mouth food passes into the digestive canal, where the nutritious parts are absorbed (Figure 95).

94. Respiration. — The clam, like other aquatic animals, gains its oxygen from the water and gives off carbon dioxide. A close inspection of the mantle shows the presence of blood vessels which are more numerous than in the gills. For this reason, the mantle is regarded as the main organ of respiration, although the gills also assist.

95. Life History. — In clams the sexes are distinct. Eggs formed in the ovaries of the female fuse with sperm cells from the males taken in with the water through the siphon. These sperm cells have reached the water through the upper siphon. Thousands of embryos form in the body of the female and develop into larvæ in the outer gills which, thus become greatly distended. Later the larvæ pass into the water through the upper siphon.

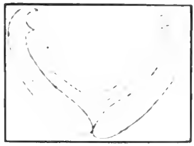

FIGURE 96. — EMBRYO OF CLAM.

That attaches itself to a fish.

The larvæ of many fresh water clams have hooks on their shells and by means of these they are able to cling to the gills or body of a fish, where they live as parasites for several weeks. They absorb food from their host and are carried from one place to another and are thus scattered. After a few weeks they leave the host and settle down to lead an independent life.

96. Excretion. — The wastes of the body are absorbed by the kidneys and passed out into the water through the upper siphon.

97. Circulation is well developed.[1] From the heart the colorless blood is carried through arteries into smaller tubes, and returns, through veins, back to the heart.

---

[1] The three chambered heart lies in the dorsal region, near the hinge, in a little soft-walled chamber, the *pericardium* (pěr-i-căr′di-um: Greek *peri*, around; *cardia*, heart).

98. **The Nervous System** is not so well developed as in the crayfish. There are three groups of ganglia (nerve cells). One located far back in the body near the posterior adductor is called the visceral ganglion because it largely regulates the activities of the *viscera* (vĭs′sē-rȧ), the internal organs of the body. Another in the foot region is called the *pedal* (pĕ′dal) ganglion, and regulates the movements of the foot. A third located in the region of the gullet (esophagus) is the cerebral ganglion, which regulates the activities of the part near the mouth. All of these are connected by nerves.

99. **Digestive System.** — The mouth, which is located under the anterior adductor muscle, leads through the short esophagus to the stomach. The intestine winds through the foot region forming a loop, finally ascending and passing through the pericardium and between the chambers of the heart itself and opening into the upper siphon (Figure 96).

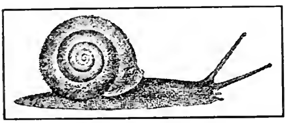

FIGURE 97. — SNAIL.

100. **Snails.** — Snails having one valve are called *univalves* as distinguished from clams, oysters, etc. which are called *bivalves* because their shells are formed of two valves. The greater number of snails are marine (live in salt water), although some live in fresh water and some on land. Snails have a broad foot which is used as a creeping disk. There is a head region provided with eyes and tentacles. The mouth of the snail is provided with a rasping structure known as the *lingual ribbon* (lĭn′gwal: Latin, *lingua*, tongue) by means of which it is able to cut and bore its way, even

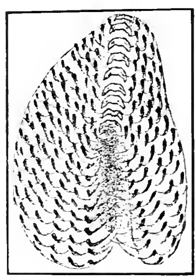

FIGURE 98. — TONGUE OF SNAIL. (Magnified.)

through rocks. Land snails by osmosis get oxygen from the air through the mantle, while water snails use gills and take their oxygen from the water.

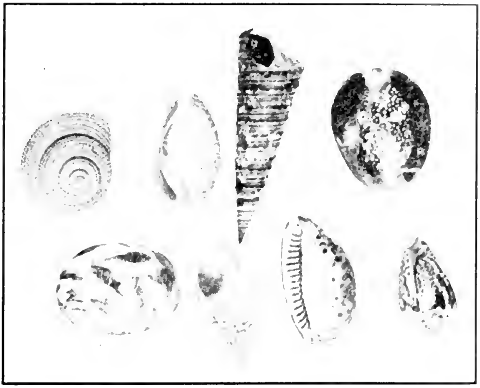

FIGURE 99. — SNAIL SHELLS.

In the garden slug the shell when present is thin and affords small protection.

101. Squids, Cuttle Fish, and Octopi belong to the *Cephalopods* (sĕf′ȧ-lō-pŏds: Greek, *kephalē*, head; *pod*, foot), the highest division of the mollusks. The nervous system is highly developed. The eye of the squid in particular is complex and more like the eye of vertebrates than of any animal thus far considered. The mouth of cephalopods is surrounded with tentacles.

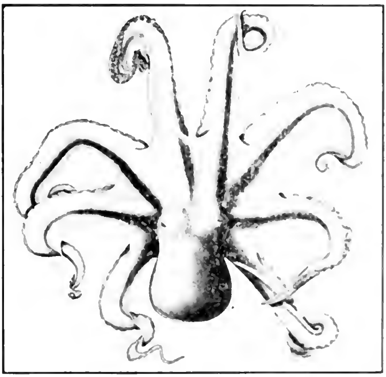

FIGURE 100. — AN OCTOPUS.

A common squid,

Sepia (sē′pĭ-a), has ten arms or tentacles, two long and eight short. It moves itself forward rapidly by shooting out water from a siphon in the collar region. When pursued, the squid ejects an ink-like fluid which clouds the water, concealing it from its prey and facilitating its escape.

Cuttle fishes are similar to squids, the marked differences being in the shape of fins, the form of the eyes, and the shape of the longer tentacles.

The octopi are the largest members of the group. They have eight tentacles, which in some cases reach a length of thirty feet. The stories about the size and behavior of the octopi are often exaggerated.

FIGURE 101. SOFT-SHELL CLAM.

a, b, siphons; *m*, mantle; *s*, shell; *f*, foot.

102. Economic Importance of the Group. — Clams, scallops, oysters, and snails are used as food in all parts of the world. In this country, oysters are gathered in great abundance from Chesapeake Bay and other bays along the Atlantic Coast.

The edible clams are of two kinds. The round clam, *Venus mercenaria* (Vē′nŭs mẽr-sė-nā′rĭ-ȧ), is more generally used as food, but the other kind, the soft-shelled clam, *Mya arenaria* (Mī′ȧ ăr-ĕn-ā′rĭ-ȧ), is eaten extensively near the seashore. The soft-shelled clam has a long siphon which may be extended several inches beyond the valves (Figure 101).

The *scallop* (skŏl′lŭp) is another mollusk that is eaten near the shore more extensively than elsewhere. This mollusk has but one adductor muscle, which is the edible portion.

Clams and oysters are raised artificially and regularly planted on natural feeding grounds. Care is taken to

Jean Louis Rudolphe Agassiz was born in Switzerland, in 1807, and died at Cambridge, Massachusetts, in 1873. He was especially noted for his work in geology and ichthyology (the science of fishes).

Agassiz came to the United States in 1846 on a scientific expedition and took up his residence here, becoming Professor of Zoölogy and Geology at Harvard, and Curator of the Museum of Comparative Zoölogy at Cambridge. He explored the Lower Amazon in 1865–66. In 1871–72 he accompanied the Hassler expedition to the South Atlantic and Pacific.

Few have done more than Agassiz to popularize science, and few teachers have trained so many young and rising naturalists.

have such natural enemies as the starfish removed, and, in the case of oysters, brush and shells are added that they

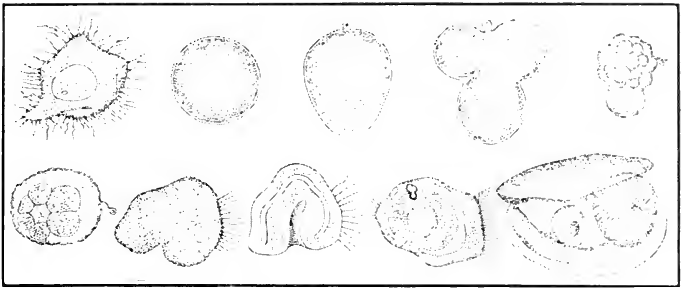

FIGURE 102. — STAGES IN LIFE HISTORY OF OYSTER.

may fasten to these rather than sink to the bottom, where they become covered with mud.

The culture of oysters and clams near the mouths of rivers contaminated with sewage is unsanitary, and disease may be caused by eating such mollusks raw. This

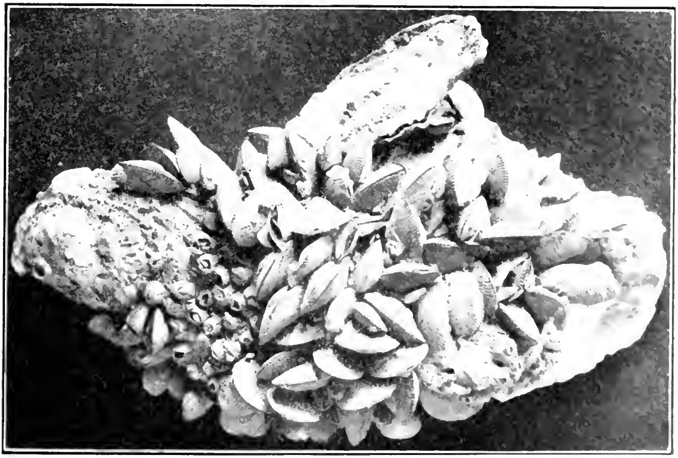

FIGURE 103. — BARNACLES AND CLAMS GROWING ON OYSTERS.

is one reason for the laws regulating the disposal of sewage, and for government inspection of the feeding grounds.

SUMMARY

The parts of mollusks are not arranged in segments like the earthworms or crustaceans. The usual presence of a shell and mantle and the fact that the soft body is not divided into segments helps to distinguish a mollusk from any other animal. The microscopic food of the clam is caught in the mucus and carried by cilia to the mouth. The clams and oysters are valuable for food but should not be eaten if taken from water contaminated by disease germs. Mollusk beds should be protected from such contamination.

QUESTIONS

What are some of the common mollusks? Where do they live? How do they get their food? What ones are used for food by man?

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CHAPTER X

FISHES

103. Vertebrates. — All of the animals thus far studied are grouped together under the name of *Invertebrates*, because they have no backbone. We are now to study the *Vertebrates*, animals with a backbone, such as fishes, frogs, snakes, and birds.

The presence of a backbone in vertebrates is their most conspicuous characteristic. The formation of the backbone is always preceded by the growth of an embryonic

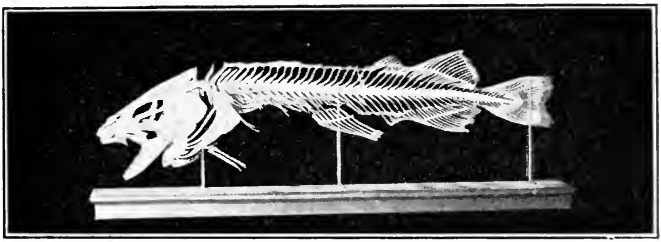

FIGURE 104. — SKELETON OF FISH.
Note backbone.

group of cells that do the work of a skeleton. This embryonic group of cells forms a structure which is called the *notochord* (nō′tō-kôrd: Greek, *notos*, back; *chorda*, cord). In all of the true vertebrates (such as fishes, frogs, etc.), the notochord is gradually absorbed and the backbone takes its place, but between the vertebræ it remains as cushions. But in the fish-like animal called

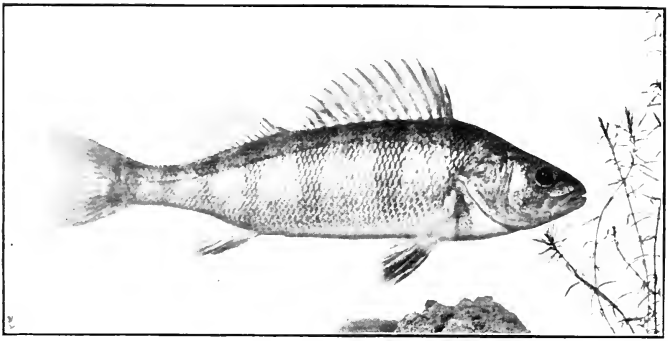

Figure 105. — Perch.

Amphioxus (ăm-fĭ-ŏks'ŭs), the notochord persists and there is never a true backbone. The notochord is always found above the food tube and below the spinal cord.

Another characteristic common to all vertebrates is the presence of gill-slits. These are external openings on

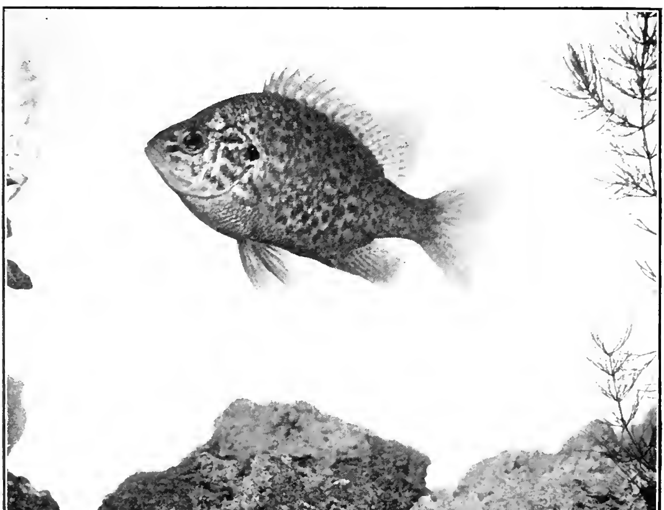

Figure 106. — Sunfish or Pumpkin Seed.

each side of the neck that in the fishes allow the water to pass over the gills. Such structures are of use only to aquatic animals, and yet all vertebrates have them at some time in their development.

In most vertebrates the skeleton is composed of bone. There are usually two pairs of appendages (legs, wings, or fins) attached to the body at the shoulder and hip. Here special bones join the limb to the body. The bones in the shoulder are known as the *pectoral* (pĕk′tō-ral)

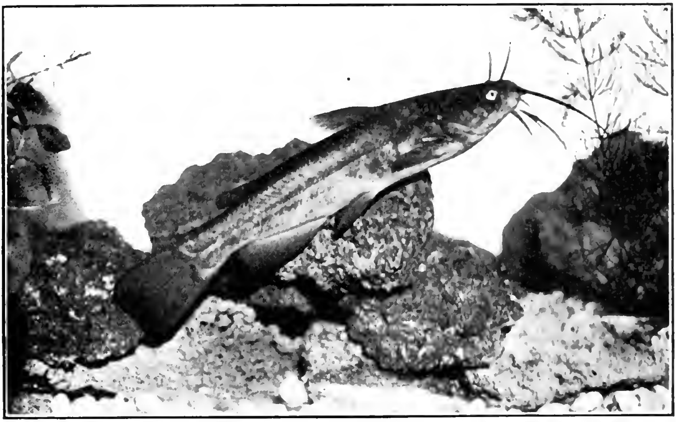

FIGURE 107. — CATFISH, BULLHEAD, OR HORNED POUT.

girdle; while those in the hip are termed the *pelvic* (pĕl′vĭk) girdle. In the snakes, only traces of legs are found (Figures 104, 139, and 158).

A further distinguishing feature of all vertebrates is the well-developed nervous system, with its large brain. The sense organs, eyes, ears, and the like, are also better developed than in any of the invertebrates.

Oxygen is obtained by external or internal gills in most aquatic animals and by lungs in all other vertebrates. In many vertebrates the skin is an active agent in the interchange of oxygen and carbon dioxide and particularly in those animals which have a thin, moist skin like frogs.

104. **Fishes.** — The fishes are vertebrates, that is, they have a notochord which as they develop gives place to a vertebral column. There are four large divisions of fishes (1) the lampreys (lăm′prĭz) and relatives, (2) the sharks and relatives, (3) the bony fishes, and (4) the small

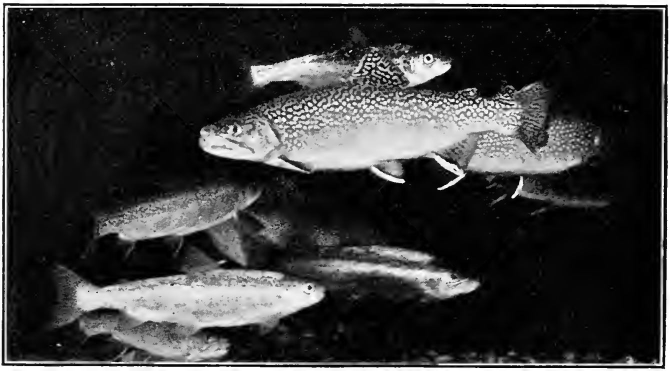

FIGURE 108. — BROOK TROUT.

group of fishes with lungs. The most important group in numbers and economic importance is the bony fishes. This group includes the salmon (săm′ŭn), trout, bass, whitefish, pike, shad, menhaden (mĕn-hā′d'n), cod, mackerel, herring, sardine, etc. Typical bony fishes are the goldfish, perch, and sunfish (Figures 105–108).

105. **External Parts of a Fish.** — The external parts of a fish show a well-marked head attached directly to the trunk; a trunk region, the largest part of the body; and a tail region which is sometimes as long as the trunk.

In a bony fish the mouth is at the front end of the head. The jaw bones, bearing many small, needle-like teeth, are not firmly attached to the skull. The side of the head next to the trunk is protected by a piece of bone that covers the gills (gill cover or *operculum*, ō-pĕr′-kū-lŭm), and the openings leading into the nostrils, which do not connect with the mouth cavity.

The trunk bears a number of fins. Each fin is furnished with several bony fin-rays covered by a thin fold of skin. On the shoulder and hip regions of the trunk, the fins occur in pairs and are called the pectoral and pelvic fins. Several fins are found that are not in pairs. These are the median fins of the trunk.

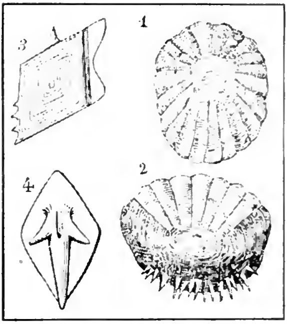

FIGURE 109. — SCALES OF FISHES. (MAGNIFIED.)

The caudal or posterior region of the fish ends in a large median fin. The tail region is chiefly important in locomotion, but the fins also help in balancing and steering.

Scales cover the trunk and tail, each one overlapping like the shingles of a house. The skin is full of mucous glands that keep the fish covered with slime. Both the slime and the scales protect the fish (Figure 109).

LABORATORY STUDY

Study living fish such as goldfish or perch. Place one or two in an aquarium and observe their behavior. Fill out the report below.

NUMBER OF FINS	NUMBER OF PAIRED FINS	NUMBER OF UNPAIRED FINS	WHICH ARE USED TO			DO THE EYES MOVE?
			Advance?	Stop?	Balance?	

Note the shape and relative position of the head, trunk, and tail region. The gills are covered by a bony shield, the operculum. What is its size and how attached? Where are the eyes located? Do they move? Can the eyes be closed? How is the body covered? Of what use is this covering to the fish?

106. Respiration. — Water is taken in through the mouth and passes out through two openings, one on each side of the neck. In each opening four or five gills are found. The gills are made up of numerous, small, very short, fleshy threads or filaments. Into each filament a blood vessel penetrates and here the blood throws off carbon dioxide and takes oxygen from the water by osmosis just as the blood of the crayfish does. The thin-walled gill-filaments are adapted to respiration in the water. The water is drawn into the mouth and forced out over the gills in much the same way as water is pumped from a well. When a fish opens its mouth, the water rushes in. As the mouth is closed, the floor of the mouth and throat is raised slightly, pushing the water against the side of the neck and through the gill opening. The mouth is thus emptied of water so that when it is opened again more water flows in.

107. Food Taking. — Fishes eat insects, worms, crayfish, snails, and other fish. The teeth of fish serve to seize, tear, and hold food. None of the fish have teeth which are adapted to crushing or chewing the food, as is the case among the higher vertebrates, like the dog, horse, and man.

Fishes which eat minute animals and plants have many sharp pointed projections on the inside of the gill arches which act as strainers and gather quantities of this small food as the water passes over the gills. These projections are called *gill-rakers*. Their development seems to vary in proportion as they are needed for service. Fishes that feed on crayfish and on small fish have no use for gill rakers or strainers and accordingly their gill rakers are undeveloped.

108. Special Senses. — The eye is well developed. It is globular and projecting, and is believed to be near-sighted. The organs of smell are usually located in the nasal cavity. In the bull-head, they are found in the feelers, on the head, and even in the skin of the tail. The ear is under the skin, and there is no external opening. As water conducts sound vibrations more readily than air, no device for gathering sound waves is necessary.

109. Circulation. — The blood of fishes is carried in well-defined blood vessels and a heart of two chambers. The blood is sent from the heart to the gills, where it is purified of carbon dioxide and receives oxygen. It is then carried by means of arteries to other parts of the body, where the oxygen in turn is given up and carbon dioxide is received. The blood from the gills and other parts of the body is returned to the heart through veins. Because the blood of fishes is at a lower temperature than the blood of man, they are called cold-blooded animals.

110. Reproduction. — The sexes of fish are distinct. At certain seasons many fish migrate upstream to lay their eggs (to "spawn"). Eggs are laid in large numbers by the females, and in the same locality sperm cells are discharged into the water by the males. The sperms unite with the eggs. The fertilized eggs hatch after thirty or forty days, or longer, depending on the kind of fish and the temperature of the water. The yolk of the eggs is attached to the young fishes for many days after they are able to swim, and they need no other food than that supplied by this yolk (Figure 111).

The spawning habits of fish must be understood thoroughly if they are to be raised artificially, as is done in the many fish hatcheries. Most states have scientific game laws which protect the fish during their egg-laying period when they are easily caught and when the destruction of even a few fish means the loss of thousands of eggs.

Spawning habits vary greatly. Some fish, like the salmon, make long journeys from the sea to the head waters of rivers and streams to deposit their eggs. The Columbia River is famous for the number of salmon which spawn there. Other fish, like shad, go up a river only a short distance to lay their eggs. Many shad, for instance, go

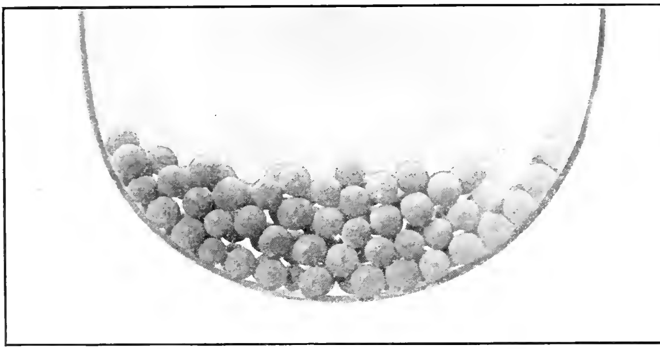

FIGURE 110. — EGGS OF LAND-LOCKED SALMON.

up the Hudson River in New York state. In the case of herring, the eggs are laid in the sea and float on the surface. Eels go down from the rivers and streams to the sea to lay their eggs, the young eels, when small, migrating up the river. Millions of small eels no larger than needles are found in the Hudson at certain seasons.

111. Fish Hatcheries. — In the natural state, many eggs are laid that never hatch because the sperm cells do not come in contact with them, and of the fishes that are hatched only a small proportion reach maturity. As it is a matter of great economic importance that fishes be saved from extermination and their numbers largely increased, the governments of the world have established hatcheries where fish are raised in great numbers.

In these hatcheries the eggs are taken from the female and placed in a jar, and the mass of minute sperm cells or "milt" is taken from the male and poured over the eggs,

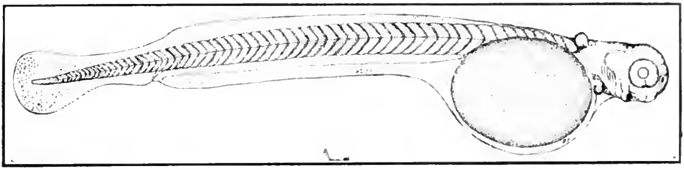

FIGURE 111.—YOUNG FISH SHOWING YOLK SAC.

so that practically all the latter hatch. Then by giving the developing eggs protection, and the young fish sufficient and proper food, nearly all of these eggs develop into active fish and the great loss that comes to the fish developing in their natural environment is prevented. When they are able to take care of themselves, these *fry*, as the young hatchery fish are called, are taken to natural feeding grounds. In New York state and most other states

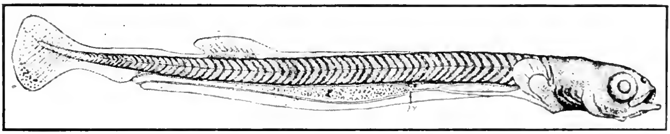

FIGURE 112.—YOUNG FISH FRY.

there are state hatcheries where such fish as shad, pike, lake trout, salmon, brook trout, and others are raised by millions.

The fish that are most useful as food are taken by hooks, nets, and seines, under certain restrictions. Those like brook trout which are caught as much for sport as for food can be taken only by a hook and line and in certain seasons;

the season of the year depending upon the time of spawning. The brook trout spawns in August and September, while the rainbow trout does not spawn until February or March.

112. Care of Young. — Some fish, like the sticklebacks, build nests of sticks and leaves in which the eggs are placed and guarded. Bass and sunfish make a circular depression several feet in diameter near the shore and lay their eggs on these so-called "beds." These beds are guarded zealously by the males, who drive off or carry away crayfish and small fish which feed upon such eggs. In former times men sought for these "beds" and by dropping a baited hook caught the bass while defending their eggs. Fortunately this practice is now illegal. Generally, adult fish pay no attention to their young and in many cases they devour young of their own kind as quickly as fish of other sorts.

SUMMARY

The term *vertebrate* is given to all animals that have a backbone. All have gill slits, either while young or as adults. Fish have scales and breathe by means of gills. Their eggs are usually laid in the water and receive no care from the parents. A few fish prepare a crude nest which they guard.

QUESTIONS

What are some of the structures that all chordates have?
Why is the word vertebrate used?
What are the common fishes near your home?
What ones are sought for food?
What is being done to keep up the supply of fish in your state?
What do fish eat?

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CHAPTER XI

AMPHIBIANS

113. Amphibians. — Frogs and toads are the best known animals of this group; but here belong also the *Salamanders* (săl′ȧ-măn-dẽrs), frequently miscalled *lizards* (see page 131). The *Amphibians* (ăm-fĭb′ĭ-ans: Greek, *amphi*, double; *bios*, life) are all small, the largest one found in America being a salamander (Cryptobranchus), which is rarely more than two feet long. This term Amphibian is used to explain the habit which frogs, toads, and certain salamanders have of spending their larval (tadpole stage) life in the water and their adult life on land, or partly on land and partly in the water.

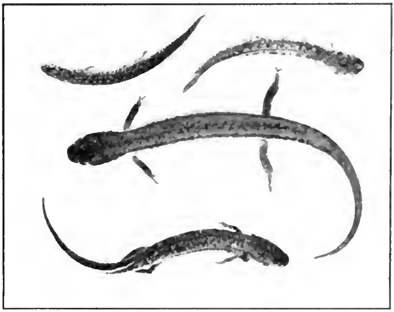

FIGURE 113. — SOME COMMON SALAMANDERS.

LABORATORY STUDY

Place one or two frogs or toads in a small jar or box and observe the points mentioned in the report below.

Do they Wink?	Can they Protect their Eyes?	How Do they Get Air?	Can they Walk? Hop?	How Do they Swim?	How Do they Catch a Fly?

114. Frogs. — There are several kinds of frogs, one of which, the leopard frog, is found generally distributed throughout the United States. It can be recognized by the presence, on the dorsal surface, of many brownish or greenish spots, edged with white, which help the frog to escape the notice of his enemies as he squats among the water weeds. These colors form rather definite bands on the hind legs, though there is much variation. The general form of the body, the shape of the head, and the long hind legs adapted for jumping are much the same in all frogs.

FIGURE 114. — COMMON FROG.

LABORATORY STUDY

Compare the general shape of fish and frog. How do the colors differ? Show how the legs and feet are adapted to the way the frog lives. Is the frog sensitive to touch in various parts of the body? Examine the eyes. Open the mouth and see that the frog can draw in its eyes. The ear membrane is on the side of the head back of the eyes. Pass a probe through the ear membrane of a dead frog and see where it comes out in the mouth. This is the opening of the Eustachian tube. How far can the living frog see? Notice the method of breathing. See the throat move up and down. Hold the frog under the water and gently rub its sides. It will usually croak. Thus we can prove that the frog is able to make the air travel from his lungs to his mouth and back again while under water.

115. Habitat. — Frogs are seldom found far from some pond or stream and they are usually seen on the bank. When disturbed, they jump into the water, swim to the bottom, stir up the mud, and quietly come to rest a short distance from the place where they entered. As the nights in the fall grow cool, frogs make ready to spend the winter in a state of inactivity. During the warmer part of the day, they may be seen sunning themselves on a bank, but as soon as ice forms on the water they remain on the bottom or become buried in the mud. The lungs are emptied of air, the heart beats decrease, and all of the usual living processes take place more slowly. This habit of passing the winter in a state of inactivity is known as *hibernation* (hī-bẽr-nā′shŭn). All of the amphibia, reptiles (Chapter XII, page 129), and several of the mammals hibernate during the winter.

116. Food. — Frogs are greedy creatures and will eat almost any animal small enough to be swallowed, such as insects, worms, snails, tadpoles, and small frogs. These are caught alive and when in motion.

117. Enemies. — As the frog's hind legs are considered a delicacy, man is the worst enemy of the frog. Next come the snakes, birds, and fish. The leech kills frogs by sucking their blood. Fish eat many of the tadpoles, and strange to say, some water beetles eat tadpoles also.

118. Respiration. — Both the skin and a pair of lungs serve to purify the blood of the frog. The air is forced into the lungs by the contraction of muscles in the floor of the mouth. Experiments have been made which show that the frog can get enough oxygen even if the lungs are missing. In this respect frogs resemble worms, which use the skin as the only organ of respiration.

119. Internal Structure. — A study of the parts of the frog or toad should be made for two reasons: (1) To understand the relative positions of the internal organs of a typical vertebrate; (2) to help explain the several organs of man which are discussed in the second part of this book.

Digestive Organs. — The mouth is large. Short lips cover the short teeth in the edge of the upper jaw. The tongue has two fleshy horns at the back end and is attached by the front end to the floor of the mouth (Figure 115). The frog can throw its sticky tongue over the tip of the lower jaw and use the forked end to catch insects which are then carried into the back of the mouth. Two groups of little curved teeth in the roof of the mouth aid in preventing the escape of the prey. The food is swallowed whole. The esophagus (the tube

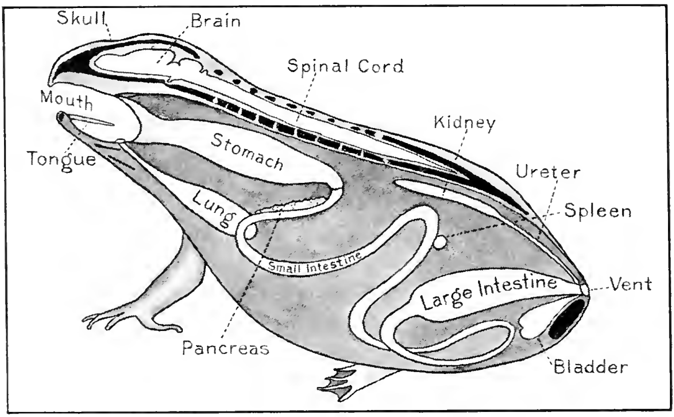

Figure 115. — Diagram to Show Organs of Frog.

connecting the mouth cavity and stomach) of the frog can be stretched so that a comparatively large animal can be swallowed. There is no sharp limit between the esophagus and the stomach, which is a long spindle-shaped sac (Figure 115), larger than the rest of the digestive tube.

The small intestine begins at the back end of the stomach as a small tube which makes several turns, and finally enlarges into a region called the large intestine, the last part of which is termed the *cloaca* (clō-ā′cȧ) or common sewer.

Two glands of importance belong to the digestive organs — the liver and the pancreas. The liver is a large, dark-red, three-lobed organ that covers the ventral (lower) surface of the stomach. The pancreas is a whitish, small, irregularly shaped body attached between the stomach and the intestine. Both of these glands drain into the intestine just beyond the stomach. The bile secreted by the liver is at first collected in a sac called the gall bladder.

All of these parts of the alimentary canal are held in place by a thin membrane (the *mesentery*, mĕs′ĕn-tĕr-y̆), one edge of which is attached to the dorsal wall along the line of the backbone and the other to the stomach and intestine. A small gland (the *spleen*) is found in this mesentery. The spleen has no duct connecting it with any other organ in the frog. Blood vessels run through the spleen and scientists believe that it is important in making new blood corpuscles.

Lungs. — The lungs are hollow sacs that lie back of the stomach, one on each side. In the freshly killed animal, these can be filled with air by inserting a blow-pipe into the windpipe and blowing air into them. The empty lungs are about as large as the blunt end of a lead pencil.

Kidneys. — The kidneys are small red bodies lying close to the back. Each one is connected with the cloaca by a minute duct (ureter). The urinary bladder is attached to the cloaca (Figure 116).

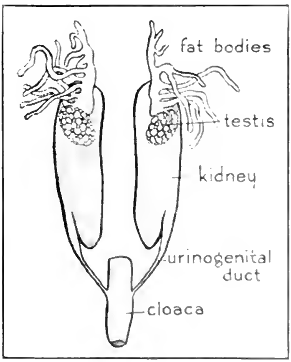

FIGURE 116.

Reproduction. — The male frog has a pair of spermaries (spẽr′mȧ-rĭz), one attached to the front (anterior) end of each kidney (Figure 116). Each spermary is yellow in color. The sperms escape through the kidney. In the female frog ovaries, sometimes filled with eggs, are easily seen. A long, closely coiled pair of oviducts (ō′vĭ-dŭkts) opens in front near the forward end of the stomach and in the back into the cloaca. The eggs break through the wall of the ovary and enter the oviducts. As the eggs pass down through the oviducts, they are coated with a jelly-like covering that swells in the water. This jelly covering protects the eggs.

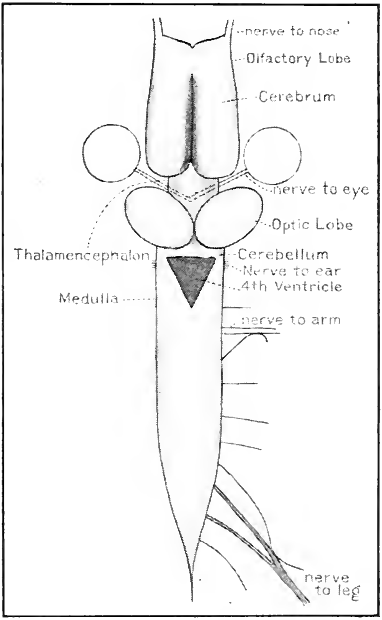

Figure 117. — Central Nervous System of Frog.

Nervous System. — The nervous system of the frog is more highly developed than that of the earthworm. It consists of a central part enclosed in the backbone and cranium (braincase). This central nervous system in all vertebrates is always found above the digestive tube, and is divided into the brain and the spinal cord, from which numerous nerves arise and extend to all parts of the body.

The parts of the brain are the same as in man and much easier to study. Beginning at the front (anterior) end of the brain the parts are as follows (1): small *olfactory* (ŏl-făk′tō̆-rȳ) lobes, which are not sharply marked off from the rest of the brain, and, as shown in Figure 117, connect with (2) the *cerebral* (sĕr′ḗ-bral) hemispheres, which are oval in outline. (3) A short mid-brain region, partly covered by the back part of the cerebral hemispheres, connects the front and back part of the brain. (4) Two large optic lobes, the widest part of the brain, are just back of the mid-brain. (5) The *cerebellum* (sĕr-ḗ-bĕl′lŭm) of the amphibians is small and easily overlooked (Figure 117). The last region of the brain is the (6) *medulla* (mḗ-dŭl′lȧ), which is occupied by a large triangular cavity called the fourth ventricle.

The work which each of these regions of the brain does is not sharply defined. The olfactory lobes receive the smell stimuli. The cerebral hemispheres control muscular action. When the latter are removed the frog loses all power to initiate any movement and will sit still in a dry, warm room for hours unless disturbed. This he never does when the cerebral region of the brain is uninjured. The mid-brain region is the passageway for all nerve-pathways that travel to and fro in the brain. The mid-brain and optic lobes explain to the frog the sight stimuli. In the frog, the cerebellum is less important than in man and is poorly developed. The medulla gives off more nerves than any other region of the brain. Here are found the nerves to the face, tongue, ear, heart, and lungs. While there is a great difference between the shape of the parts of the brain of the frog and those of man, yet the work done by each region is of the same kind.

The brain joins the spinal cord, and there is no external sign to indicate where one begins and the other leaves off. A definite number (ten pairs) of nerves leave the brain proper and are devoted to the special senses of the head and to moving the muscles of the throat and head. The frog has ten other pairs of nerves joined to the spinal cord (Figure 117). In a long salamander there are 20 or 30 pairs of nerves on the spinal cord.

LABORATORY STUDY

In connection with the study of the frog, the following additional laboratory work should be done in order that the several organs of man which are discussed in Part II may be better understood. Frogs that have been preserved in formalin can be easily dissected. Examine the digestive organs: first the mouth, then the esophagus, stomach, small and large intestine, and cloaca. For convenience, the liver will have to be removed. The pancreas can be seen as a small whitish structure in the loop between the stomach and the intestine. The spleen is a round, red organ usually found near the large intestine.

A pair of narrow kidneys lies close to the back and is connected by ducts with the cloaca. The spermaries are found attached to each kidney near the front end and the sperm cells escape to the exterior by the kidney ducts. In the female frog the large ovaries occupy most of the space of the body cavity. A pair of oviducts opens into the body cavity just back of the stomach. The eggs escape from the ovary into the body cavity.

The nervous system is enclosed in bone that is easily removed from the dorsal surface. The brain should be studied and the following divisions recognized: cerebral hemispheres ending in front in the olfactory lobes, which are not clearly marked. Just back of these the two large roundish optic lobes which are attached to the midbrain (*thalamencephalon*), thăl-å-mĕn-cĕph′å-lŏn). The cerebellum is small, and the medulla passes into the spinal cord without any sharp dividing line.

120. Development. — Late in March and early in April the frogs gather in ponds to lay their eggs. The eggs are surrounded by a jelly-like substance which holds them together. As the eggs are being laid by the female frog, the male frog spreads a large number of sperm cells over the whole mass. These sperm cells make their way through the soft jelly and one of them must enter each egg or it cannot grow into a tadpole.

As soon as the sperm cell enters the egg (Figure 119), it begins to change from a solid, pointed body into a round nucleus which is so much like the nucleus already in the egg cell that none but experts in this study can tell which came from the sperm cell and which from the egg cell. These two nuclei come in contact and unite, leaving but

FIGURE 118. — FROG EGGS.

one nucleus in the egg (Figure 119). This last change is fertilization, which is defined as the union of the contents of the egg and the sperm nuclei. After this union is completed the egg begins to divide into cells, as shown in Figure 120, and finally a tadpole is grown.

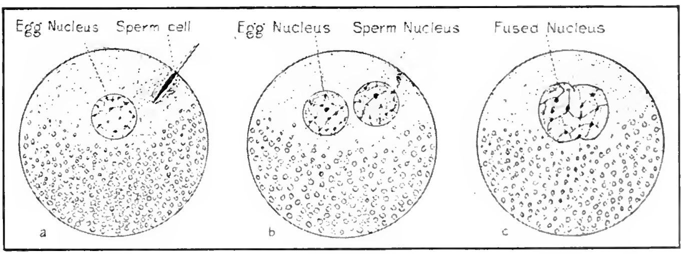

FIGURE 119. — DIAGRAM ILLUSTRATING FERTILIZATION IN FROG EGG.

As soon as the young tadpole hatches, it attaches itself to plants and lives for the first few days upon the food-yolk within its own body; the mouth forms, and horny jaws develop. Then the tadpole begins to feed upon minute plants and becomes dependent upon its own skill to get food and escape its enemies.

For a time the tadpole breathes through gills. Two sets are used. The first ones are on the outside of the body and last for only two or three days, when internal gills form in the throat and the tadpole breathes much like a fish.

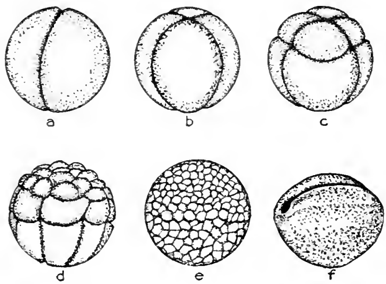

FIGURE 120. — DIVIDING EGG OF FROG.

121. The Tadpole Becomes a Frog. — In the growth of the tadpole into a frog the hind legs appear first. Later the front ones begin to show and as they develop the tail is gradually absorbed. While these external changes are going on, there are many complicated internal changes taking place; internal gills are disappearing and lungs, nerves, blood vessels, and muscles are being formed to give

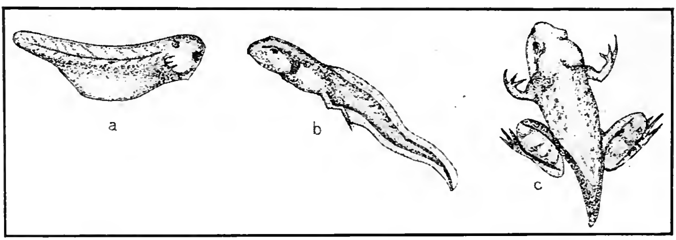

FIGURE 121. — DIVIDING EGG BECOMING A TADPOLE.

the new legs life and action. The internal lungs take the place of the gills in the throat before the legs are fully grown and such tadpoles can breathe only air. Explain in Figure 122 which tadpoles breathe by lungs and which by gills. This complicated way of growing into a frog is called *metamorphosis* and this term has the same general meaning that it did when used to describe the growth of insects (page 16).

The tadpoles of leopard frogs become small frogs in a single summer, but the tadpoles of bullfrogs and

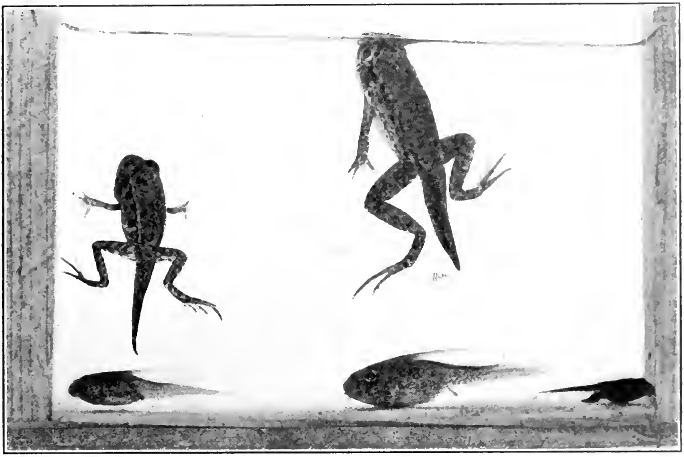

FIGURE 122. — TWO STAGES IN THE DEVELOPMENT OF TADPOLES.

green frogs require two seasons to complete their development. These latter tadpoles hibernate in the mud with adult frogs and toads.

122. Evolution. — Evolution, in a larger sense, is the theory or belief that all of the complex animals and plants on earth to-day developed from the simpler animals and plants of many generations ago. This theory tries to prove itself through the careful study and investigation of the relationships between animals and plants of the present and those that formerly existed.

The study of the changes through which the egg of the frog grows into a tadpole and then into a frog tells us much about the way frogs have developed from fishes. The tadpole breathes and eats like a fish; but as soon as lungs and legs are formed, it breathes and eats like a frog. This same study of the tadpole also illustrates how animals may gradually have come to live on land. In the early history of the earth there were hundreds of animals and plants which are no longer known to science. The skeletons, foot-prints, and whole bodies of many of these are preserved in the rocks. Such remains are called fossils.

If all the animals, or one of each kind, had been preserved in the rocks, it would be easy to investigate these

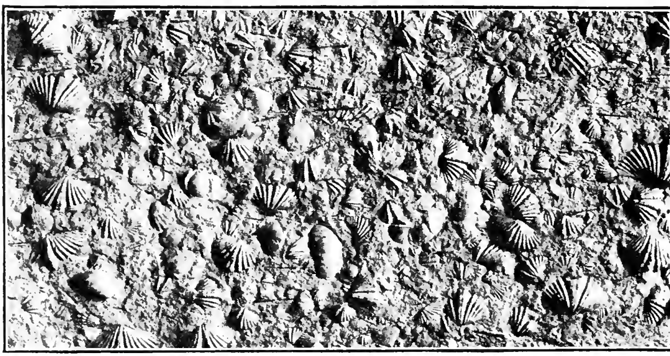

Figure 123. — Fossil Shells of Animals now Extinct.

earlier animals and their relation to the living animals of the present. But in our information there are great gaps, which we are, however, gradually bridging. Apparently unrelated animals have resemblances, so that in time we may come to see that all animals are really related forms, varying only in complexity of structure. One thing that we must always keep in mind is that the plants and animals which live now are but a small fraction of those which have lived. The rocks have preserved the remains of only a small part of the forms of the past. Many of the records of extinct animals and plants have been destroyed by decay and heat so that much that would be valuable in solving the question can never be found.

The study of the development of the frog also illustrates two other general subjects, *heredity* (hė-rĕd'ĭ-tў) and *environment* (ĕn-vī'rŭn-ment).

123. Heredity. — The tendency of all young animals to grow and live like their parents is called *heredity* and may be defined as the transmission of physical and mental traits from parent to offspring. There is no difficulty in recognizing the new frog as a certain kind of frog. The color markings on the skin are like those of the parents; it grows to about the same size; eats the same kind of food, and lives in the same region.

Every species of living thing is able to produce new forms like itself, and heredity is always at work when new plants and animals are being produced. Heredity is best thought of as that quality of living matter which expresses itself in the growing plant and animal by making sure that it resembles its parents. Thus heredity determines that leaves of the right shape and size occur in the proper place and that our fingers and thumbs grow on the end of the arm in the usual way.

There has been much study of the question of heredity and there is much yet to be learned. However, we know that we inherit from our parents and grandparents, our complexion, the color of eyes and hair, our size, our resistance to disease, our mental traits, and many other characteristics.

In 1865 Gregor Mendel, abbot of Brünn, published the results of experiments made with peas, which showed that crossing tall and dwarf peas resulted in all the offspring being tall. But the offspring of these latter (the grandchildren, so to speak, of the original peas) might be either tall or dwarf. The proportions were regular and the recurrence of tall or dwarf peas was so uniform that from these and other experiments later scientists evolved definite laws of heredity, known as the *Mendelian Laws*.

A detailed statement of these laws is beyond the province of an elementary book, but it is now well established that certain traits of parent plants and animals are reproduced in their offspring in regular and definite amounts and proportions.

124. Environment. — This word is used in two ways. First, it refers to general surroundings such as temperature, moisture, and seasons, as they vary from year to year; and secondly, to immediate surroundings. The frog responds to the first by hibernating in the winter; while the second phase of environment may be illustrated as follows: the tadpole can live only in water, and if the pond dries up before the frog stage is reached, the environment has been unsuited to the tadpole. This often happens when the eggs are laid in a temporary roadside pond which evaporates long before the tadpole becomes a frog. All such tadpoles die unless they are able to swim to some other body of water.

FIGURE 124. — TREE FROG.
Notice the sticky disks at end of toes.

The birds that are able to fly avoid hibernating in the winter. They are able to adapt themselves to the change in the seasons without burying themselves in the mud as the frogs do.

Some of the birds do not migrate, but remain all winter in the North. They have become so well adapted to conditions that they are able to get their food where birds that migrate would starve.

Man is the only animal which is able to live anywhere on the face of the earth under the most varied conditions. To realize this fully we have but to think of the different surroundings of the Eskimo, Indian, Bushman, and of ourselves.

Each animal and plant is directly dependent upon its environment for food and a home.

125. Economic Value of Amphibians. — The toad is the only member of the amphibian group that is of any great value to man. It destroys many insects. Frogs eat a few but hardly enough to entitle them to high rank as beneficial animals. Their chief value is as food and as convenient forms for dissection in biology courses.

SUMMARY

The Amphibians are an interesting group which illustrates how water animals may have become land animals. The frog has well-developed sense organs, legs modified for jumping, and feet for swimming. The skin is moist and helps to serve as an organ of respiration. The color markings and the habits of the frog serve to protect him from many of his enemies.

QUESTIONS

What animals belong to this class? How can you tell them from fish? Where do the amphibians of your region live? How many kinds do you know?

See how many kinds of amphibian eggs you can find.

How long do tadpoles live before they become frogs?

What do frogs and toads eat?

What is fertilization? Metamorphosis? Evolution? Heredity? Environment?

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CHAPTER XII

REPTILES [1]

126. Reptiles. — Among the *Reptiles* (rĕp′tĭlz) are included lizards, snakes, alligators, turtles, and crocodiles. The *Reptilia* (Latin, *repo*, to crawl) are characterized by a covering of bony plates, or scales, in the skin, by the absence of gills in the adult stages, and by the presence of lungs.

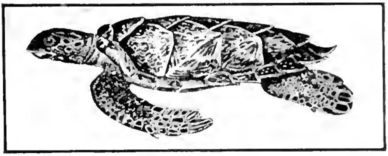

FIGURE 125. — A SEA TURTLE.

127. Life History. — Unlike the amphibians, the reptiles hatch directly into their adult form, only much smaller. The young snake just out of the egg or the young alligator just hatched is recognized by its resemblance to its parents.

FIGURE 126. — HORNED TOAD, A LIZARD.
Showing egg-capsules in which the young are hatched.

There is no metamorphosis, as in the frog. The reptiles lay their eggs in protected places and exhibit no parental care for the eggs or for the young. Some snakes hatch their young in the body of the parent and the offspring are born alive.

[1] If desired, this chapter may be omitted without affecting the sequence in the book.

128. **Turtles.** — Turtles are easily recognized by their outer skeleton. This skeleton is unlike the skeleton of the starfish or crab, or of any other group of animals. The

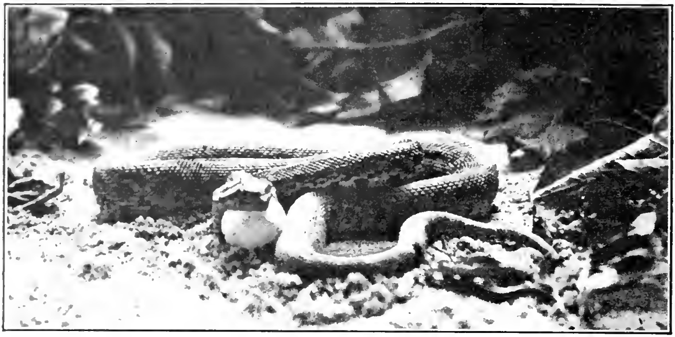

Figure 127. — Bull Snake with Hen's Egg in Mouth.

skeleton of the turtle, composed mostly of skin plates, is something like a box with a cover, the upper portion corresponding to the box itself, and the lower portion to the

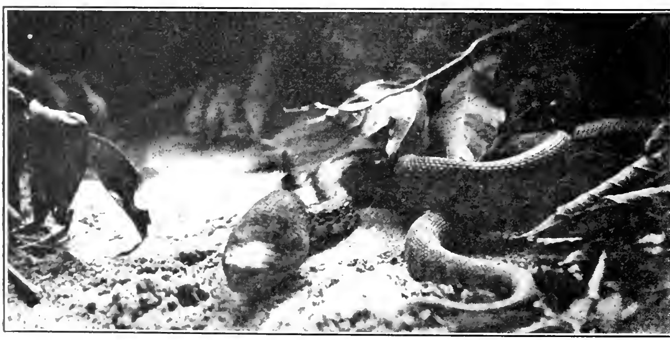

Figure 128. — Bull Snake after Swallowing Egg.

cover. The box does not fit closely all the way around, for there are places where the head, the tail, and the four legs stick out. When the turtle is disturbed, the legs, the head, and the tail are drawn inside, and the box is pulled down tightly by muscles to meet the cover.

The term turtle is often applied to aquatic forms, and the term tortoise to those living on land. Sea turtles attain a length of six or eight feet and weigh sometimes as much as a thousand pounds. The flesh of the green turtle and of the *terrapin* (tĕr′rȧ-pĭn) is used for food.

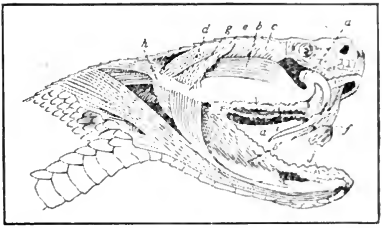

FIGURE 129. — HEAD OF A RATTLESNAKE. Dissected to show the poison gland, *a*, and its relation to the tooth. (Duvermoy.)

129. Lizards. — There is a great variety of lizards. A common lizard is the *chameleon* (kȧ-mē̇′lē̇-ŭn), which has the power of changing the intensity of the color in the skin by moving the color material nearer the outer surface or drawing it away. The horned toad of the Western United States is a lizard with scales of varying length which give it a horny appearance. Horned toads, instead of laying eggs, have the eggs hatched while yet in the oviducts and the young horned toads are born alive. A poisonous lizard is the *Gila* (hē′lȧ) monster that occurs in New Mexico and Arizona. It has the poison glands in its lower jaw.

FIGURE 130. — RATTLES OF RATTLESNAKE.

130. Snakes. — Snakes are legless vertebrates with long, cylindrical bodies covered with scales. They move by means of the scales (scutes) on the under side of the body. Most snakes lay eggs, but a few bring forth living young. Since snakes eat insects, frogs, mice, rats, and rabbits, they should be considered beneficial.

Rattlesnakes[1] and copperheads are the most common poisonous snakes of our country. Their jaws are provided with fangs (Figure 129), by means of which a poison is injected into their prey. Large snakes like the black snake or blue racer of the United States, the boa con-

FIGURE 131. — RATTLESNAKE — POISONOUS.
Compare head with snake in Figure 132.

strictor of South America, and the *python* (pī′thŏn) of Asia are constrictors. They are able to wind their bodies around their prey and to crush it to death. The most deadly snake in the world is the *cobra* (kō′brȧ) of India, where thousands of the natives die annually from the bite of this snake.

Snakes swallow their food whole, and as the teeth are used merely for holding their prey, they point backwards.

[1] The two most common rattlesnakes are the mountain rattler and the *massasauge* (măs-sa-sa̤′ge).

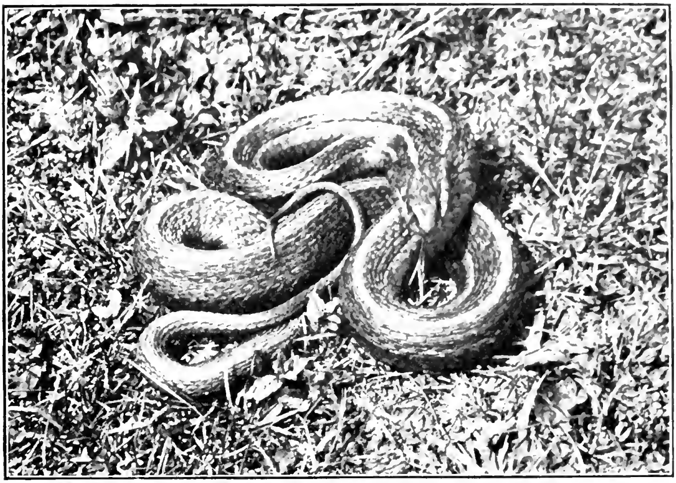

FIGURE 132. — GARTER SNAKE — HARMLESS.

131. Alligators and Crocodiles. — Crocodiles are found in the Southern United States, South America, Africa, and India. Alligators are found in stagnant pools in the

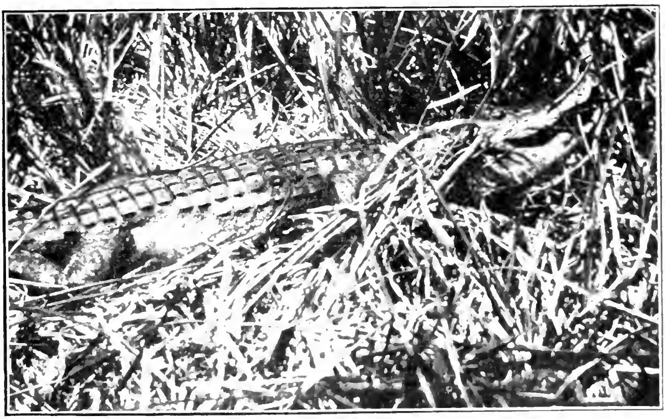

FIGURE 133. — EIGHT-FOOT FLORIDA ALLIGATOR.

Southern States. Crocodiles resemble alligators but have narrower mouths.

132. **Adaptations.** — Reptiles are peculiarly adapted to their environment. Snakes that live in trees are sometimes the color of leaves or bark. Some that are harmless are colored much like poisonous snakes. An adaptive feature of the crocodile is a fold of skin which shuts off the mouth

FIGURE 134. — ALLIGATOR NEST.

from the throat and prevents water from entering the throat while the crocodile is drowning its prey. The old world chameleons have their feet modified for clasping branches. In the case of the turtles, those that live in the sea have paddle-like feet for swimming, while those that live partly on land and partly in the water have toes with webs. Lizards are almost always of about the same color as their surroundings.

SUMMARY

The reptiles always use lungs for breathing. They usually have scales or bony plates in the skin and have either two pairs of appendages (turtles, lizards, alligators, crocodiles) or none (snakes). It is important to learn to recognize poisonous reptiles, as their bite is dangerous.

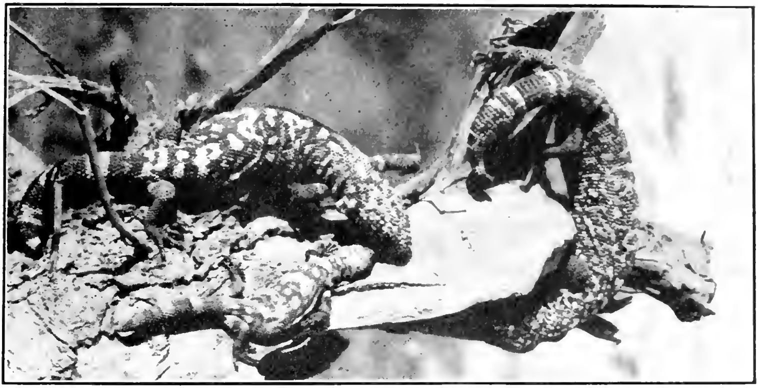

FIGURE 135. — POISONOUS LIZARDS — THE GILA MONSTER.

LABORATORY QUESTIONS

From models or preserved specimens the difference between the harmful and harmless reptiles should be worked out. The living turtle can be studied easily. Its special skeleton is an illustration of protective adaptation. Notice how the nostrils of the aquatic turtle can be closed. How does this help the turtle?

QUESTIONS

What are the most common snakes in your vicinity? Are they poisonous? How can you tell? Where do they live? What do they eat? How many kinds of turtles do you know? Where do they live?

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CHAPTER XIII

BIRDS

133. **Birds.** — Birds are the only vertebrates covered with feathers. Their front legs are modified into wings. Among some birds, like the *penguins* (pĕn′gwĭnz) of the Antarctic region, the wings are not used for flying but to assist in swimming. In others, like the eagles and condors, the expanse of the wings is sufficient to enable them to fly away with young lambs and large fish. Between the small wings of the penguin and the great expanse of the wings of the eagle and the condor there are many variations. Bird wings are adapted to the needs of their owners. Sailing birds, like the gulls, have long, slender wings, while ground birds, like the partridge and pheasant, have short wings capable of rapid, short flights. Those birds that make the most use of wings have them best developed. An example of underdevelopment, which has been increased by domestication, is seen in the domestic fowl, a ground bird, which makes little use of its flying powers, and is incapable of sustained flight.

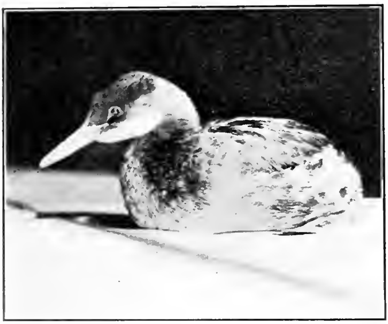

FIGURE 136. — GREBE.

The legs of birds also have many variations. In the case of the eagles, hawks, and owls there are powerful claws for seizing and holding prey, while ducks and geese have long and webbed toes, adapted to swimming. Seed-eating birds have weak claws which serve merely for perching. Chimney swifts, that spend most of their time in flight searching for food, have well developed wings, and feet used for clinging. Study Figures 139, 140, 149, 155.

FIGURE 137. — HERRING GULLS.

The beaks of birds show great variation and adaptation for defense and food getting. Hawks, owls, and eagles have the upper jaw curved over, hooked, and adapted for tearing the food; herons and bitterns have the beak modified into a long, pointed weapon of offense and defense; grosbeaks (grōs′bēks) and finches have a short, stout beak for crushing seeds and other hard foods; while humming birds have a long, slender beak which in some kinds is curved so that they may reach the bottom of certain flowers. Study Figures 137, 143, 144, 153, 154.

FIGURE 138. — ADULT SCREECH OWL.

The birds show a number of other special adaptations which are of use to them. These are hollow bones, a keeled *sternum* (breast bone), and a high body temperature.

The skeleton of a bird shows a prominent ridge on the breast bone. This is the keel of the sternum, which serves as a place of attachment for the large wing muscles (Figure 139). The lungs of the bird are small, but air tubes extend into the bones, so that the body of the bird is relatively lighter than that of animals with solid bones.

Birds lead an active life, which means that they use a great deal of energy. This energy comes from the oxidation going on in the body. In birds, oxidation is more rapid than in other vertebrates, owing to the fact that they almost completely change the air with each breathing movement and thus secure a greater supply of oxygen. The rapid oxidation requires a large supply of food to be digested and assimilated rapidly and it also makes the normal body temperature of birds higher than that of other vertebrates.

FIGURE 139. — SKELETON OF MALLARD DUCK.

134. Plumage. — The feathers of birds show great variety in form and color. In some species there are certain colors which always predominate on the males, while the females have little color; in other species it is hard to distinguish between the sexes. The brilliantly colored males are supposed to attract the females at the mating season, while the dull colored females are inconspicuous and less likely to be attacked by enemies while hatching their eggs, or caring for their young. We may say, therefore, that they are protectively colored. The color of birds varies during the first two or three years of life.

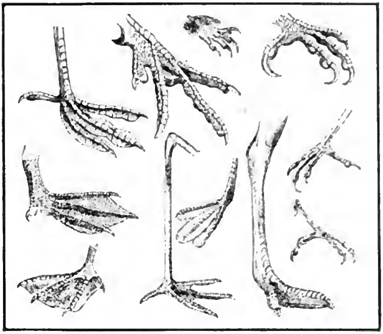

FIGURE 140. — DIFFERENT KINDS OF BIRDS' FEET.

FIGURE 141. — LOGGERHEAD SHRIKE.

135. Classification. — Birds are usually divided into groups according to their structure. The shape and size of the beak and of the feet and wings are the characteristics most used in the general classification. This is illustrated by a single group of birds, the

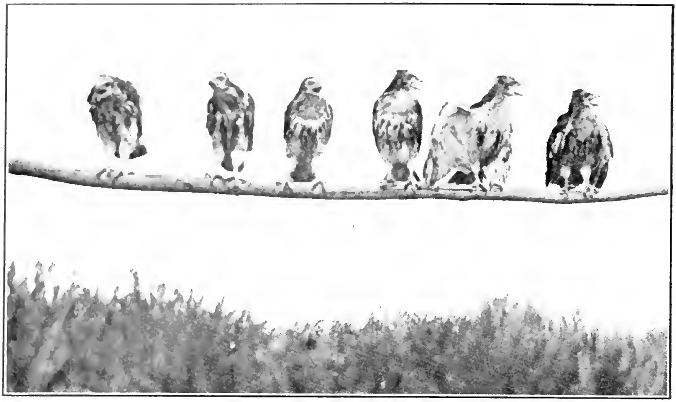

FIGURE 142. — YOUNG OF RED-TAILED HAWK — BENEFICIAL.

hawks, owls, and vultures, which are given the technical name of *Raptores* (răp-tō′rēz Latin, *rapere*, to ravish), birds of prey. The bird books describe the Raptores as

FIGURE 143. — HEAD OF YOUNG EAGLE.

follows: toes four, three in front and one behind, except in the vultures; all toes armed with strong, sharp, curved *talons* (tăl′ŭnz); bill with a *cere* (sēr: Latin, *sera*, wax) or covering of skin at its base through which the nostrils open, very stout and strong, the upper mandible tipped with a sharp pointed hook.

In addition to this classification by structure, which is essential for a careful study of birds, they are also classified by their habits. For example, birds are divided into four classes based on their migratory habits. Birds like the downy woodpecker and English sparrow are permanent residents throughout their range, that is, they can be found within given limits at any time of year, while bobolinks and humming birds are summer residents, migrating southward at the end of the season.

FIGURE 144. — THE ROBIN.
Sometimes a winter resident.

Birds like wild geese, fox sparrows, and the like, are transients, stopping along their migratory route for rest or food or to escape unfavorable weather; while such birds as the snowy owl, great northern shrike, and redpoll are winter visitants which have migrated to us from the North when the cold became excessive and the food supply diminished.

Birds are classified also by their nesting habits. Some birds, like the meadow lark and bobolink, nest in the open field, and their nests are made inconspicuous rather than inaccessible; other birds, like certain hawks and eagles,

FIGURE 145. — NEST OF GOLDFINCH.
Nest of altricial bird.

build their nests in tall trees, making them conspicuous, but inaccessible. Still others build like the oriole at the end of slender branches where they are out of reach of animals. Birds like the kingfisher, sand swallow, and puffins build their nests at the bottom of a burrow in the ground.

136. Nest Building. — Birds show great variation in nest building. Some build a large nest with materials loosely put together; others build small nests of neatly woven material, and some birds, like cowbirds, build no nest at all, but lay their eggs in the nests of other birds and leave the work of caring for their young to the foster parents.

FIGURE 146. — NEST OF LEAST BITTERN.

The number of eggs that birds lay in their nests varies from one to as many as thirty or forty. The time required to hatch the eggs varies from ten days to six weeks. Birds whose eggs hatch in ten days or two weeks are called *altricial* (ăl-trĭ′shal: Latin, *altrix*, nurse), for such young are hatched helpless, blind, and with little down. Eggs that hatch in from three to six weeks develop well-formed young, able to run around within ten to twelve hours after hatching. These are known as *præcocial* (prē-kō′shal: Latin, *prae*, before; *coquere*, ripen). Such birds have little need for a substantial nest and few of them build one. The robin is

FIGURE 147. — MOURNING DOVE.

altricial, and the domestic fowl præcocial (Figures 145 and 146).

137. Migration. — Because they are provided with wings and the power to fly long distances, birds are able to move from one region to another for the purpose of finding food and rearing young. The precise cause of migration is still unknown. Birds in general migrate to a warmer climate in the fall of the year and return to the cooler region in the springtime. In some cases birds cross the equator in migrating. For example, the bobolink nests in

FIGURE 148.—CHIMNEY SWIFT AND NEST.
Part of the birds have been crowded out.

the Northern United States and passes the winter in South America, migrating a distance of over five thousand miles. In the case of the robin the migration is limited to a short flight to the south to some protected swamp provided with water and food. A probable cause of migration is the failure of food supply as cold weather comes on in the fall.

138. Economic Importance of Birds. — The chief food of birds is insects, such as plant lice, larvae of beetles, butterflies, moths, borers, etc. The chickadee, for example, feeds on plant lice as well as other foods; the downy woodpecker feeds on codling moths and borers; the nuthatches and brown creepers feed on insects and insect eggs that are hidden in crevices and under loose pieces of bark. Other useful birds are the song sparrow, chipping sparrow, robin, bluebird,

FIGURE 149.—JUNCO.
A transient bird nesting in Canada, and on the high hills and mountains of the Northern states.

wren, blackbird, etc., which feed principally on insects that are found on or near the ground. The insects that fly, like mosquitoes, gnats, and house flies, are eaten by swifts, swallows, night hawks, king birds, and fly catchers.

FIGURE 150. — FEMALE BOBOLINK.

Among the hawks and owls is found a long list of beneficial birds, for the screech owl, red-tailed hawk, and the red-shouldered hawk are almost without exception valuable as destroyers of shrews, moles, mice, rats, weasels, and rabbits. The hawks that are partly harmful are the sharp-shinned hawk, Cooper's hawk, and the marsh hawk. All of these help themselves to poultry and feed on small beneficial birds like the song sparrow and bluebird.

FIGURE 151. — KING BIRD.

The exact relation of birds to agriculture and the foods that they eat has been a subject of study by the Department of Agriculture. Fisher reports the following results in his analysis of the stomach contents of 220 red-shouldered hawks: 3 of them contained poultry, 12 of them held 102

FIGURE 152.—YOUNG CROWS IN NEST.

mice, 40 of them other mammals; 20 of them reptiles; 39 of them amphibians; 92 of them insects; and 16 of them spiders. A similar analysis of 133 stomachs of Cooper's hawks shows the following: 34 of the stomachs contained poultry or game birds, 52 contained other birds; 11 of them mammals; 1 of them a frog; 3 of them lizards, 2 of them insects, while 39 of them were empty.

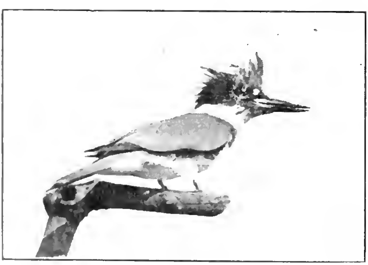

FIGURE 153.—KINGFISHER.

Aside from being of value in the destruction of insects, birds destroy waste matter and dead animals lying on the ground. The vultures and buzzards of the South and West eat dead animals. The gulls of the sea and lakes destroy refuse thrown upon the surface of the water. The eagle is also a scavenger as it eats dead fish that float on the surface of the water, or small dead animals thrown out in the open on the land. Crows also eat dead fish.

FIGURE 154. — HAIRY WOODPECKER EATING SUET.

There is also a group of birds that lives largely on seed, and such birds destroy vast amounts of weed seeds. Among the seed eaters are the quail, grouse, pheasant, goldfinch, sparrows, bobolink, and meadow lark. A

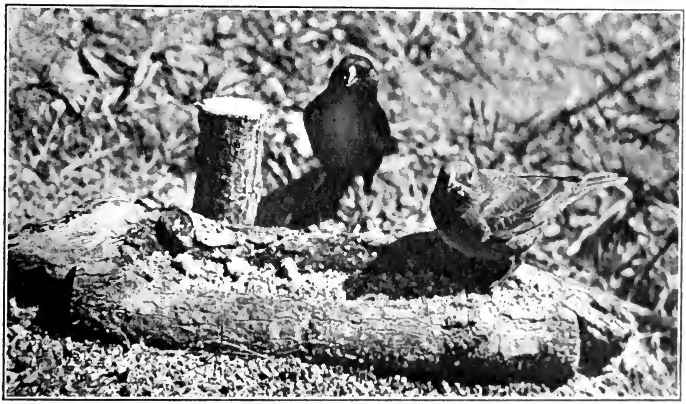

FIGURE 155. — MALE AND FEMALE COWBIRDS.

definite plan for bird study is suggested in the Appendix. There are many facts which we should know about each bird which are more important than knowing its name.

One of the best times to study birds is in the winter by means of feeding stations (Figures 154, 155). If you have trees near your home, especially if you live on the edge of a city or in a country town, it is a simple matter to get birds to come to you. It will take a little time for the birds to learn that you are friendly. The first ones to come will be house sparrows and their noisy chatter helps to attract other birds.

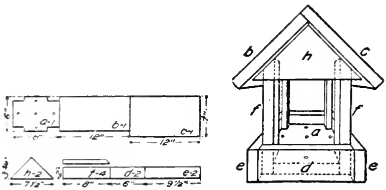

Figure 156.—Plan for Bird House.

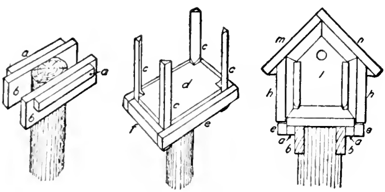

Figure 157.—Plan for Bird House.

Each feeding station may have one kind of food, as suet, seeds, bread crumbs, or whole grain. Some of the birds will visit all of the feeding places, but in general birds are either seed-eating or suet-eating.

At a suet station one may expect to see the following: Screech owl, woodpecker, blue jay, crow, tree sparrow, junco, rosebreasted grosbeak, myrtle warbler, brown creeper, nuthatch, chickadee. At a hemp and millet seed station: Pine grosbeak, red poll, goldfinch, pine siskin, vesper sparrow, white-crowned sparrow, white-throated sparrow, song sparrow, junco, nuthatch, chickadee, purple finch. At a bread crumb station: Blue jay, crow, tree sparrow, brown creeper. At a station where whole grain is used: Blue jay, crow, white-breasted nuthatch, chickadee, quail, grouse.[1]

SUMMARY

Because of their feathers birds can be easily recognized. The fore limbs are adapted for flying, and as such vary in size. The feet are modified for swimming, running, perching, or tearing; while the jaws are large and powerful, or small and weak, depending on the habits of each bird. The classification of birds according to their habits makes it easy to learn about them. Birds are of great economic importance in destroying many kinds of insects that are detrimental to man. This explains why they must be protected by law.

FIELD SUGGESTIONS

The plan for field study will be found too extensive for the time available in this course, but many are anxious to continue studying birds for several years, and the plan in the Appendix suggests a systematic method from the habit point of view. Certain parts of this plan should be undertaken whenever birds are taken up in the course. Students will find this an interesting way to spend part of the summer vacation.

QUESTIONS

How many birds do you know? What do they eat? Do they remain all winter? Which ones migrate? Where do they nest? What time of year do the young leave the nest? Why are the birds beneficial?

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W. L. McAter, How to Attract Birds in North Eastern United States. Farmers' Bulletin 621.

Chapman, Bird Life.

[1] W. L. McAter, How to Attract Birds. Farmers' Bulletin 621.

CHAPTER XIV

MAMMALS

139. **The Mammals** are the most highly developed of the vertebrates. They are warm blooded (the body temperature remaining the same in winter and summer), breathe by means of lungs, and are provided with milk glands to nourish the young. Most mammals are covered with hair. A muscular wall (diaphragm) subdivides the body

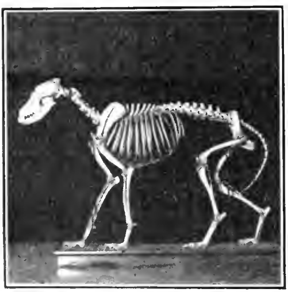

FIGURE 158. — SKELETON OF DOG.

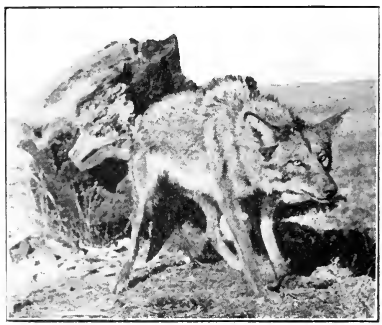

FIGURE 159. — COYOTE.

cavity into parts. The upper part contains the heart and lungs, and the lower part contains the stomach, intestines, liver, and other organs. At birth the young look like the parents.

Most mammals have two pairs of limbs. The fore limbs may be variously modified for different uses, as for walking in animals like the horse, for climbing and for food-

Figure 160. — Gray Squirrel.

Figure 161. — Young Gray Squirrel Leaving its Nest.

Figure 162. — Young Foxes.

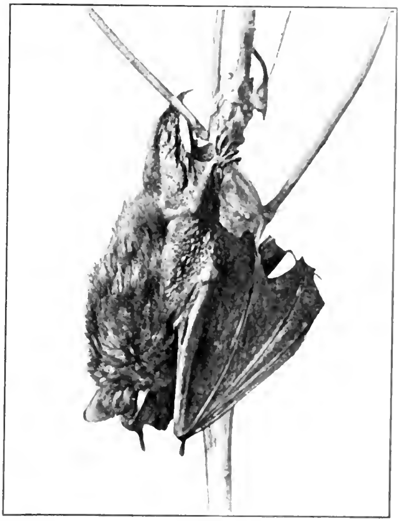

Figure 163. — Bat Hibernating.

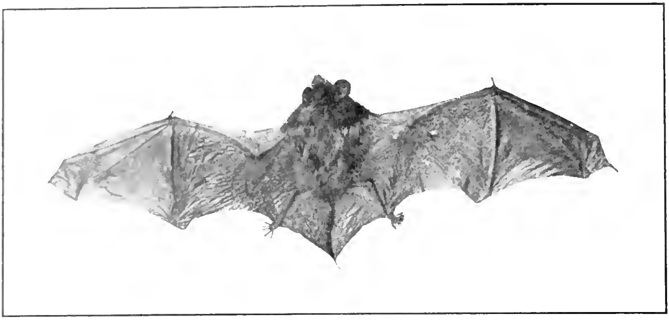

FIGURE 164. — BROWN BAT.
Showing formation of wings.

getting in the squirrel, for burrowing and locomotion in the moles, for flying in the bats, and for swimming in the seals. In all fore limbs of mammals, even in those as different as the leg of the squirrel, the flipper of the seal, and the wing of the bat, the arrangement of the bones is the same. The hind legs of mammals do not show so much variation as the fore limbs. But in some cases, as in the whale, the hind legs have practically disappeared through disuse, and there is no external evidence of them. Some animals, like the bears, walk on the soles of their feet, and some, like the

FIGURE 165. — FLYING SQUIRREL.

cats and the dogs, walk on all of their toes. In some mammals there is a variation in the number of the toes. For example, the cow walks on two toes and the horse on one toe, the hoof being a modified toe nail. In such cases the other toes are entirely lacking or rudimentary (not perfectly developed).

FIGURE 166. — DEER MOUSE.
A nocturnal rodent.

140. The Horse.— The horse is interesting because it has been associated with man since the pre-historic period known as the Stone Age. It has been suggested that man "first hunted horses for food, then drove them, and finally

FIGURE 167. — SEA LIONS.

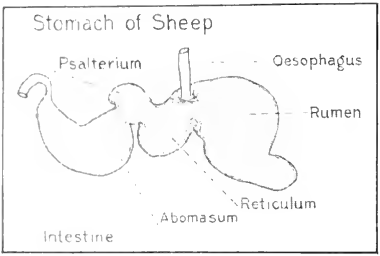

FIGURE 168.—STOMACH OF SHEEP.

Sheep, deer, and cows chew the "cud" and all have stomachs of several compartments.

used them for riding and as beasts of burden." The fine animals which we see to-day have gradually developed through this long time from a small animal about the size of a fox terrier. The earliest remains of the feet of the ancient horse show that it had four toes and the remains of a fifth in the front foot, while the hind foot had three toes and the remains of a fourth. The horse and the deer, which also has many stages preserved in the rocks, afford examples of the manner in which some of our present animals have developed. This is another good illustration of evolution.

FIGURE 169.—SKUNK.

141. Economic Importance of Mammals. — When we consider the value to man of horses, cattle, sheep, pigs, and goats in this country, and the value of the camel and reindeer in other countries, we can see the great economic importance of mammals. Mammals

FIGURE 170.—YOUNG RABBITS.

Report on Mammals to be filled out first from general knowledge, later extended by trips to fields, woods, or parks.

Kinds	Where Found	Food	Kind of Food	Life in Winter	Life in Summer	Beneficial	Harmful

are useful as food, companions, beasts of burden, and for clothing. The furs of wild animals and the leather and the wool of domestic animals are most important in protecting the body of man from unfavorable weather. Among the domestic animals the horse is useful for driving and draught work, and the cow for its flesh, milk, and butter. The sheep, through its flesh and wool, is an economic factor of great importance in civilization. There are harmful mammals like gophers (gō′fẽrz), prairie dogs, rabbits, rats, and mice. Lions and tigers sometimes kill human beings. Weasels, skunks, and mink are often harmful in poultry yards.

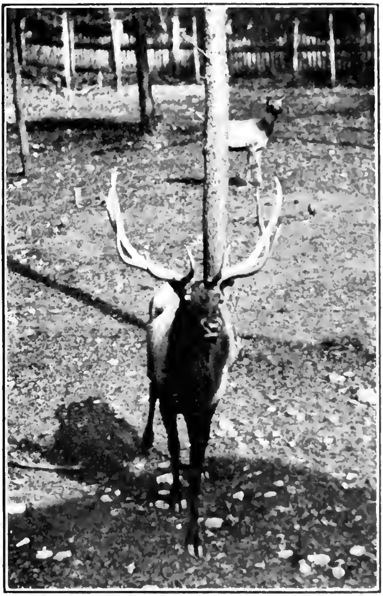

FIGURE 171. — ELK.

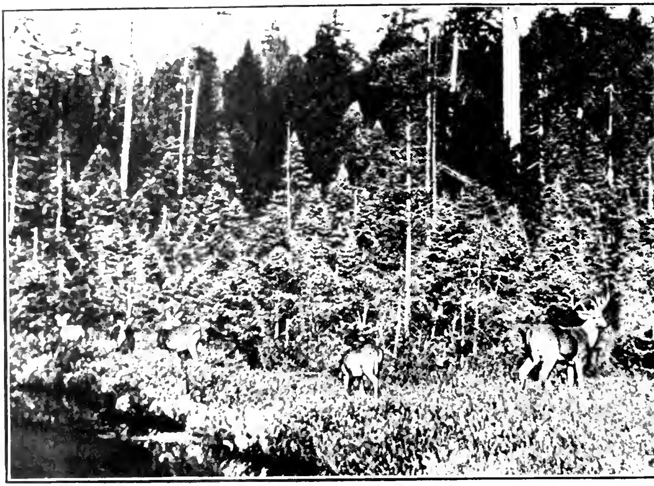

Figure 172. — Virginia Deer.

Figure 173. — Fawns of the Virginia Deer.

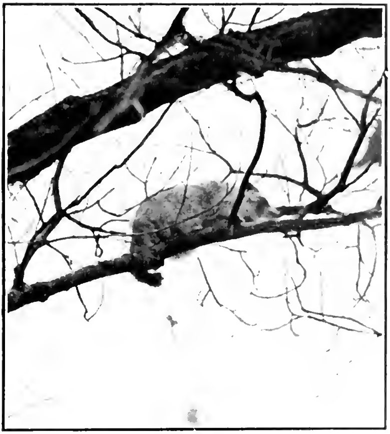

FIGURE 174. — COON.

FIGURE 175. — YOUNG WOODCHUCKS.

FIGURE 176. — CAMEL. THE SHIP OF THE DESERT.

In making long trips across the desert, the camel is able to go without drinking. During these journeys, the hump grows smaller as the fat in it is used as food. This food is gradually changed until part of it becomes water. We might say that the fat in the camel's hump is a special water reservoir.

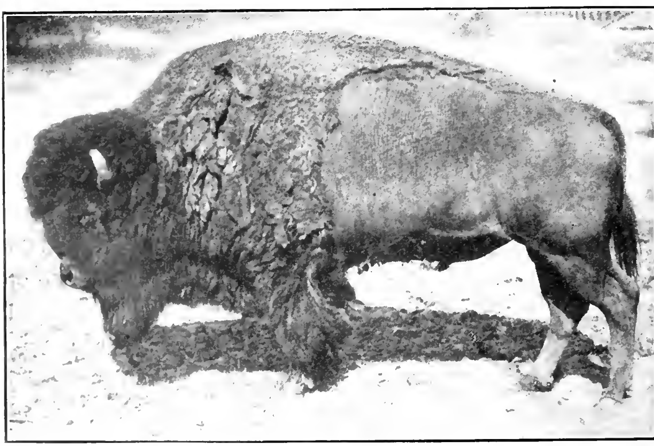

FIGURE 177. — BUFFALO.

These sturdy animals once roamed the plains in great numbers. If they were not protected in park preserves, they would now be extinct.

SUMMARY

The animals which are called mammals are covered with hair, and nourish their young with milk. There are nearly always two pairs of appendages that undergo much modification according to the habits of the animals. Our domestic animals which serve us in so many ways have gradually developed into their present form and usefulness. Man had to learn first how to use the fur and skin of wild animals, then how to improve the quality of the fur and skin by careful feeding and breeding of the domesticated animals.

FIELD SUGGESTIONS

If you are where you can visit a Zoölogical park it is an easy matter to learn how to distinguish the different mammals, a thing which every one should be able to do. There is another line of study which consists in selecting some one or two of the common mammals, such as squirrels, and making a thorough study of them from week to week, month to month, year after year, until you feel thoroughly acquainted with them. A third line of study is that of hibernation. Some mammals do not hibernate, some do so only during cold snaps, while others go to sleep for the entire winter.

QUESTIONS

How do you tell a mammal from other vertebrates? What mammals live near your home? What do they eat? Where do they spend the winter?

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PART II

HUMAN BIOLOGY

CHAPTER XV

LIFE PROCESSES OF MAN

142. Adaptation. — Adaptation includes all the variations in structures and habits which have been formed by an animal or plant to enable it to live in its own particular environment. Thus certain forms are adapted to living in the tropics, others in the temperate regions, and still others in the arctic regions. Living things which can adapt their lives to our northern winters do not need to migrate south as cold weather comes on in the fall. The frog cannot migrate, but hibernates in the mud.

Man is the best adapted of all animals to live in all parts of the world. When and where man began to live on the earth is not accurately known, but it was many thousands of years ago. He has been able to spread over the face of the earth because he can control his surroundings, that is, if he happens to live where there are many enemies, he invents destructive weapons and kills his enemies or drives them away. This is true even of disease, — man's greatest enemy. Again, most animals are either flesh-eating or plant-eating, but man is both, and because he has learned to eat a greater variety of both kinds of food than any other animal, it is easier for him to live and to raise his children in all climates.

All of the animals so far studied have been able to live only in their own limited surroundings. The grasshopper, the earthworm, the paramœcium, and the crayfish are not found in the sea or arctic regions. If the paramœcium or the crayfish is placed in sea water, where the lobster and many unicellular animals live, it dies. On the other hand, if the starfish or some of the seafish are placed in fresh water, they die. All of these animals are adapted to their own limited surroundings.

Scientists give four reasons in explaining why animals and plants are not adapted to live in all parts of the world: (1) lack of suitable food; (2) failure in adapting their lives to the peculiarities of climate; (3) too many enemies; (4) inability to raise their young.

STUDENT REPORT

The following table points out some of the common adaptations in animals. How are they related to the animal's success in life? Name some other habits which help to protect animals.

			Home				Protection				
	Active in Summer	Active in Winter	Earth	Water	Air	Nest	Night Feeding	Day Feeding	Color	External Skeleton	Method of Escape
Earthworm											
Grasshopper											
English Sparrow											
Dog											
Man											
Etc.											

143. Youth, Maturity, Old Age. — The life of man is divided into three general periods, which are youth, the period of maturity, and the period of old age. These same terms are given when describing the life of animals and plants.

Youth is the period when living protoplasm always grows, if furnished with proper food. This is the time when boys and girls grow taller and heavier each year; when the tree grows new leaves and the limbs become longer; and when the small puppy is turning into a full grown dog. During this period of change the boys and girls, the tree, and the puppy are all nourished by food and this makes it possible for them to grow.

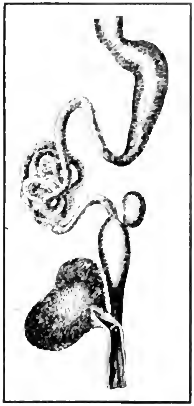


FIGURE 178. — ALIMENTARY CANAL OF FROG.

Compare with Figure 179. In what are they alike? In what different?

Maturity is the period when man ceases to grow taller, although he continues to eat food as he did during the period of youth. The living protoplasm in his body does not increase in amount. The same can be said of the tree, for it does not grow taller; and the puppy of last year has become a full grown dog. During this period of maturity, each living organism is able to repair its body as fast as the body wears out. The period of maturity varies in all living things; in some butterflies lasting but twenty-four hours, in man continuing for about twenty-five years.

Old age in man begins when the body wastes faster than it is repaired, and in the tree when growth is over and decay begins. During this period of old age all living things use food as they did in youth and maturity, but the body wastes faster than it can be repaired and death is the final result. Old age occurs at different ages in different individuals; and the same is true of animals and plants.

STUDENT REPORT

Fill out the following table and describe the digestive system of the animals studied thus far in Part I. This will help you to understand better the parts of the digestive system of man and the work that each part does.

	One Cell	Many Cells	No Digestive Tube	Digestive Tube	No Well Defined Digestive Glands	Which Ones Require Food?
Paramœcium						
Hydra . .						
Earthworm .						
Frog . . .						
Man . . .						
Etc. . . .						

144. Digestive Organs. — The digestive organs of man consist of the same parts which have already been described for the frog. Each region of the digestive organs is more perfectly developed and the biological principle, the division of labor, reaches its highest development in man. The parts of the alimentary canal in man are: the mouth, containing the teeth, tongue, and glands; the throat or pharynx; the esophagus, the stomach, the small and the large intestine. The last part of the large intestine is called the rectum. These several parts form a continuous tube, and each does a particular work in digestion (Figures 178 and 179).

The mouth is lined with a soft membrane, kept moist by the saliva secreted by three pairs of glands, and poured into the mouth in sufficient quantities to moisten the dry food and thus assist in swallowing. The tongue is a muscular organ and bears on its upper surface many small fleshy projections called *papillæ* (på-pĭl′lē: Latin *papilla*, bud), some of which are fairly large and are arranged on the back of the tongue in the form of a V (Figure 180).

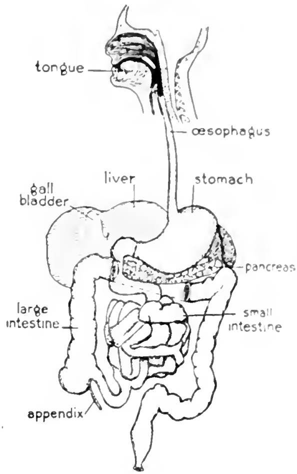


FIGURE 179. — ALIMENTARY CANAL OF MAN.

Our power to taste sweet, sour, bitter, and salt, which are the four fundamental tastes in man, is due mainly to certain nerve cells located on the larger papillæ. The food stimuli received by the special sensory cells of the papillæ are carried to the brain by the taste

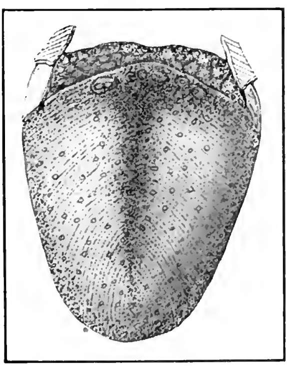


FIGURE 180. — TONGUE.

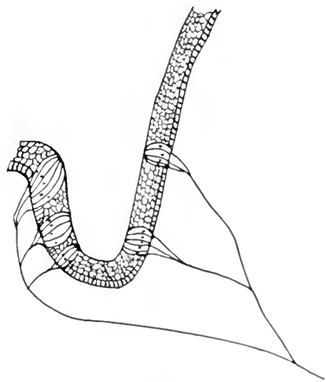


FIGURE 181. — TASTE CELLS. The taste nerve ends among these cells.

nerves. In the brain the food stimulus is interpreted as sweet, sour, or bitter (Figure 181).

LABORATORY STUDY

Blindfold in turn several members of the class and have each hold his nose while a small amount of some highly flavored food is placed on the tongue. Such common foods as maple syrup, vanilla extract, marmalade, jams, etc., are admirable for this test. Make a record of each test. This experiment will prove that we do not taste flavors. Remove the hand from the nose and again taste the same substances. This time there will be no difficulty in telling the name of the substance because it has been smelled as well as tasted.

The roof of the mouth is called the *palate*. The front part contains supporting plates of bone and is therefore called the hard palate. The back part (the soft palate) is a thin sheet of muscle covered by the mucous lining of the mouth. The palate separates the mouth from the nasal cavity. Beyond the soft palate is the throat cavity called the *pharynx*. This is a funnel shaped cavity, having two openings at its lower end, the front one being the opening into the windpipe which leads to the lungs, and the rear one, the opening into the esophagus. In the upper part of the pharnyx on each side, is the opening of an *eustachian* (ū-stā′ki-an) tube which passes to the middle ear.

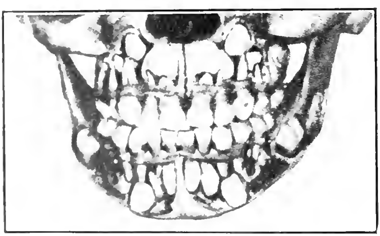


FIGURE 182. — MILK TEETH.
Age 3½ to 4 years. Notice the permanent teeth deeper in the jaws.

Teeth. — Just back of the lips are the teeth. In adults there are thirty-two, sixteen in each jaw, belonging to four classes according to shape. In front are the eight *incisors* (in-sī′zers) with sharp cutting edges; next the four sharp-pointed *canines* (kā'nīns), and back of the canines the eight *pre-molars* (prē-mo'lers) shaped for tearing and crushing, while the remainder of the teeth, twelve in number, are the flat-topped *molars* which do most of the grinding of the food.

Care of the teeth. — We all know that the teeth are hard. That, however, does not prevent them from becoming broken by carelessness or accident, or from decaying because of neglect. When the teeth are not cleaned, a substance called tartar forms on them, which prevents the bacteria from being rubbed off and sometimes pushes the gums away from the teeth. The bacteria cause food particles to ferment and form acids which dissolve the hard outside covering (enamel) and then rapidly the softer parts of the teeth. This results in toothache, a foul breath, and the imperfect chewing of the food. The teeth should be brushed after each meal to remove particles of food and particularly sugar which ferments easily. At least once a year there should be a visit to the dentist who will remove those portions of teeth that are decayed and will fill cavities, thus preventing further decay of the teeth. The value of good teeth cannot be overestimated.

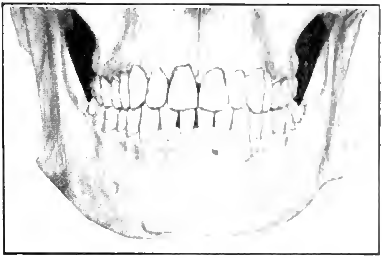


FIGURE 183. — PERMANENT TEETH.

The *esophagus* is a nearly straight tube connecting the mouth with the stomach. It passes through the *diaphragm* (Figure 208), enlarges, and becomes the stomach. As soon as one swallows, control of the food is lost, and further action becomes involuntary. Two sets of muscles, one extending lengthwise, the other around the esophagus, act together in forcing the food or water into the stomach. This explains why we can drink from a brook when the head is much lower than the stomach.

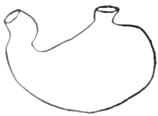


FIGURE 184.—PEAR-SHAPED HUMAN STOMACH.

Stomach. — In man the stomach is the largest section of the digestive tube, and it has a capacity of about three pints. It is usually described as pear-shaped although there is much variation in its form (Figures 184 and 185). At the point where the esophagus joins the stomach there is a muscular ring (*cardiac* valve, kär′dĭ-ăk) which ordinarily prevents the food from passing again into the esophagus. In vomiting, this valve becomes relaxed. The opening at the larger and lower end of the stomach is guarded by a similar valve (*pyloric*, pĭ-lŏr′ĭk) which serves to retain the food in the stomach until certain digestive changes have taken place.

FIGURE 185. — X-RAY PHOTOGRAPH OF HUMAN STOMACH.

This is a shape familiar to physicians and is called the J-shape. — Dr. C. F. Potter.

The intestine has two parts, a small, much coiled tube about an inch in diameter and about twenty feet long called the *small intestine;* and a large section about five feet long and four inches in diameter, bent in a rough ∩ shape and called the *large intestine.* At the junction between these two regions projects a short sac, the *vermiform appendix* (vẽr′mĭ-fôrm ap-pĕn′-dĭks). The disease called *appendicitis* (ăp-pĕnd-ĭ-sī′tĭs) affects this organ. The large intestine ends in a special region called the *rectum.* The opening of the rectum to the outside is the *anus* (ā'nŭs).

FIGURE 186. — X-RAY PHOTOGRAPH OF APPENDIX AND PART OF LARGE INTESTINE.

The constrictions are natural.

Glands. — A gland is a group of special cells which secrete a fluid. The glands which produce the digestive fluids are (1) the three pairs of *salivary* (săl'ĭ-vȧ-ry) glands, located below the ear, and beneath the tongue and lower jaw; (2) the numerous *gastric* (găs'trĭk) glands found in the lining of the stomach, possibly 5,000,000 in number (Figure 187); (3) the *pancreas;* and (4) the *liver,* the largest gland in the body.

145. Food. — One of the best definitions of food is the following. Food is that which when taken into the body builds up tissue or yields energy. All organic foods or foodstuffs are divided into three classes, the *proteins* (prō'tė-ĭns), the *carbohydrates* (kär-bō-hī'drāts), and the *fats.* This classification is made whether we study the foods of a plant, an animal, or of man. Scientists are able to tell to which class meat, bread, oatmeal, milk, and all other foods belong by finding out the chemical composition of each. The chemists have made a thorough study of food and tell us that certain chemicals are present in each of the three classes of foods. Definite chemical tests tell us to which of these three classes any given article of food belongs. In general it may be said that the

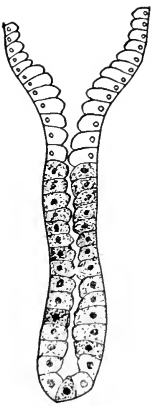


FIGURE 187. — GASTRIC GLAND.

proteins are necessary for the growth and the repair of the body, and that the carbohydrates and fats furnish heat to keep the body warm, and energy for muscular work. The unused fat is stored up as fatty tissue. All classes of food are found in the various foods obtained from plants. Some, like honey, are nearly pure carbohydrate, while the English walnut contains, in addition to fat, a large quantity

FIGURE 188. — MICROPHOTOGRAPH OF STOMACH.

The stomach is an organ composed of several tissues arranged in layers. The gastric glands are in the innermost ragged layer and look like rows of black dots.

of plant protein. Animal foods can furnish us with only proteins and fats. In primitive times man used a restricted diet and led an active out-of-door life. To-day man is living on a mixed and varied diet. This is to be regarded as an acquired habit and one that is questionable when carried to an extreme. The question of how much to eat is a modern problem, and on its solution depend our health, length of life, and energy for work.

Thomas Henry Huxley (1825–1895) was a celebrated English biologist. As a young man he made a trip around the world in H.M.S. *Rattlesnake*, which was on surveying service in Australasia. On returning home Huxley devoted himself to the study of biology. He held a number of important academic positions and was made President of the Royal Society in 1883.

Huxley was one of the most laborious workers in biology. He rearranged the animals in new classes and discovered remarkable similarities in their development. He is celebrated for his theory of protoplasm and for his able advocacy of the views of Darwin.

Huxley showed great skill in putting the conclusions of science into simple language.

STUDENT REPORT

Animals eat a large variety of things, parts of which serve to furnish energy or to nourish the body. In the following report, work out the sources from which the animals derive their food. To what extent are they alike?

	Paramœcium	Hydra	Earthworm	Frog	Man	Flies
Minute plants						
Minute animals						
Plants						
Flies						
Add food of man						

146. Digestion. — Digestion begins in the mouth. The teeth break up the food and mix it with the fluid of the mouth, the *saliva.* During this process, sugars and starches are changed into soluble sugars. The fluids of the mouth are usually slightly *alkaline* (ăl′kȧ-lĭn or līn, a chemical term, the opposite to sour or acid), but as soon as the food passes into the stomach it enters an acid (sour) medium, and the digestive action of the saliva is destroyed in a short time by the stomach fluid. For this reason, the sugar and starch undergo no further digestive changes until they reach the intestines.

Into this acid medium of the stomach, the gastric glands (Figure 179) pour out the gastric juice (a digestive fluid), and the pepsin in this juice acts on the proteins so that they can later pass through the walls of the intestines. In the stomach the heat of the body dissolves some of the fats into oils, but many of the fats used as food remain solid at body temperature and are unchanged in the stomach.

After one or two hours the food passes into the intestine and undergoes further changes in another alkaline medium. Here the pancreatic juice, which is made in the pancreas, comes into contact with the digested and partly digested food, causing three different changes. One is to complete the change of proteins into simpler products; a second is to finish converting starches into sugar; while the third is to assist the bile (the digestive juice made in the liver) to digest the fats. The digestion of the food is practically completed in these three regions of the digestive tube, although digestion continues to some extent after the food is passed into the large intestine.

The pepsin in the gastric juice is called an *enzyme* (ĕn′zīm: Greek *enzymos*, fermented) or ferment. There are three different enzymes in the pancreatic juice, none in the bile, and one in the saliva. These enzymes are the chemical bodies which digest food. All plants and animals digest their food by means of enzymes.

Inorganic foods, such as water, oxygen, and salts, man takes into his body, making them part of his living protoplasm, or using them in oxidation. There is a large amount of water in man, enough to make up nearly two-thirds the total weight of his body. All of his food contains water.

STUDENT REPORT

Where the Food is Digested

	In the Cell	In the Leaf	Primitive Digestive Tube	Stomach	Mouth	Digested by Enzymes
Paramœcium .						
Hydra . . .						
Frog						
Man, etc. . .						
Bean						
Yeast						

Teacher may explain yeast and bean to help out the comparison.

Oxygen is breathed in from the air, and the various salts, such as common salt, *sodium chloride* (sō′dĭ-ŭm klō′rĭd, or rīd), *calcium* (kăl′sĭ-ŭm), *magnesium* (măg-nē′zhĭ-ŭm, or -shĭ-), *potassium* (pō-tăs′sĭ-ŭm), and *phosphorus* (fŏs′fŏr-ŭs) are taken in with our food. They are useful to the body. A small amount of iron is also contained in food and water and becomes a part of the red blood cells.

LABORATORY STUDY

Study food and food tests. Artificial gastric juice is easily prepared by taking ½ gram of pepsin, $\frac{1}{10}$ cc. of strong *hydrochloric* (hī-drō-klō′-rĭk) acid and adding 50 cc. of water. Take white of egg that has been cooked and subject it, in a test tube, to the above mixture. A variety of tests should be made, with and without heat (100 F.) with and without the acid. Pancreatic juice is made by uniting 15 grams *sodium* (sō′dĭ-ŭm) *carbonate* (kär′bŏn-ăt), 5 grams *pancreatin* (păn′krē-à-tĭn), and 100 cc. water. The action of this fluid may be tested as above on the fats, as olive oil; on starch, as flour; and on proteins, as raw lean meat or milk. Also examine several of the common articles of food to determine to what class of foodstuffs they belong.

147. Absorption of Food. — The absorption of food in man and animals is the process of taking the digested foods from the alimentary canal into the blood. Practically no food is absorbed in the mouth or esophagus, and but little in the stomach.

The absorption of food from the intestinal canal is done by small folds in the lining of the small intestine. To the naked eye, these folds appear as a covering of minute hairs, called *villi* (vĭl′lī). Their structure is shown in Figure 189.

The process of osmosis, which has been so frequently referred to in Part I, is the chief factor in the passing of the food into the blood vessels. This process is assisted by the action of the living cells in a manner not well understood.

The digested proteins and sugars pass directly into blood vessels which lead to the liver. In the liver, these blood vessels unite to form the *portal* (pōr′tal) *vein*, which is divided into minute branches that distribute the blood to the cells of the liver. As the blood thus passes among the liver cells, the larger part of the sugar is changed into *glycogen* (glī′kō-jĕn), an animal starch, and stored temporarily in the liver cells. This stored-up starch is given out gradually and changed back into sugar, which results in keeping a uniform amount of sugar in the blood.

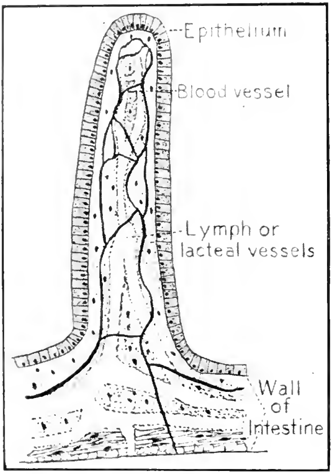


FIGURE 189. — DIAGRAM OF VILLUS.

The fats pass into certain distinct vessels, *lacteals* (lăk′tē-als), which in turn open into larger ones. Eventually these vessels unite to form a large duct — the *thoracic* — which empties into one of the veins near the heart. The food is now in the blood stream and is carried to the individual cells of the body. Each cell takes the kind of food which it needs and by a series of changes, as yet only partly known, makes the food into living protoplasm.

The indigestible part of the food is not absorbed, but continues to move through the small intestine into the large intestine, and on through the rectum. During this progress much moisture is absorbed, especially in the large intestine, which leaves the "undissolved food" harder and harder. The regular removal of the unused part of the food, *faeces* (fē′sēz), is of much importance in maintaining health, because the bacteria living in the digestive tract cause the waste material to decay and the poisonous substances thus formed are injurious when absorbed into the blood.

Foods normally remain in the stomach from one to five hours, and in the small intestine about four hours; while they may be from six to twenty-four hours in passing through the large intestine.

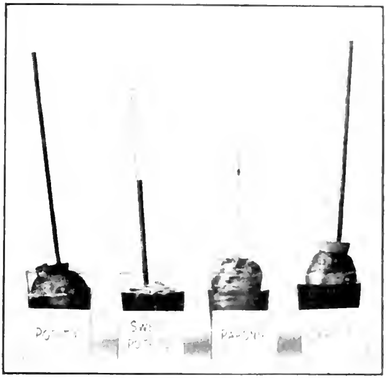


FIGURE 190. — HOME-MADE APPARATUS TO SHOW OSMOSIS.

We become hungry each day and feel relieved only after eating. A person frequently eats a large meal because of an extra amount of work that is to follow. But is he helped to do the extra work? Probably not, for the strength to do the work of to-day comes from the food eaten yesterday, or possibly the day before yesterday. The food, even after digestion is completed, must pass through many changes before it is built up into protoplasm. The actual building of the food into protoplasm is the process for which the word *nourishment* is used, and it should not be confused with *absorption*.

Food as purchased contains	Edible portion *e.g.*, flesh of meat, yolk and white of eggs, wheat, flour, etc.	Water.		
		Nutrients	Protein.	
			Fats.	
			Carbohydrates.	
			Mineral matter.	
	Refuse *e.g.*, bones, entrails, shells, brain, etc.			

Alcohol is made up of carbon, hydrogen, and oxygen. All proteids contain nitrogen in addition to these three. Because alcohol contains no nitrogen, it cannot be used as a food to build up tissue.

USES OF NUTRIENTS IN THE BODY

Protein *e.g.*, white (albumen) of eggs, curd, casein (kā′sē-ĭn) of milk, lean meat, gluten of wheat, etc.	Forms tissue	All serve as fuel to yield energy in the form of heat and muscular power.
Fats *e.g.*, fat of meat, butter, olive oil, oils of corn and wheat, etc.	Are stored as fat	
Carbohydrates *e.g.*, sugar, starch, etc.	Are transformed into fat	
Mineral matter (ash) *e.g.*, phosphates of lime, potash, soda, etc.	Shares in forming bone, assists in digestion, etc.	

Comparative amount of food required for persons of various ages and conditions, taking as the unit, the amount of food required by a man at moderately active muscular work:

Man at hard muscular work requires 1.2 the amount of food of a man at moderately active muscular work.

Man with light muscular work or boy 15–16 years old requires 0.9.

Man at sedentary occupation, woman at moderately active work, boy 13–15, or girl 15–16 years old requires 0.8.

Woman at light work, boy 12, or girl 13–14 years old requires 0.7.

Boy 10–11 or girl 10–12 years old requires 0.6.

Child 6–9 years requires 0.5.

Child 2–5 years old requires 0.4.

Child under 2 years old requires 0.3.

Heat is a form of energy and one of the reasons for taking food is to keep up the supply of this energy. The more work a person does the more energy he uses, but even a resting body uses some energy, for the heart beats and the muscles of the chest move. The amount of this form of energy a person uses is measured by a unit of heat named the *calorie* (kăl′ō-rĭ). A calorie represents the amount of heat required to raise the temperature of a pint of water about four degrees Fahrenheit. A man in rising from a chair, walking eight feet, and returning uses about one calorie.

Pecuniary Value of Food. — The table on page 178 from the government bulletin helps to give students an appreciation of the relative cost and value of the more common foods.

148. The Preparation of Foods. — Some foods, such as milk, fruit, and nuts, may be eaten without being cooked, but most of our food has to undergo this process before it is suitable for eating. As no two kinds of vegetables or meat are best cooked in exactly the same way, attention should be given to the preparation of food for the table. Successful cooking accomplishes four ends. (1) Changes are brought about to make the food more digestible, such as softening or dissolving it. (2) The nutritious parts are carefully saved. (3) Certain amounts of the three classes of foodstuffs are selected in order that all the chemical elements which the body needs may be supplied. This is known as a "balanced ration." (4) The food is made attractive in appearance and taste, "good to eat."

Every woman who wishes to have a happy, healthy family should make a serious study of cooking. Many of the facts about the nutritive elements which foods contain, and the many changes which they undergo in cooking are found out by chemists who study them in laboratories. It is not necessary for all of us to know all these facts, but a good cook follows the rules and recipes which have been made as a result of scientific laboratory studies.

To illustrate how much is involved in cooking, let us

Comparative Cost of Digestible Nutrients and Energy in Different Food Materials at Average Prices [1]

It is estimated that a man at light to moderate muscular work requires about 0.23 pound of protein and 3,050 calories of energy per day.

Kind of Material	Price per Pound	Cost of 1 Pound Protein [2]	Cost of 1,000 Calories Energy [2]	Amounts for 10 Cents: Total Weight of Food Material	Protein	Fat	Carbohydrates	Energy
	Cents	*Dollars*	*Cents*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Calories*
Beef, sirloin	25	1.60	25	0.40	0.06	0.06	—	410
Beef, round	16	.87	18	.63	.11	.08	—	560
Beef, shoulder clod	12	.75	17	.83	.13	.08	—	595
Beef, stew meat	5	.35	7	2	.29	.23	—	1,530
Beef, dried, chipped	25	.98	32	.40	.10	.03	—	315
Mutton chops, loin	16	1.22	11	.63	.08	.17	—	890
Mutton, leg	20	1.37	22	.50	.07	.07	—	445
Roast pork, loin	12	.92	10	.83	.11	.19	—	1,035
Pork, smoked ham	22	1.60	13	.45	.06	.14	—	735
Pork, fat, salt	12	6.67	3	.83	.02	.68	—	2,950
Codfish, dressed, fresh	10	.93	46	1	.11	—	—	220
Halibut, fresh	18	1.22	38	.56	.08	.02	—	265
Cod, salt	7	.45	22	1.43	.22	.01	—	465
Mackerel, salt, dressed	10	.74	9	1	.13	.20	—	1,135
Salmon, canned	12	.57	13	.83	.18	.10	—	760
Oysters, 35¢ per qt.	18	3.10	80	.56	.03	.01	.02	125
Lobster, canned	18	1.02	46	.56	.10	.01	—	225
Butter	30	30.00	9	.33	—	.27	—	1,125
Eggs, 36¢ per doz.	24	2.09	39	.42	.05	.04	—	260
Cheese	16	.64	8	.63	.16	.20	.02	1,185
Milk, 7¢ per qt.	3½	1.09	11	2.85	.09	.11	.14	885
Wheat flour	3	.31	2	3.33	.32	.03	2.45	5,440
Corn meal, granular	2½	.32	2	4	.31	.07	2.96	6,540
Wheat breakfast food	7½	.73	4	1.33	.13	.02	.98	2,235
Oat breakfast food	7½	.53	4	1.33	.19	.09	.86	2,395
Oatmeal	4	.29	2	2.50	.34	.16	1.66	4,500
Rice	8	1.18	5	1.25	.08	—	.97	2,025
Wheat bread	5	.64	4	2	.16	.02	1.04	2,400
Rye bread	5	.65	4	2	.15	.01	1.04	2,340
Beans, white, dried	5	.29	3	2	.35	.03	1.16	3,040
Cabbage	2½	2.08	22	4	.05	.01	.18	460
Celery	5	6.65	77	2	.02	—	.05	130
Corn, canned	10	4.21	23	1	.02	.01	.18	430
Potatoes, 60¢ per bu.	1	.67	3	10	.15	.01	1.40	2,950
Turnips	1	1.33	8	10	.08	.01	.54	1,200
Apples	1½	5.00	8	6.67	.02	.02	.65	1,270
Bananas	7	10.00	27	1.43	.01	.01	.18	370
Oranges	6	12.00	40	1.67	.01	—	.13	250
Strawberries	7	8.75	47	1.43	.01	.01	.09	215
Sugar	6	—	3	1.67	—	—	1.67	2,920

[1] Principles of Nutrition and Nutritive Value of Food, W. C. Atwater, Farmers' Bulletin No. 142.

[2] The cost of 1 pound of protein means the cost of enough of the given material to furnish 1 pound of protein, without regard to the amounts of the other nutrients present. Likewise the cost of energy means the cost of enough material to furnish 1,000 calories, without reference to the kinds and proportions of nutrients in which the energy is supplied. These estimates of the cost of protein and energy are thus incorrect in that neither gives credit for the value of the other.

see what it means to produce a loaf of wholesome bread. Flour contains much starch, some sugar, some mineral substances known as phosphates, a large quantity of gluten (a protein), and some bacteria (tiny plants, see Chapter XXIV) which may or may not be of value in making bread. When water is added to the flour, it becomes tough and sticky, this being a characteristic of gluten, and the most important one, so far as the making of bread is concerned. A small bit of yeast (a small plant, see Chapter XXIV) is added to the water used in making bread, and the dough is placed where it will be neither too hot nor too cold (70°–80° F.).

The yeast begins to grow rapidly, feeding on the proteins of the flour, and as the yeast grows, it acts on the sugar. A substance called *zymase* (zīm′ās), secreted by the yeast plant, breaks the sugar up into carbon dioxide, alcohol, and a small quantity of *glycerin*. The gas tries to escape, but is held in by the sticky dough. If the yeast plant is well distributed, the gas collects in many small bubbles, and the loaf is fine-grained. The alcohol keeps other plants from growing there, and also helps to soften the gluten.

When the loaf is put into the oven, the heat kills the yeast plant, drives off the carbon dioxide, and causes the alcohol to evaporate. The heat changes the gluten into a substance more easily digested and of a more pleasant taste. In "salt rising" bread bacteria from the air, instead of yeast cells, form the gas which makes the bread light. When a batch of bread "sours," it is usually because harmful bacteria get into the dough and grow more rapidly than the yeast plants. Sometimes other kinds of yeasts than the helpful ones employed in bread-making accidentally get into the batch of bread and it spoils as a result.

149. **Adulteration of Foods.** — Foods are adulterated either by subtracting some of the nutritious parts and substituting less valuable parts, or by adding materials which cannot act as a food.

The food formerly subject to the most adulteration was milk. This adulteration was done by adding water to make the milk go farther when being measured out, and adding *formalin* (fôr′mȧ-lĭn) to make it keep sweet.

For a time many of the cereals were adulterated with sawdust, peanut shucks, or bran. Many of the special foods put up in packages used to be adulterated, and it would require a long description to enumerate all that have been found unsatisfactory for food by the Department of Agriculture.

Pure Food Laws. — Congress in 1906 passed what is known as the Pure Food and Drug Law. This law requires manufacturers of food and medicine to state on the label what is in each package or bottle. This enables one to know just what he is buying.

150. **Indigestion.** — Few children that have an opportunity to romp and play out-of-doors and have plenty of simple and plain food ever experience any ill feeling in the digestive canal. However, as children grow older, exercise less, and eat richer food, they may suffer much inconvenience from indigestion.

Indigestion is a condition which rarely extends to all parts of the digestive canal; it is located either in the stomach or in the small intestine. This may indicate that certain kinds of food are not properly digested. Indigestion may be caused by eating the wrong kinds of foods or by overloading the stomach. If the food is chewed thoroughly, the appetite is usually a safe guide as to the amount needed by the body. Moreover, food thoroughly chewed is more easily acted upon by the digestive fluids.

To some people certain foods are indigestible at all times, while other foods are indigestible only at special times. We should learn to understand our bodies in this particular. Some of the causes of indigestion are: lack of sufficient regular exercise, too much rich food, and the failure to drink enough water.

Students and professional men use their brains more than their muscles, but they require protein to repair nerve waste just as laborers require proteins to feed their tired muscles. Unless students and professional men exercise their muscles, they do not feel vigorous and eager for their work. On the other hand, unless the laboring men exercise their brains, they do not do their work as well as they might. The amount of exercise required varies with the individual. The best way to prevent indigestion is to have regular habits of eating and exercising.

There are in the market many tablets and remedies for indigestion, which may, for example, contain pepsin and pancreatin. Now we know that these substances when found in the pancreatic fluid act in an alkaline medium. As these tablets must first pass into the stomach, which is an acid medium, the action of the pancreatin is probably destroyed long before the remedy reaches the intestine where it would naturally act. This means that such tablets are largely useless and is one of the reasons why many doctors believe that digestive tablets are doing more to cause indigestion than they do to help it. There are only a few commercial tablets made which act on the undigested foods of the intestine. No medicine, in fact, can give permanent relief to indigestion. Predigested foods, a recent attempt to relieve indigestion, serve a useful purpose in cases of sickness, but in our regular life, should be used sparingly because they do not give the digestive organs the proper amount of work to do.

151. **Effect of Alcohol on Digestion.** — Alcohol taken into the digestive tube is closely related to the question of indigestion. The lining (mucous membrane) of the stomach and intestine is delicate and tender, and contains thousands of cells which secrete the gastric juice, and many more thousands that help to digest the food. When alcohol comes in contact with these delicate cells, it prevents them from doing their normal work. The result is that food is not properly digested.

Indigestion disguised by alcohol but not cured. — It is a serious error to regard alcohol as a genuine remedy for indigestion or abdominal pain. It is true the sense of pain is sometimes abolished by alcohol, and as a result of this many a man believes that alcohol aids his digestion, whereas it merely exerts a numbing effect on the stomach nerves, and his indigestion is disguised rather than removed. In fact, instead of being cured the mischief is increased since digestion is retarded. Some digestive medicines contain enough alcohol to be injurious. Alcoholic drinks taken with meals make the food hard to digest because the alcohol makes the food tough.

SUMMARY

Man is able to live in all climates and localities on the earth. No plant or other animal can do this. Man controls his surroundings. Plants and animals are controlled by their surroundings. Like other animals, man passes through the periods of growth known as youth, maturity, and old age.

Man has a definite set of digestive organs that are more highly developed than those of any other animal. These digestive organs prepare proteins, carbohydrates, and fats so that they pass into the blood. The blood is forced by the heart through definite blood vessels. The study of food is important because we require food in order to live. The cost of food and the amount needed are problems that science is helping to solve.

QUESTIONS

How does man differ from other animals in regard to the places where he lives? Why? What do man and other animals require in order to grow? Name the kinds of foods. What is the value of protein? Of carbohydrates? What does cooking do to foods? Why is this important? What is digestion? What is indigestion? Absorption? How are the cells of the body fed?

CHAPTER XVI

SKELETON AND MUSCLES

152. **Skeleton and Muscles.** — Muscles which serve to move the body cover and protect the skeleton of man. The more delicate organs of the body are protected further — the heart and lungs by the ribs, and the brain by the cranium. The skeleton and muscles of man are similar to the corresponding parts in the frog and the dog. Certain technical differences are noted by anatomists, but in general plan or structure and in their functions, the skeleton and muscles are alike in all the higher animals.

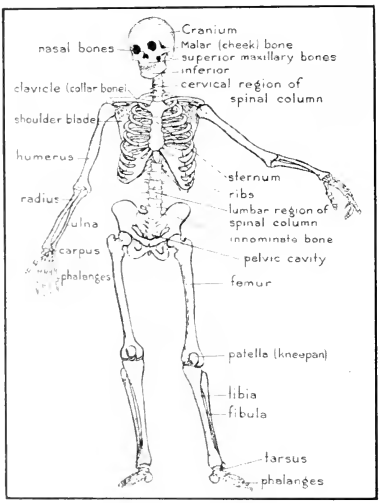


FIGURE 191. — SKELETON.

153. **The Skeleton.** — Unlike the rest of the body the skeleton proper is hard. It consists of bone and a comparatively soft substance known as *cartilage*, or gristle. There are cells in the bones just as there are cells in the liver, the muscles, and in the nervous system. So, like the other parts of the

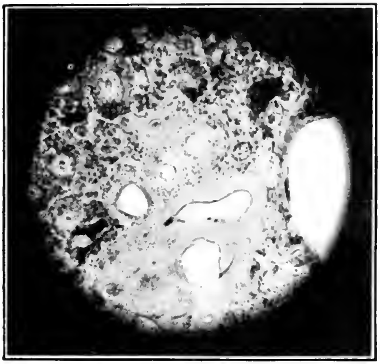


FIGURE 192. — MICROPHOTOGRAPH OF BONE.

Compare Figure 193.

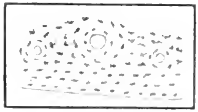


FIGURE 193. — DIAGRAM OF BONE STRUCTURE.

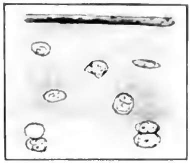


FIGURE 194. — CARTILAGE.

body, the bones grow because the individual cells are supplied with food from the blood.

Cartilage occurs near the ends of the bones, in the ear, and in the nose. It is especially prominent in the wrists and ankles of children. Therefore children should not be lifted by their hands nor allowed to stand until a

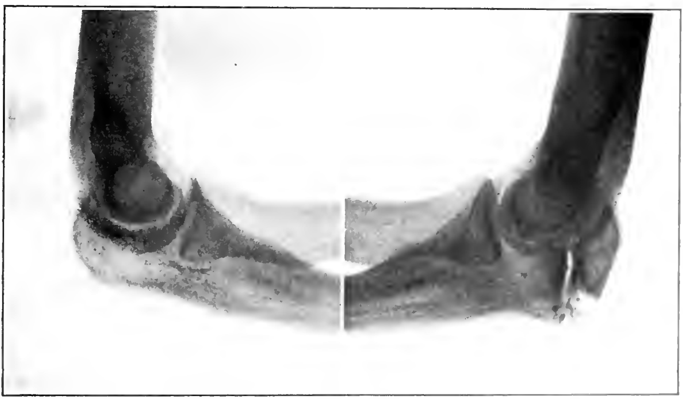


FIGURE 195. — X-RAY OF A NORMAL AND A BROKEN ELBOW.

certain amount of bone has taken the place of this soft cartilage.

When the bone of a limb is broken the physician sets it, *i.e.* places the broken ends together, and puts splints on the limb to keep the parts from slipping until the new bone has formed and hardened.

The joints of the bones of the arms and legs allow movements in many directions. The tearing or stretching of

FIGURE 196. — X-RAY OF HAND OF CHILD.

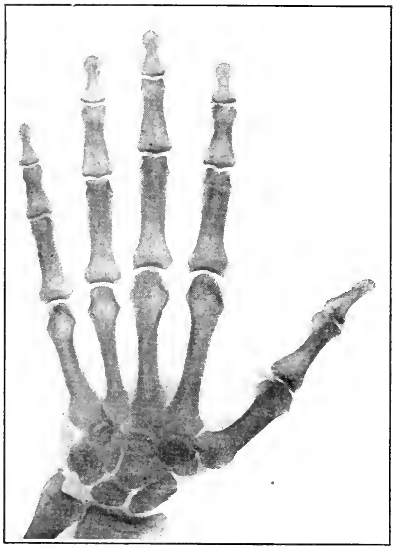


FIGURE 197. — X-RAY OF HAND OF ADULT.

the structures which hold the bones together at the joints is called a *sprain*. The joints in the spinal column allow only a limited movement, while the joints in the cranium are immovable and some of its bones gradually grow together.

The erect position of man gives to his skeleton important characteristics which the skeletons of other animals do

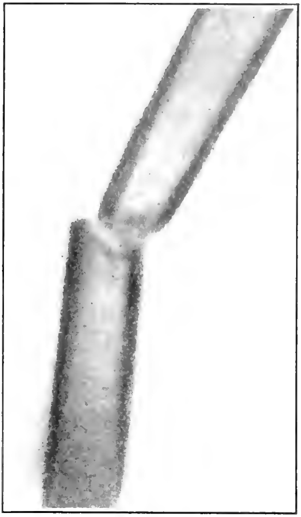


FIGURE 198.
BROKEN FEMUR.

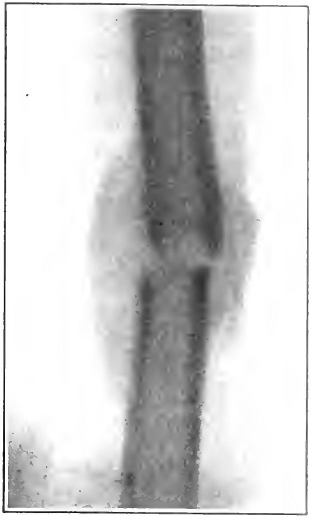


FIGURE 199.
SAME BONE TEN WEEKS LATER.

Notice the large "callus" of newly forming bone. An illustration of a poorly set bone. The broken ends of the bone should match. (Potter.)

not possess. Among these may be mentioned the curves in the spinal column, the large hip bones, and the heel and arch of the foot.

STUDENT REPORT

Make a report on the skeletal structures of animals as follows:

EXTERNAL

	ABSENT	JOINTED	NOT JOINTED	HORNY	BONY	INTERNAL
Paramœcium .						
Crayfish . . .						
Clam						
Frog						
Man, etc. . . .						

LABORATORY STUDY

Study the skeleton, and examine long, flat, and irregular bones. How is the bone modified to do its work?

154. Muscles. — The muscles are the lean parts of the flesh of animals and are usually dark in color. Birds are an exception, for their breast meat is generally white. Muscles are of two kinds: *voluntary* (governed by the will), such as those which we use in walking, or in moving the arms; *involuntary*, such as those which move the food along the digestive tract or assist in breathing.

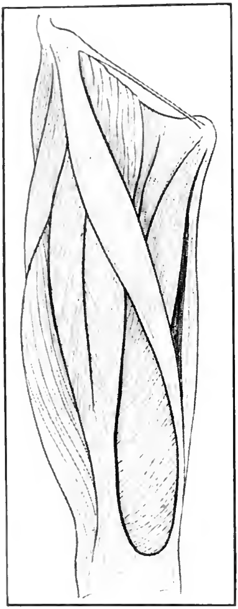


FIGURE 200. — MUSCLES OF UPPER LEG.

Note how they are arranged in bundles.

The voluntary muscles consist of many long muscle cells (fibers) bound together into a distinct bundle. Usually the muscle bundle is attached at each end to the bones. A single muscle moves the arm in one direction only, and in order to lift the arm from the desk to the head, for instance, several muscles must act together.

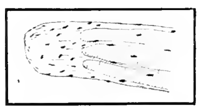


FIGURE 201. — VOLUNTARY MUSCLE CELLS.

Showing how the cells are bound together with connective tissue. At the end of the muscle, the cells of the connective tissue form the tendon.

The cells of the involuntary muscles are unlike the cells of the voluntary muscles. Involuntary muscle cells occur in layers in the walls of the digestive tube, blood vessels, the bladder, and the like, and they are not under the control of the will.

The muscular tissue of the heart has characteristics of both the voluntary and involuntary muscles, so that it may almost be said to belong in a special class.

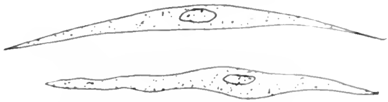


FIGURE 202. — INVOLUNTARY MUSCLE CELLS.

155. Skin. — The skin covers and protects the voluntary muscles, regulates the body temperature, gives off waste matter, and acts as a general sense organ. The outer layer of skin is called the *epidermis*, and is chiefly composed of dead cells. These outer cells are constantly breaking off, a process which is most apparent in the case of sunburn. Whatever *pigment*, or coloring matter, there is in our skin is located in the inner cells of

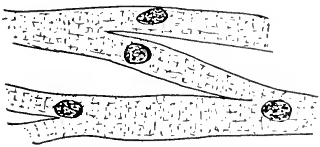


FIGURE 203. — HEART MUSCLE CELLS.

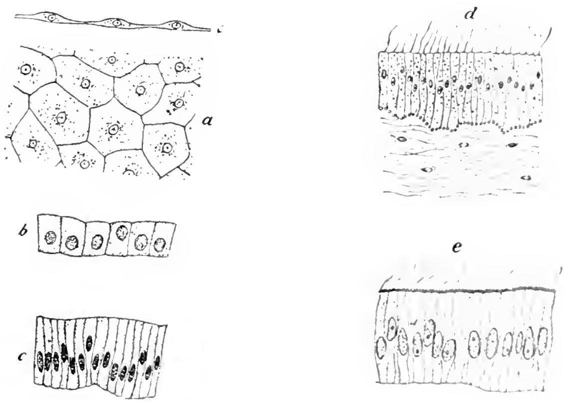


FIGURE 204. — VARIOUS FORMS OF CELLS IN HUMAN BODY.

a, side and top view of flat epithelium; *b*, *c*, columnar epithelium *d*, *e*, ciliated epithelium. How do these cells differ from the muscle cells in Figures 201–203?

the epidermis. The amount and kinds of pigment determine whether a person is of light or dark complexion, white, black, or yellow. These inner cells are constantly growing new cells to replace the cells which scale off.

The nails and the hair arise in the outer layer of the skin. Other structures which arise in the same way are the scales of fishes and snakes, the hoofs and horns of cattle, and the feathers of birds.

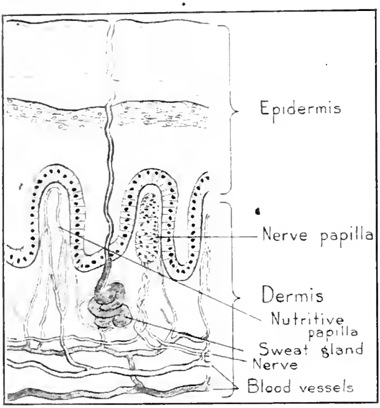


Figure 205. — Diagram of Skin.

The inner layer of the skin is the *dermis*, and contains blood vessels, nerves, connective tissue, the sweat glands, and sense organs of touch. It is estimated that there are over two million sweat glands in the skin of a man. Their work is to eliminate waste substances from the blood and to keep the body temperature normal (98.4° F.) by regulating the amount of perspiration excreted. The amount of perspiration is influenced both by the temperature of the body and of the air. The evaporation of perspiration keeps the body at the normal temperature.

SUMMARY

Man has a skeleton covered by muscles and skin. The bones grow and are fed just like the muscles. This is proved when the broken bone heals. The muscles are the flesh covered by the skin. The muscles are both voluntary and involuntary. The skin is made up of several layers of cells. Nails and the hair grow from the outer layers. The sense of touch is in the skin.

QUESTIONS

How does the skeleton of man compare with the skeleton of the crayfish? How do bones grow? Why do they grow? When is there the most cartilage in our skeletons? How many kinds of muscle are there? What is the work of each? What is the work of the skin? Of what is the skin composed?

CHAPTER XVII

RESPIRATION, BLOOD, AND EXCRETION

156. Respiration is the life process in which oxygen is used in, and carbon dioxide eliminated from, the cells of the bodies of plants and animals. All animals carry on respiration, and in all the process is alike, although the various animals use different structures to secure the interchange of oxygen and carbon dioxide. The hydra and earthworm use the entire surface of the body in this process; the fish has special organs, the gills, while the frog and man have lungs.

STUDENT REPORT ON RESPIRATION

	Get Oxygen		Get Rid of Carbon Dioxide		Breathe Through				
	Water	Air	Water	Air	Skin	Gill	Lung	Air tubes	Leaves
Amœba									
Crayfish									
Fly									
Clam									
Toad									
Bird									
Man									
Bean									
Yeast									

In order to help comparison the teacher may explain about the plant.

Organs of Respiration in Man. — Air enters the nose and passes into the windpipe or trachea (trā′kē-ȧ). The opening into the windpipe is covered by the *epiglottis* (Greek, *epi*, upon; *glotta*, tongue), which is raised during breathing and closed when food is swallowed. The windpipe divides into two branches, one entering each lung. Each branch is called a *bronchus*. The windpipe and bronchi are the air passages which carry air to the lungs. These passages are kept open by numerous stiff cartilage rings, which, in the trachea, are not entirely complete on the side of the esophagus, and in the smaller tubes even less so.

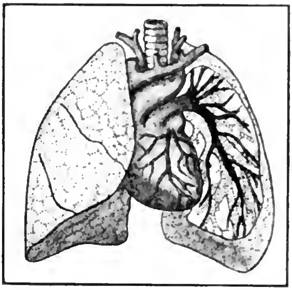


FIGURE 206. — LUNGS AND HEART.

Note the branches of the bronchus and blood vessels on the right side.

On entering the lung each bronchus divides into branches which in turn branch out again and again, until the entire lung is penetrated in all its parts by these passages. Finally each branch ends in a small pouch-like sac called an air cell. The walls of the air cells are thin, and the cells themselves are surrounded by minute branches of the blood vessels. It is estimated that the highly folded condition of the walls of the bronchi make a surface larger than the entire surface of the body. All these thin walls of the lungs and blood vessels are adapted to the passage of oxygen into the blood.

The lungs of man, then, consist of two large bronchial air tubes, many branches of the bronchi, air cells, blood vessels, and a few nerves, all bound up into two definite bodies (Figure 206).

The voice box or larynx (lăr′ĭnks) is found just below the opening into the windpipe and is called "Adam's apple." The larynx is formed by several large pieces of cartilage lined with a mucous membrane. On the inside

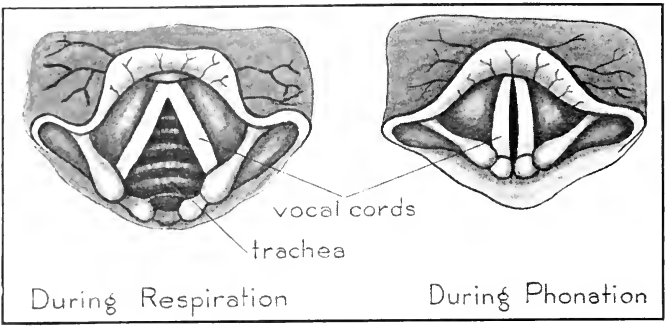


FIGURE 207. — VOICE BOX OR LARYNX.

of the larynx project two folds of elastic tissue which are called the *vocal cords*.

157. **Breathing.** — The lungs are elastic and can be squeezed like a sponge. *Inspiration* is the term applied to the taking of air into the lungs, and *expiration* to the forcing out of air. When air is drawn into the lungs, the chest expands, and the *diaphragm* (Figure 208), the horizontal muscle which divides the lung cavity from the abdomen, is drawn down. Thus the chest cavity is enlarged and air is sucked into the lungs. In expiration the air passes out gently.

When we breathe naturally, only a small part of the air in the lungs is exchanged at each inspiration and expiration, but by breathing deeply a few times we can remove the larger part of the air from the lungs and replace it with fresh air.

The natural rate of breathing is about eighteen times a minute, but the rate is higher in persons with a small lung capacity. Exercise increases the rate of breathing. Explain why exercise out-of-doors is better for us than that taken indoors.

All the air passages are lined with cells bearing numerous cilia (Figure 204), and these cilia are constantly in motion. Their work is to carry toward the mouth the particles of dust and other foreign materials brought in by the air. This foreign matter is removed when we cough or clear our throats. Explain why clean air is better for us than dirty air.

The air that enters the lungs is rich in oxygen and there is some oxygen in the air which is expired. But the proportion of carbon dioxide is greater in the expired air of plants and all animals.

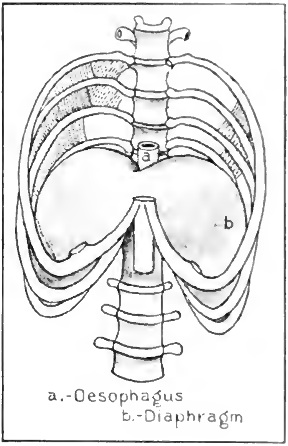


FIGURE 208. — DIAGRAM OF THE DIAPHRAGM.

Note the position at the bottom of the thorax.

Ventilation.—Associated with the question of breathing is the problem of supplying our homes with fresh, clean air. Every one feels better after a walk in the open air. How to have plenty of fresh air in our rooms is a difficult problem. One of the difficulties is to get the air down to the breathing line and not stir up the dust on the floor. Figures 209 and 210 show the best plans for ventilating a room. They are adapted to the two common methods of heating, hot air and steam or hot water. They show the course taken by the currents of fresh air entering the room at night with the window open, and in the daytime with it shut.

Exercise. — Even if the home is furnished with fresh air, we should observe good habits of breathing. When we walk out-of-doors, we should take plenty of fresh air into our lungs in a series of deep breaths. All young people should take exercise in the open air, because such exercise develops all the organs and makes them strong. Thus the whole body becomes more robust and better able to withstand disease and to do its work.

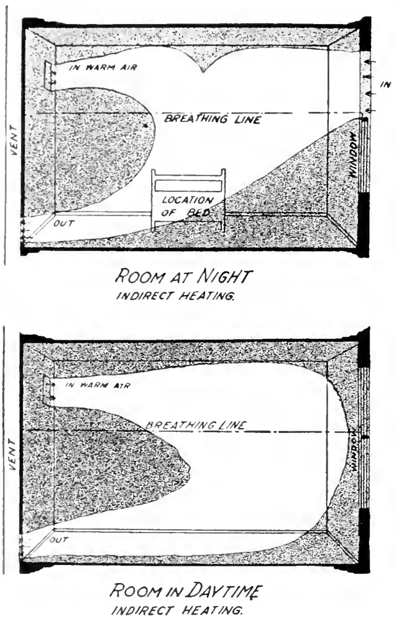


FIGURE 209. — HOT-AIR HEATING.
By Earl Hallenbeck.

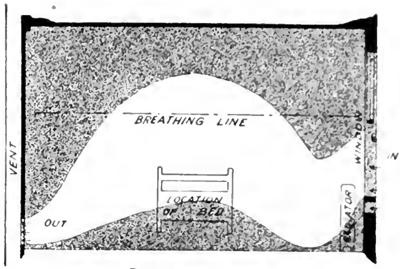
Suffocation. — When the body is deprived of a sufficient supply of oxygen, suffocation results. This is what happens in drowning or when the windpipe becomes closed.

In many cases a person who is suffocating may be saved through artificial respiration. This is the name given to a series of movements which are used to restore natural breathing. The simplest method is to place the patient on his back, with the head lower than the hips. Then raise the arms upward and outward until they come together above the head. This movement enlarges the chest cavity and helps to draw air into the lungs. The air is forced out of the lungs by bringing the arms back to the side of the body and pressing gently against the sides of the chest. This series of movements should be repeated gently every few seconds, and may have to be continued for hours before natural breathing is restored.

Diseases of the Respiratory Tract. — The most common of these diseases is a cold located in the nose and throat. The nasal passages become clogged with mucus which contains many germs. These germs are widely distributed in sneezing.

Diphtheria is a germ disease which is located in the throat and nose. For many years diphtheria was one of the most deadly of our diseases, but through the use of the diphtheria antitoxin the danger has been greatly reduced.

Tuberculosis of the throat and lungs is a widely distributed disease which causes many deaths each year. See page 235.



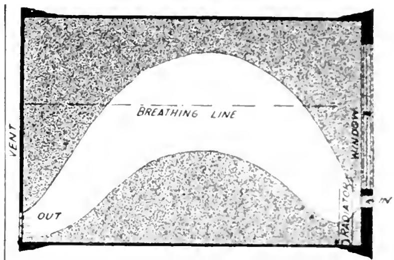


FIGURE 210. — STEAM HEATING.
By Earl Hallenbeck.

158. **Blood.** — The blood is the fluid which circulates through the heart, arteries, and veins, supplying nutritive material to all parts of the body. Blood is made up of a fluid (plasma) which contains cells or corpuscles (Latin, *corpusculum*, little body). The blood cells or corpuscles are of two kinds, red and white.

The red corpuscles are colored with a substance called *hœmoglobin* (hē-mō-glō′bĭn: Greek, *haima*, blood; *globus*, ball). When a few of these corpuscles are examined through a microscope, they appear yellowish instead of red; but when a large number of them are seen in a mass, the red color is apparent. When the red cells are first formed, they have a nucleus which gradually disappears. As a result, the mature red corpuscles, unlike all the other cells we have studied thus far, have no nucleus. Red corpuscles are about $\frac{1}{3200}$ of an inch in diameter and $\frac{1}{12400}$ of an inch thick.

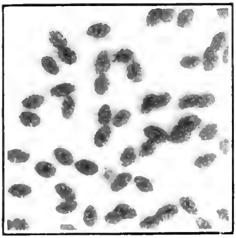


FIGURE 211. — MICROPHOTOGRAPH OF BLOOD OF FROG.

The red corpuscles carry oxygen from the lungs to the cells of the body. This oxygen unites with the hæmoglobin. By osmosis the oxygen passes from the blood to the body cells which are deficient in oxygen. These cells take the oxygen and use it in the process of oxidation, which goes on continuously in every living cell. A good supply of red blood corpuscles is, therefore, necessary, if the cells of the body are to have a sufficient supply of oxygen. The feeding of the cells with oxygen is one part of respiration.

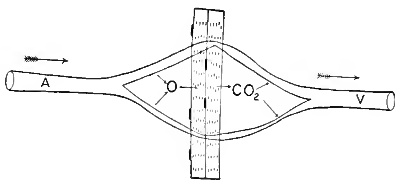


FIGURE 212.

As the blood flows through the capillaries which are found in all voluntary muscles, for example, oxygen and other food products are given off to the muscle cells, and carbon dioxide and other waste substances pass off from these same muscle cells into the capillaries on the way into the veins.

At the same time that oxygen is received from the blood by the body cells, carbon dioxide is given off. Again osmosis explains the method of this transfer. Most of the carbon dioxide is

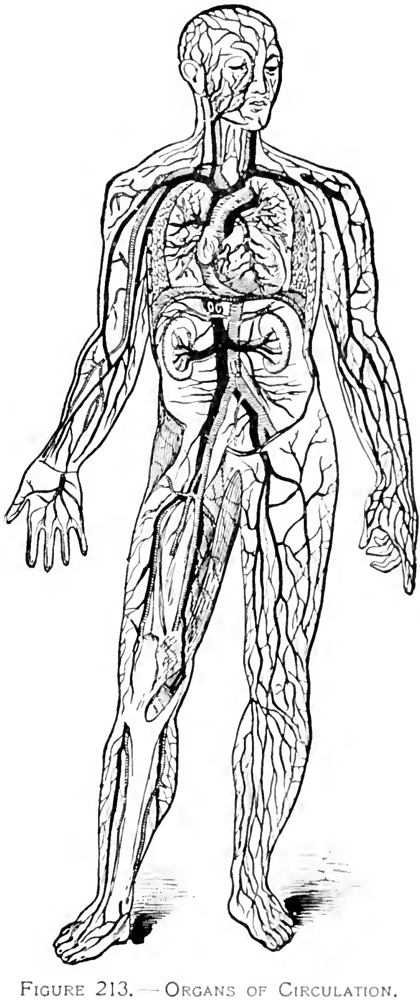


FIGURE 213. — ORGANS OF CIRCULATION.

Veins, black; arteries, with transverse lines. Left side of figure shows superficial vessels, while right side shows deeper vessels.

carried by the plasma, although some of it unites with the hæmoglobin.

White blood corpuscles are much like the amœba in that they are colorless and can change their form. They move about in the body and often leave the blood vessels and collect at one place to aid the body in destroying disease germs.

The blood plasma is straw-colored and varies in composition from day to day, and hour to hour. It contains the foods on their way to the cells and waste products on their way to the kidneys, lungs, or skin.

The volume of blood in the average person is about six quarts.

When exposed to the air, blood forms a clot, because of the presence of a substance (*fibrinogen*) which produces fibers that hold the red and white corpuscles.

Student Report on Blood

Name of Animals	Not Colored	Colored	Color in Plasma	Color in Corpuscles	Not in Vessels	In Vessels	No Heart	Heart

159. **Heart and Blood Vessels.** — The blood is carried from the heart to all the cells of the body and back to the heart again and again. The heart serves as a pump to force the blood along. The heart is about the size of the fist and has strong muscular walls. In a healthy person, it contracts regularly about seventy times a min-

ute. It is obvious, therefore, that the work which the heart does is very great.[1]

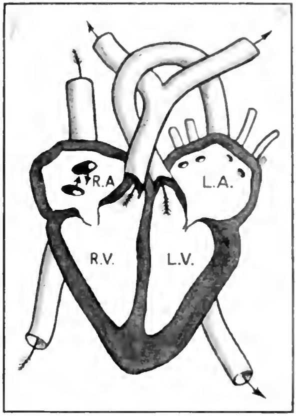


FIGURE 214. — HEART.

The heart is located in the *thoracic*, or chest cavity, a little to the left side and between the lungs. It is a cone-shaped organ, inclosed in a membranous bag called *pericardium* (pĕr-ĭ-cär′dĭ-ŭm: Greek, *peri*, around; *cardia*, heart).


FIGURE 215. — DIAGRAM OF VEIN.
Showing the valves.

The heart is divided by a wall into right and left chambers. A nearly complete cross partition divides each side into upper chambers, the *auricles*, and the lower ones, the *ventricles*. The opening between an auricle and a ventricle is guarded by a valve, which is partly membranous and partly muscular. The auricles receive blood from the veins, while the ventricles force blood into the arteries.

Artery is the name given to the blood vessels which carry blood from the heart, and *vein* is the term applied

[1] "The work the heart does during the day is about equal to the energy expended by man in climbing to the top of a mountain 3600 feet high. Assuming that the man weighs about 150 pounds, this would be equal to an amount of energy sufficient to lift 90 tons to a height of three feet. The work of the left side is greater than that of the right, since the former has to drive the blood all over the body, while the latter has only to force it to the lungs which are near by. For this reason the muscle walls of the right ventricle are much thinner than those of the left ventricle." — CONN AND BUDDINGTON.

to the vessels which return blood to the heart. There is little structural difference between the veins and arteries except that the walls of the arteries are thicker, and there are no small valves as in the veins. As the branches of the arteries become minute, the walls become much thinner, thus allowing the food and oxygen to pass more easily to the individual cells. These minute branches are called *capillaries* (Latin, *capillus*, hair). From a cluster of capillaries a small vein begins which soon connects with a slightly larger vein, which leads back to the heart through larger and larger veins.

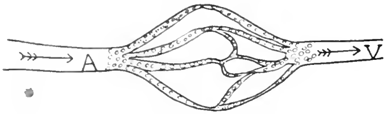


FIGURE 216. — DIAGRAM OF CAPILLARIES.

The artery breaks up into minute branches, the capillaries, which in turn unite to form veins.

The blood follows a regular course through the body, passing from the left ventricle into the *aorta*, which is the largest artery in the body. As soon as the aorta leaves the heart, smaller arteries branch from it, and the aorta itself also branches until the entire body is supplied with blood. The right ventricle gives off a short artery which divides, and a branch enters each lung. At the point where an artery leaves a ventricle, there are three half-moon-shaped valves which prevent the blood from flowing back into the heart (Figure 215).

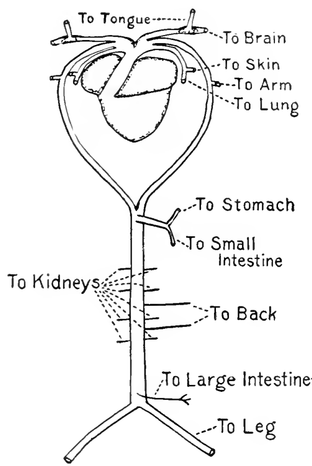


FIGURE 217. — MAIN ARTERIES OF FROG.

The blood which is carried into the lungs contains a large amount of carbon dioxide which gives it a dark color. In the lungs the carbon dioxide is given off and oxygen taken up, so that when this blood is returned to the left auricle, it is of a bright red or "arterial" color.

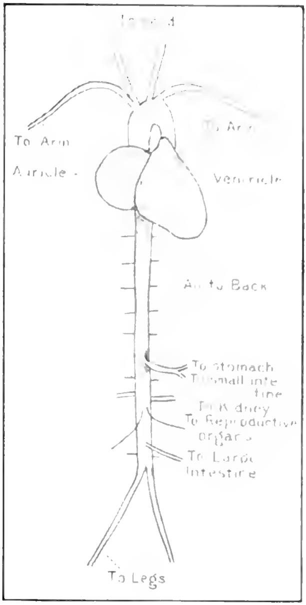


FIGURE 218. — MAIN ARTERIES OF MAN.

Compare with Figure 217.

Every time the heart beats the blood is forced into the arteries in waves which can be felt in the wrist or neck by placing the finger over an artery. The wave is called the *pulse*. By counting the number of waves each minute, the rate at which the heart beats is determined. When a person runs or takes violent exercise, the pulse rate increases. It is advisable to know what our usual pulse rate is, for an increased pulse rate is sometimes an indication of approaching illness.

Lymph. — As the blood flows through the capillaries, part of the plasma passes through the thin walls into the spaces between the cells and bathes the cells. This fluid which escapes from the capillaries is called *lymph* (lĭmf). It is composed of digested food, water, and other substances. The cells take up the food which they need and cast back into the lymph the wastes which they have formed in the process of growth and repair. These spaces between the cells are small and irregular in shape. The spaces, however, form a sort of mesh, or net, the parts of which join, forming larger vessels, and finally all the lymph is collected into two large vessels which open into veins. Thus there is the *lymphatic circulation* which differs from that of the blood in several ways. (1) There is no special organ for forcing the lymph along, the circulation depending mainly upon the movement of the muscles.

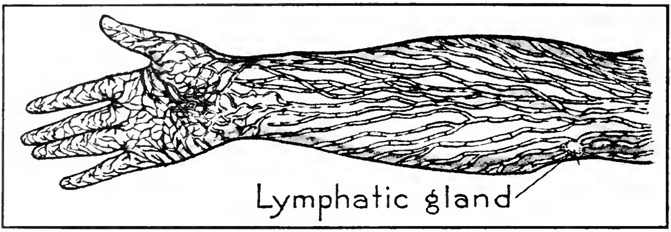


FIGURE 219.—SUPERFICIAL LYMPHATICS OF ARM AND HAND.

(2) The lymphatic vessels are imperfect in the beginning, being only irregular spaces. (3) The lymph contains no red corpuscles and only a few white corpuscles.

Cuts. — Since every part of the body inside the skin is traversed by blood vessels, we cannot injure any part without breaking at least some of the blood vessels. A small cut causes the blood to flow only from capillaries, and it flows slowly and in small quantities. If a vein is cut, the blood will be dark in color, and will flow in larger quantities, but steadily. A severed artery sends out bright red blood in waves corresponding to the beat of the heart. To stop the flow of blood from a vein, compress the vein beyond the cut; from an artery compress the artery between the cut and the heart. In either case remain quiet to aid the blood to form a clot.

Exercise. — The object of a circulatory system and of a circulatory fluid is to supply every cell in the body with food and to carry away the waste. The more active the process of circulation, the more perfectly is this object accomplished. It is the common experience that the heart beats more rapidly, the lungs work harder, and the body becomes warm after a few minutes of vigorous exercise. These changes have a decidedly beneficial effect upon building up the body and removing the wastes.

In most kinds of work only one set of muscles is used. This set gets a full supply of blood, but others get less than a full supply and so they get too little food and accumulate too much waste. Every one should, at some time in the day, take exercise in the open air which will bring all his muscles into play. If it is enjoyable exercise, the effects upon the mind react favorably upon the body. This is the advantage of such exercises as skating or baseball. In the winter it often requires real effort to force oneself to leave a warm room and to go out for exercise, but if one is properly clothed, cold air has a bracing effect not obtained at any other time of year.

Fainting. — Fainting is due to an insufficient supply of blood in the brain. This lack of blood may arise from several causes, but the most common is some disturbance of the digestive processes, which causes the heart to beat too slowly. A fainting person should be placed flat on his back, if possible, with his head slightly lower than the rest of his body, and should be given plenty of fresh air. A dash of cold water in the face, or a bottle of ammonia held to the nostrils, is often helpful in restoring consciousness.

The Effect of Drugs and Alcohol. — "The flow of the blood is modified by various drugs, some causing the blood to flow more rapidly, others more slowly. Coffee causes the heart to beat harder and at the same time causes some of the arteries to become smaller. For this reason it is called a stimulant." — CONN AND BUDDINGTON.

It has been stated frequently that alcohol increases the activity of the heart. Careful experiment, however, shows that not only is the effect not that of a stimulant, but that when used in large amounts, it markedly weakens the action of the heart. If taken only in small amounts, the heart sometimes shows a slight increase in its rate of beating, but this occurs only when the brain becomes excited, and if the person is kept quiet no change in the heart beat is noticeable. Thus the primary action is on the brain.

"A second effect of alcohol is more evident. The small blood vessels in the skin are enlarged. This produces a flushed skin, a feeling of warmth, and a false feeling of increased circulation. Its result is to send more blood through the skin with consequent extra loss of heat. This action is evidently not due to stimulation, but to the relaxation of the muscles, and is thus a decrease of activity rather than an increase, even though the blood does flow a little more rapidly through the skin. These facts make it clear that alcohol cannot be properly called a stimulant of the circulatory system." — CONN AND BUDDINGTON.

160. **Excretion.** — Every animal uses energy in carrying on its work. During this process a certain amount of waste substance is produced, which has to be removed from the body. The skin, kidneys, and lungs are the chief organs which assist the body in getting rid of this waste. When any part of the living cells is broken down in the simple act of living, a waste product results. By osmosis these waste products enter the blood and are removed by the lungs, which give off carbon dioxide; by the sweat glands in the skin; and by the kidneys, which remove the wastes that contain nitrogen. The sweat

glands and kidneys are usually regarded as the excretory organs of man. These organs remove from the blood the wastes which have been excreted by the cells of the body. The excretion from the living cells is one of the fundamental life processes of all plants and animals. This form of excretion should not be confused with the indigestible part of the food which is not taken up by the blood and which passes out through the large intestine as fæces.

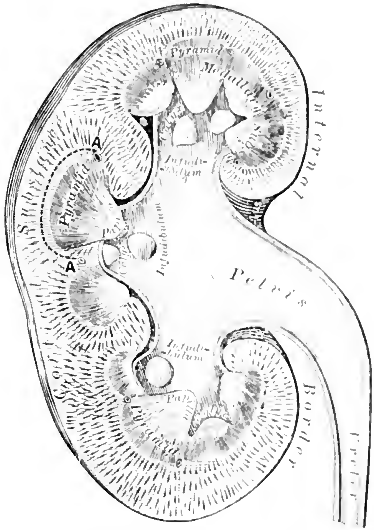


Figure 220. — Section of Kidney.

The kidneys are two bean-shaped organs located in the abdominal cavity, one on each side of the "small" of the back. Each is about four inches long, two and a half inches wide, and half an inch thick. The color is a dark red. The kidney is made up of two layers, the outside or *cortical*, and the inside or *medullary*. Each layer is composed of many small tubes (*tubules*) which open into an area called the *pelvis*,[1] the space within the kidney. The pelvis continues into a duct (*ureter*), and from each kidney the ureter passes into the *bladder*. A small duct (*urethra*) connects the bladder with the exterior of the body.

Each tubule in the kidney is in close relation with the

[1] The word *pelvis* is also used in referring to the hip bones, and it is better to call the latter structure the bony pelvis.

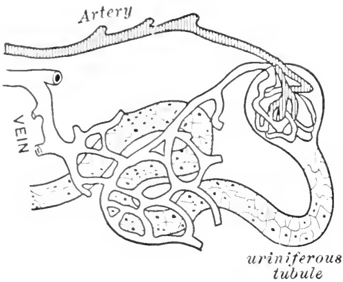


FIGURE 221. — DIAGRAM.

Showing relation of artery and vein to portion of minute kidney tube (uriniferous tubule).

blood capillaries. At the place where this close relation takes place, *glomerulus* (glŏ-mĕr′ū-lŭs), the walls of the capillary and the walls of the kidney are very thin. Through these thin walls a large amount of water filters out of the blood into the tubes. At the same time waste material which contains nitrogen, salts, and other organic wastes is removed. If these wastes are not removed, they create toxins which poison the body.

SUMMARY

All living things breathe oxygen which, in the higher animals, is carried by the blood to the cells of the body. The parts which man uses in breathing are more highly developed than in any other animal. Man has a voice box, the larynx, by means of which he is able to make a wide variety of sounds. The blood of man is similar to the blood of all the other vertebrates, although not identical. It consists of red and white corpuscles which move freely in the plasma. The blood is confined in the blood vessels through which it is forced by the heart. Excretion includes the waste products derived from living protoplasm. The kidneys and sweat glands remove the liquid wastes from the blood.

QUESTIONS

Compare the respiration of man, the hydra, and the earthworm. Compare the lungs of man with the gills of a fish. What is blood? What is its use? What is the difference between veins and arteries? Explain the work of the kidneys and of the lungs

CHAPTER XVIII

THE NERVOUS SYSTEM OF MAN

161. **Parts of the Nervous System.** — The nervous system of man consists of the same general parts as the nervous system of the frog (See page 118). There is a brain and spinal cord, from which nerves extend to the special senses, the muscles, the heart, and the stomach. When the brain of man is compared with that of the frog, it is obvious that the cerebrum of man is proportionately larger. Although some of the other parts of the brain appear unlike the corresponding regions in the frog, scientists tell us that they are really the same.

162. **The Nerve Cell.** — The nervous system of man consists of many thousands of nerve cells which differ from all other cells in having more parts and branches (Figures 223, 224, 225). The nerve cells are unlike other cells in appearance, although they have the usual parts. Examination shows that the nerve cells have a prominent nucleus surrounded by cytoplasm, which grows out into a number of branches called fibers. The shorter branches divide and form, together with the branches from the neighboring nerve cells, a mass of tangled fibers. There is usually one unbranched fiber, perhaps several feet long, which ends either in the skin, in some muscle, or in the nervous system. When this long fiber reaches the muscle or skin, it divides into several fine branches. All of these branches which arise from a nerve cell belong to it, and in this connection the word cell includes all the branches, the nucleus, and the cytoplasm.

163. The Location of the Nerves. — The nerve fibers which have the same work to do occupy certain definite places in the brain or spinal cord. So a student of the nerves can tell the route which the stimulus arising from feeling a pencil must travel before reaching that part of the brain where it is interpreted as a pencil; or the route over which the stimulus arising from tasting candy must pass before it is known to be candy. When we see the pencil or the candy, the route over which the sight stimuli of these two objects travel is not the same as that of the feeling of the pencil or tasting the candy. The nerve cells which interpret the stimulus arising from feeling the pencil or from tasting the candy or seeing the pencil and the candy are probably not the same. We may say, therefore, that the spinal cord and brain are made up of many

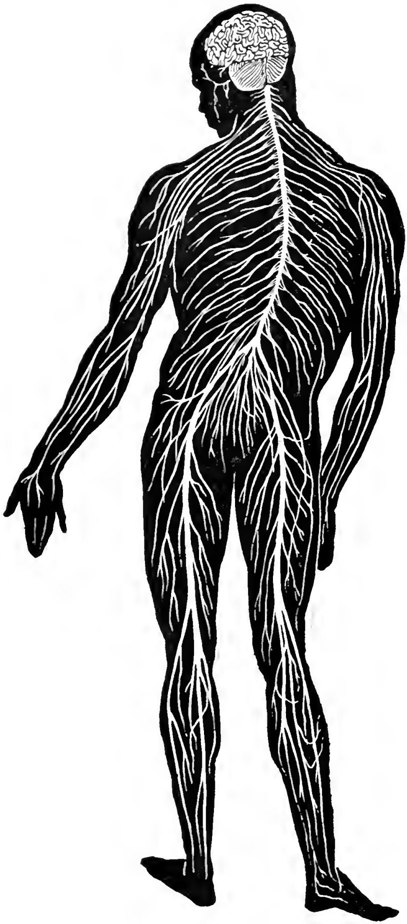


FIGURE 222. — NERVOUS SYSTEM OF MAN.

special nerve pathways which end in nerve cells that interpret stimuli.

The nerves which connect the central nervous system, that is, brain and spinal cord, with all parts of the body, consist of many long nerve fibers. Each nerve looks like a small white thread and is covered with a thick, fatty sheath (medullary sheath). In the living animal, this fatty sheath is white and the nerve fibers so covered are found to occupy a certain part of the spinal cord and brain. Thus, we get the name *white substance*. Other of the nerve fibers and cell bodies are not covered with a sheath and so have a gray appearance. Thus we have the term *gray substance* in connection with the nervous system.

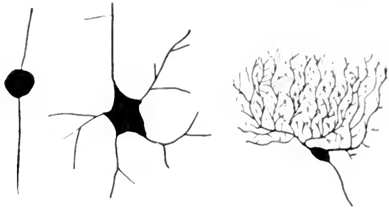


FIGURE 223. — NERVE CELLS.

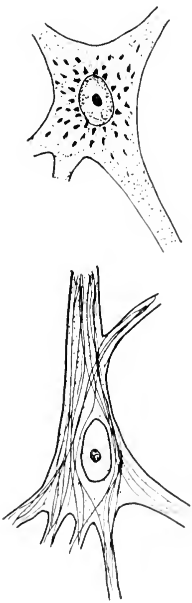


FIGURE 224. — NERVE CELLS.

164. Growth of the Nervous System. — The nervous system of man, like all other parts of the body, has a definite beginning and grows in an ordered manner. Not only is this true in man, but also in the frog and fish. The tissue of the embryo, which is to grow into brain and spinal cord, gradually changes until the adult parts are formed. During this early period of growth, the nerve cells send out processes which become nerve fibers, so that at birth the nervous system is ready to go to work. Indeed, nearly all the nerve cells which

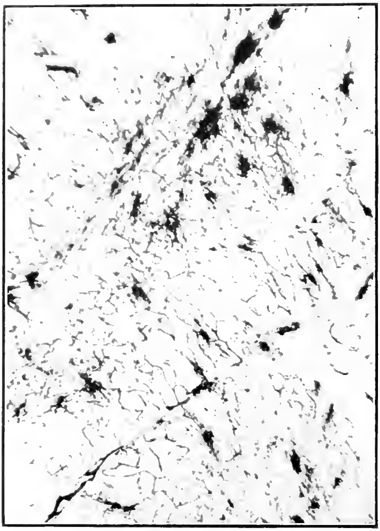


FIGURE 225. — MICROPHOTOGRAPH OF BRAIN.

The nerve cells are black.

the human being is ever to use are made before birth. These cells gradually become more active and the different parts of the brain work more perfectly as we go through the periods of childhood, youth, and maturity. The brain becomes a more perfect working organ by making the brain cells do their specific work over and over and over, until each group of cells can be relied upon to do a definite thing.

165. Reflex Action. — Reflex action is the simplest form of nervous activity in man. For example, when the finger is placed on a hot stove and suddenly

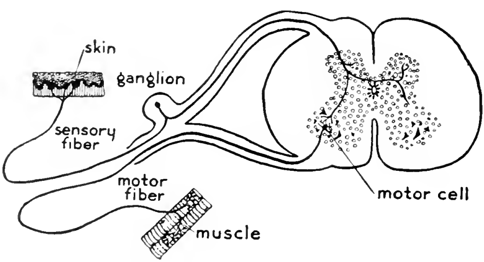


FIGURE 226. — DIAGRAM TO SHOW REFLEX ACTION.

The stimulus comes in contact with the skin and is carried to the spinal cord. It then passes to the motor cells which carry the order to the muscle. The same skin stimulus goes to several other parts of the spinal cord.

withdrawn the following actions take place. The heat stimulus affects the nerve endings in the finger and that stimulus is carried to the spinal cord. If this were all that occurred, the finger would burn, because this stimulus and the nerve fibers over which it travels have no control over the muscles. The removal of the finger calls into play another set of nerve cells, — the cells which have their fibers ending in the hand and arm. All of these changes take place involuntarily, and the reaction to the stimulus is known as reflex action. Specific names are used in describing these several changes; the nerve fibers which connect the skin with the spinal cord and brain are called *afferent* (ăf′fĕr-ĕnt: Latin, *ad*, to; *fero*, to carry) fibers because the stimulus always travels toward the brain.

Their function is sensory, for they carry the stimulus to the brain. The fibers which connect the muscle with the brain or spinal cord are the *efferent* (ĕf′fĕr-ĕnt: Latin, *ex*, from; *fero*, to carry) fibers, because they carry their message away from the central nervous system. Their function is motory. In the special instance we are studying, the heat stimulus causes the spinal cord to send a special message to the muscles of the finger, so that the latter is removed from the stove.

This is a typical illustration of the simplest way in which the nervous system works, but in most reflex actions there are other results. After the finger has been removed from the hot stove by reflex action, we soon realize that the skin is burned, the realization coming through the smarting sensation. This second stimulus has been carried to the brain, and we are now conscious of the stove, heat, burn, etc. If there were no afferent nerve fibers, the individual could not experience any pain when hurt.

The afferent and efferent nerves, whether in reflex or in general nervous action, never vary in the work which they do. The sensory afferent nerves form the only paths over which our knowledge of the outside world travels to the brain. The stimuli which cause the different sensations, such as taste, sight, etc., have their individual paths and receiving organs. This is indicated by the fact that no other nerves than those of the ear are ever affected when we hear.

Reflex Action in the Frog. — The frog, like man, is able to act in a definite way. If any one approaches a frog while it is sitting on the edge of a pond, it jumps into the water, stirs up the mud, and then returns to the shallow water near the place where it entered. The frog, in this case, acts as if it, or its ancestors, had learned that this is the best way to escape enemies. While this series of acts is called a habit, it is really a series of reflex acts which are similar to the reflex action described for man, and require the same nerve structures.

Reflex Action in the Earthworm. — If a light is flashed on an earthworm at night, the worm will quickly withdraw to its burrow, before it can be seized. The earthworm has no eyes, but it is able to respond to light and can tell the difference between night and day. It is believed that special nerve cells in the skin, which are connected with the nerve ganglia, help the earthworm to become aware of the light stimulus.

Reflex Action in Hydra. — Hydra is a minute water animal which has no definite nervous system, but only a few nerve cells scattered through the body. As the hydra waves its arms about in the water, there seems to be no purpose in its motions. But if a water flea swims against one of the tentacles, a part or all of the tentacles at once begin to carry the flea to the mouth of the hydra.

The hydra, then, without a definite nervous system, can carry out a definite reflex action.

Reflex action is similar in all animals. In all of these illustrations, it is necessary for the stimulus to be received by an afferent nerve, or some structure which can do the same work, and for the stimulus to be transformed into a series of purpose-like movements.

166. **Sense Organs.** — All of the higher animals have eyes, ears, a nose, and a tongue. Each of these organs contains nerves specialized to respond to a certain definite kind of stimulus. The result of this specialization is that not only are these special sense organs complex in structure, but also the region of the brain which receives their messages. The ear nerve responds to a stimulus of air-waves of a certain length, and we say we hear a sound. The eye nerve is stimulated only by light. Each nerve and the brain cells to which it sends its messages have become so specialized that practically only one kind of reaction takes place. For example, all stimuli acting upon the eye nerves are interpreted as light.

The skin is a simpler sense organ than the eye or ear, and tells us of pain and touch and the difference between heat and cold.

The Eyes. — The eyes of all vertebrates have the parts arranged in a similar manner. The eyeball is roundish and is located in the eye sockets of the skull, which are termed *orbits*. There is an upper and a lower eyelid, and the remains of a third eyelid in the corner next to the nose. The front of the eye is covered by a transparent membrane, the *cornea* (kôr′nē-à); and the rest of the eye is surrounded by a tough membrane, the sclerotic coat, or the white of the eye. Within the combined covering of the cornea and sclera are a number of structures which take part in receiving and transmitting the rays of light to the brain.

A cross section of the eye shows two more membranes in close relation to the sclerotic coat (Figure 227). The membrane in direct contact on the inside with the sclerotic layer is the *choroid* (kō′roid). The choroid coat is filled with blood vessels and pigment. Through this layer the food in the blood is distributed to the eye. The third layer or coat is the retina, which is composed of nerve cells and which is nearly transparent.

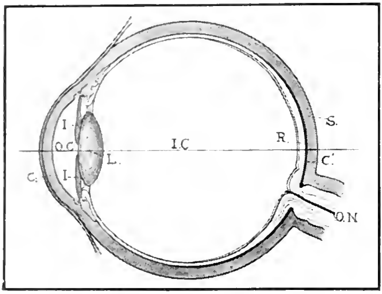


FIGURE 227.—SECTION OF EYE.

C, cornea; *C′*, choroid layer; *I*, iris; *I. C*, inner chamber; *O. C*, outer chamber; *L*, lens; *O. N*, optic nerve; *R*, retina; *S*, sclerotic coat.

The cornea and these three layers inclose two chambers which are separated by the *lens* (Figure 227). In front of the lens a curtain-like membrane, the *iris*, partly covers the lens, except for a round opening in the center which is called the pupil. The color of the eye, gray, black, blue, or brown, is due to the presence of pigment in the iris. The small front chamber is filled with a transparent fluid which is composed principally of water and is known as the *aqueous* (ā′kwē-ŭs) humor. The large back chamber is filled with a thin, transparent, jellylike fluid, the *vitreous* (vĭt′rē-ŭs) humor.

In order that we may see any object, a pencil in our hand, for example, two general conditions must be present. The picture (image) of the pencil must be placed on the retina, and this picture must be carried to the brain by the eye (optic) nerve. When these two conditions take place, we see.

As we have learned, the stimulus for the eye is always light. In physics we learn that the rays of light travel in straight lines. This fact explains why we cannot see round a corner. When the rays of light are made to pass through a glass lens, the rays which pass through the thin edges of the lens are bent and do not travel to the same place they would have reached had they not passed through the lens. In the same way light rays from an object pass through the lens in our eyes and are bent. This results in the image of the object, the pencil in this instance, being inverted on the retina. The light rays of the pencil stimulate the nerve cells in the retina, and this stimulus, after being carried to the brain, is interpreted to us as a pencil, though we do not know how stimuli travel on nerves. The inverted image of the picture on the retina is made to look natural to us because we are used to seeing everything in inverted images.

FIGURE 228. — HOW WE SEE THE PENCIL.

Care of the Eyes. — The eyes are our most precious sense organs, and as such they should receive the best of care. Certain imperfections in the lens or other parts of the eye can be helped by the use of glasses. If your eyes annoy you, or if you cannot see objects as clearly as your schoolmates, have a competent oculist examine and treat them.

The Ear. — The ear is a sense organ for the reception of the stimuli which we interpret as sounds. The ear of man consists of the outer, middle, and inner ear. The first two carry the stimuli to the third, where they are received by nerve cells and carried to the brain.

The diagram of the ear (Figure 229) shows the several parts and their relations. The outer ear leads to the *tympanic* (tĭm-păn′ĭk) cavity; the middle ear is in communication with the mouth, and the complex inner ear is partly shown. There is a group of small bones in the middle ear which conduct the sound vibrations to the delicate inner ear. The internal ear receives the various sound waves, and transmits them to the brain, where they are explained as sounds.[1]

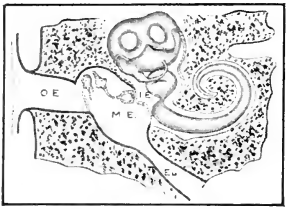


FIGURE 229. — PLAN OF EAR.

O. E, outer ear; *M. E*, middle ear; *I. E*, inner ear; *Eu*, eustachian tube.

Hearing.—Sound waves strike the ear drum (tympanic membrane), which in turn causes the small bones in the middle ear to vibrate. The bones cause the water in the internal ear to move, thus stimulating the nerves of hearing.

The pressure of air on each side of the ear drum is normally the same. This is due to the entrance into the middle ear of air from the mouth, through the eustachian tube (see page 166). This tube is a trifle more than an inch long. When it becomes closed, partial deafness results.

Defects in hearing may be caused by blows upon the ears, by the accumulation of wax in the ears, and by sore throat. When there is a continued ringing or hissing sound in the ears, consult a doctor at once.

167. **Brain Efficiency.** — While the efficiency of the brain depends upon mental training, in order properly to exercise the many functions of this organ at least three things

[1] When certain parts of the ear (semicircular canals) are injured, one has difficulty in standing or in walking erect. This is because the inner ear serves both as a hearing and a balancing organ.

are necessary: good food, sufficient sleep, and abstinence from alcohol and tobacco. We have already discussed the question of food (page 169).

The amount of sleep which grown people need depends in part upon the kind and amount of work they do. But all young people require a large amount of sleep. Children from seven to ten years of age need at least twelve hours of sleep every night, while youths of high school age need at least nine hours, and ten would be better.

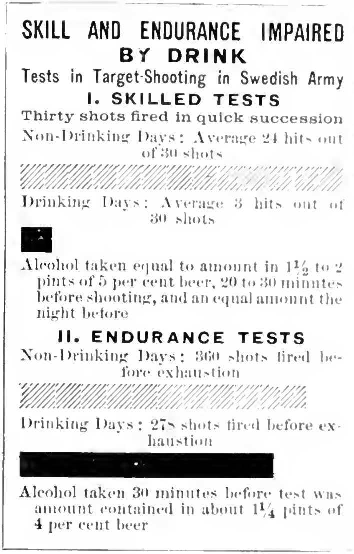


FIGURE 230.

At a baseball game, you have noticed a boy catch a "fly" when it looked like a "home run," or how enthusiastic the crowd became when the pitcher struck out the last man with the bases full. The nervous system of both players was efficient in a critical test.

We all ride on the street cars or railroads, but do you know that most of the men who run the street cars and trains have to pass an examination to determine whether they can be trusted to do their work properly and well; *i.e.*, whether their nervous systems will stand the test? Among the questions which their prospective employers are sure to ask is, "Do you use alcoholic drinks?"

In order to judge the success of a piece of work we must consider the quality and speed with which it is done. Kraepelin made the following experiment, the results of which show that both these elements in mental work are influenced by the use of alcohol.

Several men who were allowed to drink no alcohol utilized half an hour daily for six days in adding figures. Their ability to add increased each day. On the seventh day the work was begun under the influence of alcohol. In spite of the skill gained in the previous practice, their accuracy did not increase, but on the contrary began to decrease rapidly. On the nineteenth day the use of alcohol was stopped, and immediately an improvement in the work manifested itself; but on the twenty-sixth day, when the use of alcohol was resumed, a decided decrease in the power of adding manifested itself.[1]

It is difficult to estimate how efficient each of us may become in our life work, but one thing is certain, that if we use alcohol, we shall lose that perfect control over our nervous systems, which enabled the two players to be so efficient in the ball game. It is also equally certain that if we use alcohol, we shall find fewer men willing to employ us in places of responsibility, not only because of our

[1] Schiller was wont to say, "Wine never invents anything," and Helmholtz, one of the greatest observers and thinkers of the nineteenth century, noted in himself the effect of alcohol in interfering with the highest powers of thought and conception. At the celebration of his seventieth birthday in Berlin, when the courts of Europe and the whole scientific world joined to confer numerous honors upon Helmholtz, he described in the course of a speech the condition under which his highest scientific thoughts had matured and come to fruition. He said:

"Frequently they slyly enter the mind without one's immediately attaching any importance to them; later some very simple accident or circumstance may be sufficient to reveal to us, when and under what circumstances they arose, or they may be present without our even knowing from whence they came. At other times they come to us suddenly, without any exertion whatever, just as an inspiration. As far as my experience is concerned, they never came to a wearied brain, or at the writing desk. They were especially inclined to appear to me while indulging in a quiet walk in the sunshine or over the forest-clad mountains, but the smallest quantity of alcohol seemed to scare them away."

mental inefficiency, but also because of our unreliable judgment.

Alcohol Shortens Life. — At least nineteen of the great American life insurance companies do not consider that a man who uses alcohol is a good risk, because he does not live so long as the man who abstains. The statistics of one insurance company, which cover the period 1884–1909, show that during that period 79.7 % of their risks who were moderate drinkers died; while but 52.2 % of the abstainers died. In the case of a second company, during the period 1886–1909, 93 % of the drinkers and only 70 % of the abstainers died.

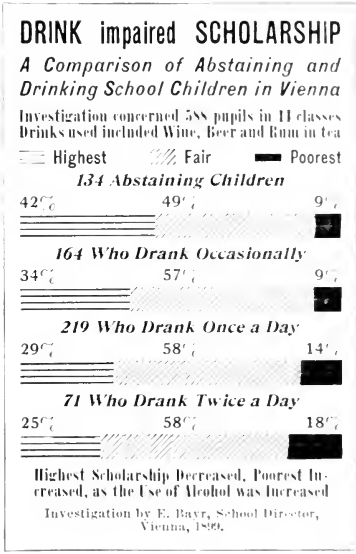


FIGURE 231.

168. **Alcohol, a Narcotic.** — Before studying this subject further, we must understand the meaning of the terms *poison*, *anesthetic* (ăn-ĕs-thĕt′ĭk), and *narcotic*. A poison is a substance which when taken into the body tends to cause death. Aconite, opium, carbolic acid, and mercury are all poisons, and when taken in sufficient quantities cause death.

An anesthetic is a substance like ether or chloroform, which when breathed into the lungs causes a temporary loss of sensation. However, unless anesthetics are administered properly, they may cause death.

A narcotic is a substance which causes dullness or stupor, and even a temporary relief from pain.

To understand how alcohol comes to be classed as a narcotic, it is necessary to learn about a substance called *lipoid* (Greek, *lipos*, fat ; *eikos*, like).

"Within recent years a new sort of body substance has been discovered, and has been elevated to first-rate importance. This new class is termed 'lipoid.' Its importance is immense. It is quite as important in the body as the nitrogenous or albuminous material which is present in every living tissue. It is very like fat in many respects, but in other respects it is different. It contains nitrogen, which fats do not; it contains phosphorus, which fats do not; again it mixes with water, which, as is well known, fats do not. It has certain remarkable properties, in that it can make certain bodies soluble which are otherwise not soluble.

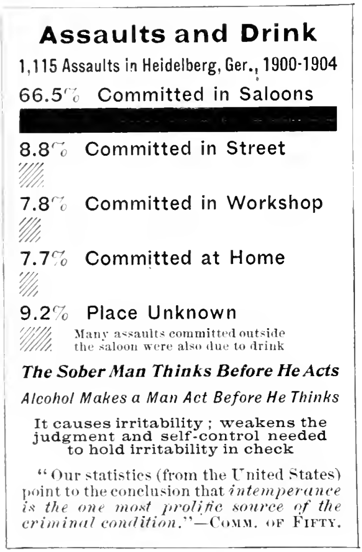


FIGURE 232.

"The walls of practically every living cell in the whole body are made chiefly of lipoid, and it is found that there are strands of this material running through and through the substance of every cell. In fact, there is no region of any cell in any part of the body that is without this material.

"Perhaps the largest accumulation of lipoid is that in the nervous system. There is far more lipoid in the brain than in any other tissue. If you examine a nerve, or what physiologists call a nerve trunk, you will find that this nerve is composed of many thousands of nerve fibers, and each nerve fiber that conveys messages into or out of the brain is invested with an insulation jacket (similar to the insulation covering an electric wire) of lipoid and thus the stimuli are prevented from scattering.

"It may be asked, 'What has all this to do with alcohol?' The connection is an important one, for only a few years ago two physiological investigators, — one with the English name of Overton, and the other with the distinctly German name of Hans Meyer, — without knowledge of each other's work, discovered the principle that any substance that dissolved lipoid, or, what is the same thing, is dissolved in lipoid, is an anesthetic. Chloroform, ether, and all of these agents which are used in modern surgery to produce unconsciousness are dissolvers of lipoid.

"Besides acting as anesthetics such substances act as poisons to every living thing in the body as well. The brain, owing to its high percentage of lipoid, is more sensitive to the action of chloroform than other organs of the body.

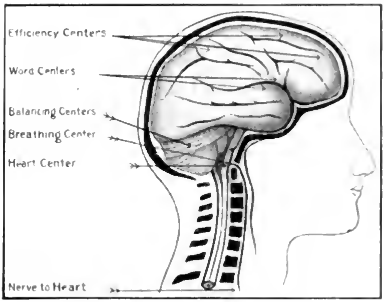


FIGURE 233. — BRAIN CONTROL.

"When chemists and physiologists found that alcohol is soluble in lipoid, it enabled them to rank it as a narcotic poison, and it is now so classed. This statement is altogether irrespective of the effects it will produce on an animal." — OSBORNE.

The question of brain efficiency is further illustrated by Figure 233. Long before birth the heart in the embryo begins to beat and is under the control of the nervous system. The part of the brain which superintends the heart is located in the medulla, where a special cluster of cells sends out nerve fibers which enter the heart nerve. These nerve cells are called the heart center.

The next nerve center to begin work is the breathing center, located close to the heart center, which controls the breathing. This does not become active until after birth.

About a year after birth, several more nerve centers become active in the child's brain. These are the ones which help him to walk. The cerebellum contains nerve centers which play an important part in walking and in learning to balance. The muscles which move the arms and legs are regulated by nerve centers in the cerebrum.

FIGURE 234.

Soon after the child learns to walk, he begins to talk and learn words. The several nerve centers which now become active are all located in the cerebrum. These are the nerve cells which are necessary in speaking, hearing, reading, and writing words.

After fifteen years of age the brain goes through important structural changes and the young person begins to do difficult tasks well. It is difficult to locate the exact spots in the cerebrum where the nerve centers are that now become active, for they are widely distributed. These nerve centers may be called the efficiency centers and they are the last to develop. But as they become active, every one becomes skillful along some particular line, although many years of training are necessary before the maximum of efficiency is reached.

The efficiency centers which are the last to become active and which require so much energy to train properly are the first to be affected by alcohol.

169. Structural Changes Due to Alcohol. — Definite changes are found in the protoplasm of nerve cells after the use of alcohol. These consist in a shrinking of the nucleus, the loss of the spindle-shaped (*Nissl*) bodies (Figure 224), the swelling of the cell, and the presence of vacuoles in the cytoplasm. It is also probable that some of the nerve cells are actually destroyed. These physical changes explain why the results are so great and why complete recovery of mental efficiency in the drunkard is so doubtful. The modern point of view and the one which is becoming firmly established in the treatment of drunkards by physicians is that alcoholism is a disease. Many of the authorities on alcoholism are urging that drunkards should be cared for just as we care for people sick with diphtheria or tuberculosis.

Anything which can destroy all of the higher and finer emotions, take away ambition, destroy shame, modesty, pride in personal appearance, render one especially liable to common diseases, or lead unerringly to insanity is to be avoided by those who are strong enough to resist, and should be made inaccessible to those who are weak and ignorant. And alcohol has all these effects on man.[1]

[1] Alcohol fills our state hospitals for the insane. Insanity is a disorder of the mind due to various causes. The one cause which produces the greatest number of cases is the intemperate use of narcotics, of which *alcohol* in its various forms is the most common. No less than twenty-six per cent of the inmates of our state institutions for the insane have become deranged as the result of intemperance.

There can be no doubt that some persons are more susceptible to the influence of alcohol than others. They become easily intoxicated and readily

170. **Tobacco.** — "Training starts to-morrow, no more smoking," is part of the athletic coach's orders at the

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succumb to disease. Others appear to resist the daily use of moderate quantities for a long time and, to the ordinary observer, seem to be in good health. Slow changes, not easily detected, however, are taking place in the blood vessels, brain, stomach, and other organs, which will in time become apparent in serious ill health. These changes are organic, that is, the structure of the organs is changed, and even if the alcoholic drinks be then wholly abandoned, the organs will not return to a healthy condition — though further damage may be averted by this course.

"Influence of Alcohol on the Development of the Brain. The brain and spinal cord do not reach complete development until the age of twenty-four or twenty-five years. During that time it is of particular importance that they be well nourished, supplied with an abundance of pure oxygen by the blood, and that all substances likely to injure their delicate structure be excluded. One would not expect to produce a fine flower from a plant which had been neglected or abused. It is well known to the florists who raise wonderfully beautiful chrysanthemums that perfect blooms cannot be produced on plants which have suffered even a slight injury from drought or other cause. No amount of care subsequently bestowed will result in anything more than a mediocre blossom. The human brain is in structure and function the most wonderful product of nature. It needs even more than a plant to be protected from harmful influences, in order that its millions of tiny cells and fibers may be properly built up day by day as the brain and body grow. Alcohol will produce in a mature man such a disturbance of the functions of the brain and spinal cord that he will be for a time unable to walk steadily or to speak distinctly. It would be idle to expect the immature nervous system of a boy or girl to develop properly if exposed, even occasionally, to the influence of such a powerful poison. The bad effect is twofold. Healthy growth is interfered with, and the habit of craving a *stimulant* is more easily acquired than in an adult. The same is true of the tobacco habit; it is seldom contracted except in early life. It has been found among those who became insane from the use of alcohol, that a very large majority began its use when less than twenty years of age.

"Persons most easily harmed by alcohol are those who are most susceptible to it. One who becomes intoxicated by a relatively small quantity of alcohol, who when under its influence shows a change of disposition by speech or behavior different from what is normal to him, or who after its effects have passed away cannot remember what he did or said while under its influence, has this susceptibility. Its continued use by such a person will inevitably lead to the most serious results. The same is true of all women. Women and girls are more susceptible to alcohol than the opposite sex, and show, at an early period, that peculiar blunting of the intellectual and moral faculties which make their appearance at a later period in men." — R. H. HUTCHINGS, M.D., Superintendent, St. Lawrence New York State Hospital for the Insane.

beginning of each season. He knows that the boy who smokes cannot reach his highest efficiency or be relied upon at critical times in the contest. He would rather have boys who do not smoke, because they are stronger, larger, and steadier than those who smoke. The cigarette habit has spread until it threatens the health of thousands of boys of America to-day. How is it known that their health is not so good? The charts on "smoker's heart" prove this point.

171. **How the Smoker's Heart is Affected.** — The following illustrations on the rate of the heart beat and the strength of the pulse, by W. A. McKeever, show what really happens when we smoke. There is much in these illustrations to warrant the conclusion that the heart of the habitual cigarette smoker is weak and feeble, except for the few minutes during which he is indulging the habit, and that the pulsations at this time are unduly excited. Figure 235 shows three records of a young man nineteen years old who began smoking cigarettes at the age of fifteen and who inhaled the fumes. The three records were taken without removing or readjusting the instrument, as follows: No. I, immediately before smoking; No. II, during the indulgence of the habit, and No. III, fifteen minutes later, after the effect of the narcotic had become apparent. Now, by reference to Figure 236, No. III, we may observe how this young man's heart should record itself, for the latter is the tracing of the heart pulsations of a normal young man of the same age and temperament. Nos. IV to VI (Figure 235) are representative of another inhaler twenty years old, who began the practice at thirteen. He now uses a strong pipe.

In Figure 236, Nos. I and II, taken respectively before and after smoking, are tracings of a sensitive youth of eighteen who has been smoking only two years. Observe the skip of his heart beat at *x* and the corresponding partial skip under the stimulus of smoking in No. II. No. III (Figure 236), as mentioned above, is a tracing of a strong healthy heart of a young man of somewhat excitable temperament. No. IV represents the phlegmatic temperament, that is, a person who is cool and calculating. No. V is the heart tracing of a strong and healthy young woman.

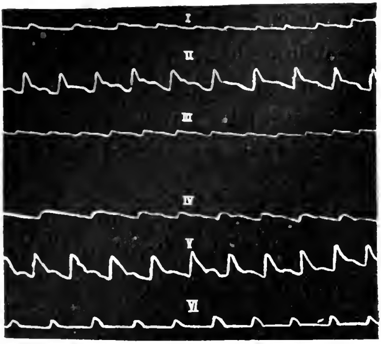

FIGURE 235.

In Figure 237, Nos. I and II are the pulse records of a man of splendid physique, thirty-six years old and weighing 230 pounds. No. I was taken before and No. II after smoking a cigar. He does not inhale. His pulse responded readily to the stimulus, but as the first tracing indicates he does not seem to suffer from any heart prostrations between indulgences. No. III is the record of a person whose vitality is temporarily low from nervous fatigue. No. IV is the record of a young woman who was on the verge of nervous prostration. No. V is representative of a heart weakened by long indulgence in the smoking habit. The young man in question began early and continued the

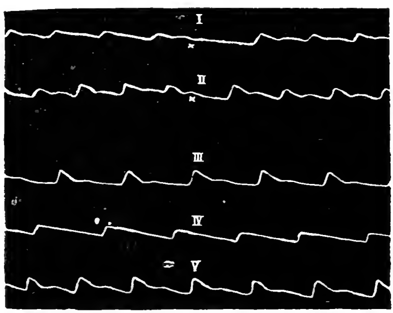

FIGURE 236.

practice till his physician convinced him of the extreme danger threatening his life. The pulse wave is nearly normal in length, but is entirely too weak. Under such conditions of heart a man is capable of little courage or aggressiveness.

"From the foregoing evidence we are led to the conclusion that in the case of boys and youths cigarette smoking is very deleterious to the physical and mental well-being. Moreover my investigations indicate that it makes very little difference in the effects whether the victim uses pipe or cigarettes, provided he inhales the fumes; and with few exceptions the young smokers are inhalers. The ordinary case exhibits about the following type of conduct: (1) While the craving is at its height the victim manifests much uneasiness and often much excitation. (2) During the indulgence the cheek is alternately flushed and blanched, the respiration considerably increased and the hands tremble. (3) About twenty minutes after smoking the muscles become relaxed, the respiration slow and shallow, the skin on the face dry and sallow and there is an apparent feeling of unconcern about everything." — W. A. McKeever.

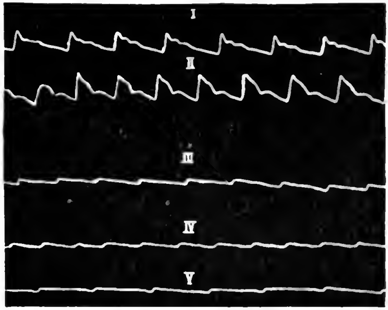

FIGURE 237.

172. Smoking and Scholarship. — Several thousand boys have been studied and classified according to age and whether they were smokers or non-smokers. In all cases the non-smokers had a higher average grade of scholarship. The experience of city superintendents and principals is that they can usually tell a cigarette boy by his general attitude, poor scholarship, and disregard of personal appearance.

When cigarettes are burned, three distinct poisons are produced, which cause serious effects on the boys who use tobacco in this form. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in larger quantities when the smoke is inhaled in the lungs.

A simple way to prove that cigarette smoke contains a poison is by blowing the smoke through a glass tube into an aquarium containing goldfish. Only a small amount of smoke will kill the fish.

While we can all gradually adapt ourselves to small amounts of poison, poisons are never beneficial unless prescribed by a physician to try to remedy some bodily defect. The poisons which arise from the burning of a cigarette are never prescribed even as medicines, and have never been found in any way beneficial to the human body.

SUMMARY

The nervous system of all vertebrates consists of a brain and spinal cord with nerves passing to all organs of the body. The brain of man is the most highly developed.

All our movements are controlled by means of the nervous system. Through our sense organs we gain our information of the world.

The nervous system is made up of cells which are highly specialized. Their main work is to transmit and interpret stimuli. The nerves of man are so highly specialized that all stimuli which affect the eye are thought by us to be light stimuli; or all stimuli which enter in the ear, seem to be sounds. The information which passes over any of our special sense organs travels over several different nerve cells before it reaches the place in the brain where it is interpreted. The highly specialized nervous system and sense organs grow and are fed just as muscles or skin grow and are fed. There is no special food which we can eat that is used exclusively by the nervous system.

QUESTIONS

What is the nervous system? Of what parts is it composed? What animals have you studied that have a nervous system? Which ones lacked a special nervous system? How does the nervous system grow? Describe the nerve cell. How does it differ from other cells in man? What are special senses? What kind of information do you receive through your eyes? What kind through your ears? Which do you remember? (The well-trained mind remembers equally well the information that comes in through each of his sense organs.)

To most of us it is given to play an unimportant rôle in the period in which we live. Inheriting from our parents healthy, normal bodies we can at least pass on this priceless heritage to our children. It will be their chief pride, as it is ours. Life is not easy, and we need the best bodies, the best nervous systems, and the best trained minds that it is possible for us to have in order to make our lives count for the most. This means that it is the duty of every boy and girl to know about sanitation, public and private hygiene, and disease.

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CHAPTER XIX

THE BIOLOGY OF DISEASE[1]

STUDENT REPORT

How many in the class have been sick during the past year? Of how many different diseases? What was done to aid each one in getting well? What was done to prevent others from taking the same diseases? What was done by your Board of Health officer? (Consult the reports of the State Board of Health and of the local health official.)

173. **Disease.** — Usually people go through their daily occupations without feeling pain or bodily discomfort. Such a condition is known as health. Sometimes, however, they go about their usual duties when they do not feel well and the indisposition gradually passes away. But in other cases the ill feeling becomes severe, the usual activities are given up, and we say that they are sick. Sickness may last for only a short time or for many years. The usual conditions of the body are changed, and we say that the body is diseased. The apple, the tree, the dog, the horse, each has its own diseases.

174. **Cause of Disease.** — While there are many causes of disease, all of them may be grouped under four headings: (1) Inherited diseases, *i.e.* those transmitted from parent to child, as certain forms of insanity and imbecility where the exact cause is not known. (2) Diseases caused by such poisons as lead, arsenic, mercury, phosphorus, opium, cocaine, alcohol, and the like. The disturbances which these chemical agents set up in animal tissues are

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[1] Chapter XXII, Bacteria, may be read in connection with this chapter.

easily recognized by a good physician. (3) Diseases which cause certain tissues to take on an abnormal growth, as in tumors and cancers. (4) Diseases caused directly or indirectly by some definite living plant or animal. Such diseases are called "biological diseases," because the source or cause is in all instances some definite living plant or animal. In our ordinary daily speech we often speak of such ills as "germ" diseases.

175. **Biological Diseases.** — The rattlesnake secretes a poison which is forced through fangs or hollow teeth into the blood of its prey. This poison affects the heart and may result in death. One of the common and beautiful mushrooms produces a similar poison which is not destroyed by cooking. If this particular mushroom is eaten, death is almost certain to follow in from twenty-four to forty-eight hours. In both of these cases the animal or plant is large enough to be seen and easily recognized.

But there are a considerable number of microscopic plants and a few microscopic animals that have formed the habit of living for at least a part of their life in other plants and animals. During this time, as we have seen in the study of animal parasites, they usually secure all, or the greater part, of their food from the plant or animal in which they are living. Two general causes of disease result from this parasitic habit. The parasite may destroy certain cells of the body, or the material thrown off from the body of the parasite may act as a specific poison.

176. **Communicable Diseases.** — The term *communicable disease*[1] is used in this book to mean the diseases caused by

[1] New York State designates the following as communicable diseases: anthrax; chickenpox; cholera, Asiatic; diphtheria (membranous croup); dysentery, amoebic and bacillary; epidemic cerebro-spinal meningitis; epidemic or streptococcus (septic) sore throat; German measles; glanders; measles; mumps; ophthalmia neonatorum; para-typhoid fever; plague; poliomyelitis,

a plant or animal living as a parasite in plants, animals, or man. These diseases are communicated in various ways from one individual to another, from one animal to another, or from one plant to another.

The following are among the most common communicable diseases. Diseases caused by bacteria (minute plants) are tuberculosis, pneumonia, diphtheria, typhoid fever, bubonic plague, and whooping cough. Measles and scarlet fever are so similar to these in many ways that it is believed that they are caused by bacteria, although the definite bacteria which cause them have not been discovered. Diseases caused by protozoa (minute animals) are malaria, yellow fever, sleeping sickness, possibly smallpox, and others less well known.

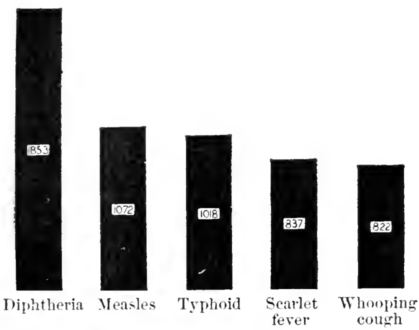

FIGURE 238. — DEATHS FROM COMMUNICABLE DISEASES.

This is for the year 1913 in New York State.

The biological diseases are all preventable, especially the communicable diseases which result from the parasitic habit of some plant or animal. In order to prevent these diseases, it is necessary to know how the different plants and animals gain access to the human body and proceed to live there. This can be illustrated by describing pulmonary tuberculosis, a plant or bacterial disease; and malaria, an animal or protozoan disease.

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acute anterior (infantile paralysis); puerperal septicæmia; rabies; scarlet fever; smallpox; trachoma; tuberculosis; typhoid fever; typhus fever; whooping cough.

Robert Koch (1843–1910) was a celebrated German physician, noted as the discoverer of the bacilli of tuberculosis and of cholera. In 1882 he announced in Berlin the discovery of the tubercle bacillus, and the same year he published a method of preventive inoculation against anthrax. Later he discovered tuberculin, a substance intended to check the growth of the tubercle bacillus. In 1883, Koch led the German expedition to India to investigate cholera, and discovered the cholera germ. In 1885 he became Professor of Medicine at Berlin and in 1891 Director of the new Institute for Infectious Diseases.

177. Pulmonary Tuberculosis. — Pulmonary tuberculosis is a disease located in the lungs. The cause is a definite plant with parts and habits which are easily recognized by bacteriologists (students of bacteria). This plant is called *Bacillus tuberculosis*, and was proved to be the cause of consumption, or tuberculosis, by Robert Koch, a German scientist, in 1882. These tuberculosis bacteria, or germs, in countless numbers are found leading a parasitic life in the lungs of a tubercular patient. The bacteria are extremely minute, and can be seen only by the use of a microscope of high power.

The large number of germs in the lungs grow rapidly and they are set free in the air by coughing. One tuberculosis patient may give off millions of these germs in a day. For this reason great care should be taken in destroying the sputum of patients, for if the germs become dry, they are carried about as dust particles.

Tuberculosis and other disease germs are so numerous that it is impossible to escape taking some of them into our bodies, but they usually do us no harm unless we are in a weakened condition.

Modern methods of cleaning the streets by flushing with water, keeping garbage covered, and wiping up the dust in our homes instead of using the old-fashioned feather duster are doing much to keep down the number of germs in the air which we breathe.

The bacteria that are breathed in from the air may find some weak place in the lungs in which to take up their parasitic lives. Those which enter on the food pass from the digestive tract into the blood and are eventually carried to the lungs. The introduction of tuberculosis germs in this way is especially frequent in children. In many cases milk from tuberculous cows is the source of the disease germs. See § 248, page 349.

The cause of pulmonary tuberculosis is, then, the tubercle bacillus, which is taken into the lungs in the air we breathe, or through the food eaten, or by personal contact with a consumptive patient. These germs cause certain parts of the lungs to become diseased.

178. **Getting Well.** — Consumption is not necessarily fatal, especially if treated in its earliest stages. But many

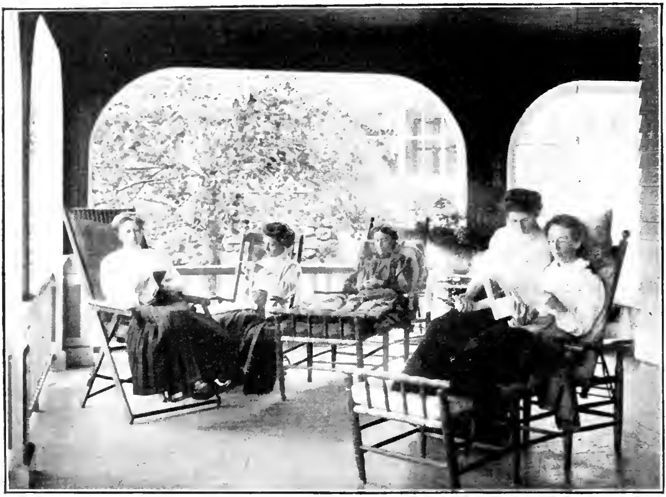


FIGURE 239. — TUBERCULOSIS CURE, SUMMER.

people who have the disease do not consult a regular physician until it has made considerable progress, and then it is too late to bring about a cure.

Figures 239 and 240 show the present method used in treating tuberculosis. The patients are given tissue-building food (protein) and are required to sit and sleep out-of-doors as much as possible. Rest, good food, and fresh air work wonders in arresting the progress of this disease.

When the body gains the requisite amount of strength the disease and its germs are usually thrown off. Patent medicines and alcohol should be avoided, as they reduce the power of the body to resist disease and give no aid in building up the diseased tissues. In addition, alcohol causes serious disturbances in the general circulation.

FIGURE 240. — TUBERCULOSIS CURE, WINTER.

In addition to pulmonary tuberculosis physicians recognize tuberculosis of the throat, intestines, kidneys, brain, and joints.

179. Malaria. A Protozoan Disease. — Malaria is a disease caused by a protozoan or minute animal which is distributed over the greater part of the world. The malaria protozoan is a minute simple cell of living matter. It resembles the amœba in its form and ability to change. This parasite penetrates into the red blood corpuscles and remains in them for twenty-four or forty-eight hours, or until the substance of the corpuscle is nearly used up.

Then the parasite escapes into the plasma of the blood and later enters a fresh corpuscle.

180. **Source of the Malarial Parasite.** — The word malaria means bad air, for it was formerly believed that foul air caused the disease. When it was learned that a definite animal was the cause both in man and in other animals, the problem was to find how the parasite entered the body.

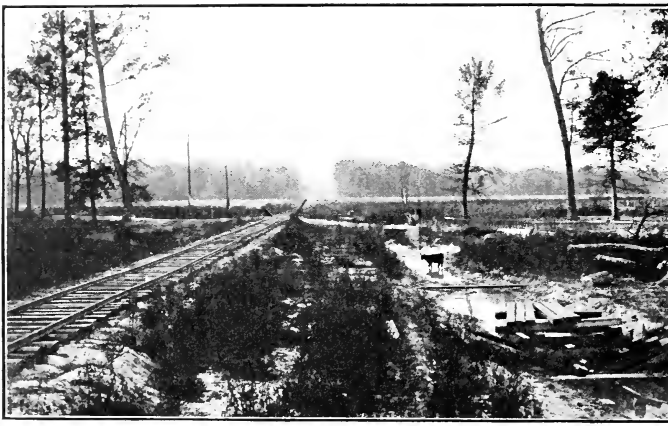


FIGURE 241. — MALARIAL SWAMP.
An ideal place for mosquitoes to breed.

It has been proved to the satisfaction of scientists that the malarial protozoan is injected into the blood by a particular kind of mosquito (Anopheles) which carries malaria germs in its body.

The mosquito sucks the blood from a man or an animal suffering from malaria. This blood contains some of the malarial parasites, which pass into the stomach of the mosquito. They then migrate into the salivary glands of the mosquito, so that as soon as the mosquito bites another man or animal, it pours out some saliva which introduces the parasites into the victim's blood. While in the body of the mosquito, these parasites pass through definite stages in their life history; and when they reach the blood of man, the remaining stages are completed. Thus a man, or an animal, and a particular mosquito are necessary for the complete life history of the malarial parasite.

This means in addition that for the prevention of malaria all that is necessary is to destroy the Anopheles mosquito, or in case this cannot be done, to screen adequately the houses, tents, and bedrooms in the regions where the mosquitoes live. It is interesting to note that this discovery of the cause of malaria and the methods for its prevention was more than anything else responsible for the successful completion of the Panama Canal. The construction of this important work was more a health than an engineering problem.

181. Other Protozoan Diseases. — Other protozoan diseases are produced in the same manner as malaria. The carrier may be different, but the principle of spreading the diseases is the same. Yellow fever, for instance, is spread by another kind of mosquito, and sleeping sickness by the tsetse fly.

182. Hookworm Disease. — This disease is caused by a parasite which is classified as one of the worms. Hookworm disease belts the earth in a zone which extends thirty-three degrees each side of the equator. Great progress is being made in the United States in curing those suffering from this disease. The wearing of shoes and the use of a sanitary closet are usually sufficient preventives to protect the people who live in a hookworm district.

183. Prevention of Communicable Diseases. — The prevention of these diseases depends upon an understanding of the causes which produce them, close adherence to the laws of hygiene, and especially the exercising of proper care in the production and cooking of our food. Germ diseases are unnecessary, and it should be considered a disgrace to a community if some of them appear. Proper hygienic measures will do much towards eliminating most of the communicable diseases, but until the intelligence of communities can be aroused enough so that such measures shall be insisted upon, we must depend upon proper food, rest, fresh air, and exercise to keep ourselves fit, and thus avoid the conditions which help disease to

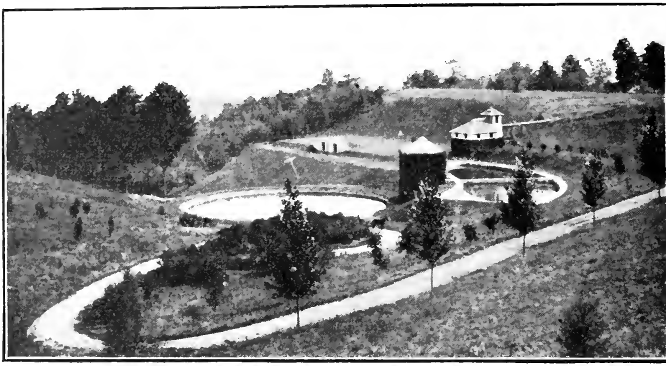


FIGURE 242. — A MODEL RESERVOIR.

gain a foothold. Tuberculosis, for example, is more likely to occur in persons who are underfed and overworked, and a cold often follows an attack of indigestion.

Care of Food. — The care of food is extremely necessary in preserving our bodily well-being, for the same germs live and grow in food which cause disease when taken into our bodies. One method of keeping the bacteria on food from growing is by proper refrigeration. The temperature of a well-cooled refrigerator does not destroy the germs, but makes them incapable of growth until heat is supplied them. So if food is taken from the refrigerator and allowed to stand for a time, the bacteria will at once begin to grow and cause the food to spoil.

If such food is eaten, an intestinal disturbance usually results.

In the attempts to prevent disease, more study has been given to milk and water than to other foods. For discussion of milk, see pages 347–350.

While milk is used as a food by all mankind, water is even more important, for it is absolutely necessary if we

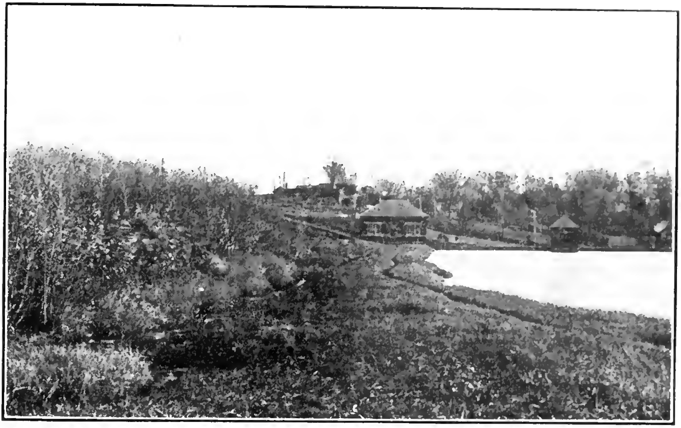


FIGURE 243. — A POOR RESERVOIR.

Note the open stream that empties into the main body of water. The impure water of the Erie Canal drains into this open stream.

are to continue to live. In this respect man is like all plants and all other animals, water being necessary for the preservation of all life.

Two conditions must be met before a water supply can be deemed satisfactory. There must be an abundant supply; but more important still, the water must be *pure*, that is, free from disease-producing germs. Farmers and residents of small towns may without great trouble secure sufficient pure water, but the large cities have to spend millions of dollars in providing an adequate water supply.

Sanitary measures are adopted to keep the sources of the water from becoming impure, as well as to keep clean the reservoir where it is stored. Certain harmless plants and animals living in reservoirs may give an unpleasant taste or odor to the water. Harmful disease germs live in water for months. Such germs may be frozen in ice, stored in ice houses, and when later put with the ice into drinking water, may cause typhoid fever. It is, therefore, important that we have plenty of pure water, and we should do all we can to help in giving the town or city in which we live a pure water supply.

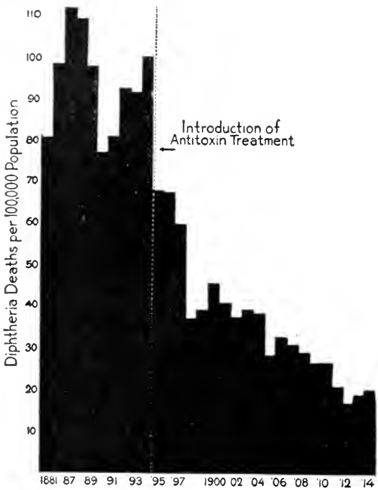


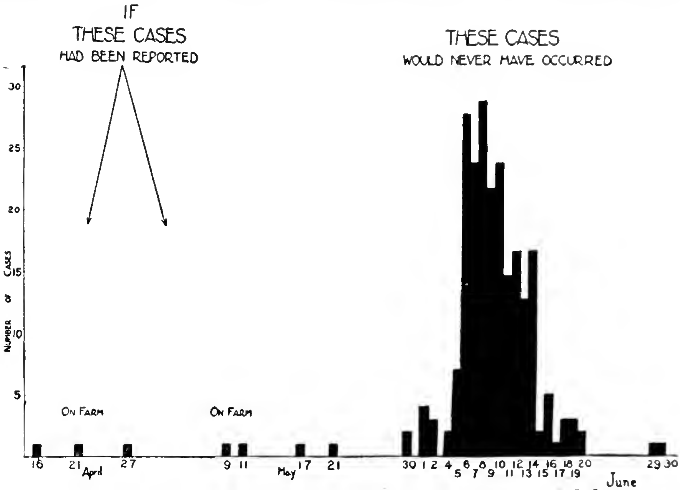
FIGURE 244. — DIAGRAM. Thirty years of diphtheria in New York State.

STUDENT REPORT

Prepare a report on the water supply in your locality and find where it comes from. What measures are taken to keep the sources and reservoir clean?

184. Keeping Well. — Our best doctors are spending much effort in showing how to avoid disease, for no one is benefited by illness. The old notion that children should be exposed to measles, scarlet fever, and whooping cough is wrong, for none of these childhood diseases is necessary. The time will come when our homes and surroundings will be so sanitary that the common diseases caused by germs will be eliminated, or at least decreased in number.

Government inspection of meats is lessening the amount of disease contracted from eating diseased pork, meat, and fish. The United States Department of Agriculture is making every effort to inspect such products, and the department is fairly successful in inspecting the larger establishments. However, many cattle and hogs are killed and sold locally and they escape inspection, so that buyers



THE STORY OF THE EPIDEMIC OF SEPTIC SORE THROAT AT ROCKVILLE CENTRE, L. I.

FIGURE 245.

of this meat have no protection against a general condition of disease.

Another danger to health is from the people known as "carriers" of disease, as such people give no evidences of illness. Typhoid and diphtheria are the two diseases most likely to be carried in this way. Many of these carriers serve as cooks, and as they give no evidence of being in other than perfect health, they often spread the germs through the food they prepare. If habits of absolute cleanliness are insisted upon, much of the danger of the dissemination of germs in this way will be removed.

Many hotels, public institutions, and well-run households insist that a prospective servant shall be examined by a competent physician before being engaged for work. In this way carriers may be detected, and persons with germ diseases, like tuberculosis, for instance, are prevented from spreading disease either in the food or in the air.

Children in the schools frequently have diphtheria germs living in their nasal passages or throats, but are not ill. After a time a number of children come down with the disease. A doctor then takes a sample of the contents of the throat and nose of each child. The bacteria in the mucus from the nasal passages is allowed to grow for twenty-four hours in a special preparation called a *culture* (page 346). At the end of that period the cultures are stained and examined with a high power of the microscope, and if diphtheria germs are present, they are easily seen. If one of the well children has these germs, he is treated until they disappear.

185. Quacks and Patent Medicines. — The term *quack* is applied to a person who advertises that he can cure various diseases by some new invention or newly discovered remedy. A *patent medicine* is one which has been registered at the patent office, and this registration gives the patentee exclusive right to the use and name of the so-called remedy. Many millions of dollars are spent annually in advertising special "cures" and new mechanical contrivances guaranteed to cure diseases for which they can do nothing, or even to cure such diseases as cancer, for which there is no known remedy.

Many people who do not understand the causes of disease are reluctant to consult a well-trained physician, but read and believe the carefully worded advertisement of some quack doctor or of some patent medicine. The untrained sufferer cannot interpret the meaning of his distress and is incompetent to select the proper medicine. As real medicine is given for specific symptoms associated with a specific disease, it is apparent that a patent medicine advertised to cure from six to forty diseases is worthless. Furthermore, real medicine is given to relieve a certain set of symptoms at a given stage of the disease, and is frequently changed. This is, of course, impossible when using a patent medicine. If every one would consult regular physicians, and cease patronizing the quacks and patent medicines, one of the sources of much sickness and suffering would be destroyed.

186. **Alcohol and Patent Medicine.** — Repeated chemical analysis of many of the patent medicines shows that they contain a considerable amount of alcohol. There are over 120 patent medicines which the United States Government will not permit to be sold except by the possessor of a liquor license. This fact alone shows the harmful nature of patent medicine.

187. **Alcohol and Disease.** — It is unnecessary to make an elaborate series of quotations from eminent men to prove that alcohol is not useful and necessary as a medicine in the cure of disease. One of the chief reasons has already been given in connection with the discussion of tuberculosis. There is no evidence that alcohol has any effect on the destructive course of a disease, or any beneficial effect upon the person suffering from disease. This last phase of the problem has been under critical study long enough to show that the earlier claims of the helpfulness of alcohol in disease are not supported by the facts. The reverse is true. Alcohol is known to decrease the power of the body to withstand disease and does not assist in destroying the poisons which arise in the case of bacterial diseases. At present there is no

scientific evidence which justifies the use of patent medicines, or of alcohol unless definitely prescribed by a physician.

188. **Headache and Anti-pain Patent Medicines.** — Many preparations advertised under these general names are taken by persons ignorant of the fact that these medicines generally contain harmful drugs. It should be sufficient to know that no reputable doctor will ever give any of these preparations except in a mild form, and in case of extreme pain. No person except a trained physician has a right to prescribe drugs; and he only after a knowledge of the patient's symptoms. Many of these preparations affect the heart and blood, and none of them has any beneficial effect on the real cause of the pain.

189. **Boards of Health.** — Communities and physicians have endeavored to prevent the spread of communicable diseases by the formation of boards of health, by quarantine, vaccination against smallpox, immunization against typhoid fever, the use of antitoxin in diphtheria, disinfectants and fumigants.

The term *Board of Health* is applied to a number of individuals, appointed or elected by a nation, by a state, or by a community, to enforce the national, state, city, or town health laws and regulations. The local officer of this board is a physician, and in some states, New York for example, is appointed according to the regulations governing the city or town in which he is to serve. The New York state law defines his work as follows:

"Every such local officer should guard against the introduction of such communicable diseases as are designated by the State Department of Health by the exercise of proper and vigilant medical inspection and control of all persons and things infected with or exposed to such diseases, and provide suitable places for the treatment and care of sick persons who cannot otherwise be provided for."[1]

Violation of quarantine and of the various health regulations, such as the pollution of water and improper care of refuse and sewage, should be reported to the local health officer. In case no satisfactory results are obtained from the local health officer, the question may be referred to the

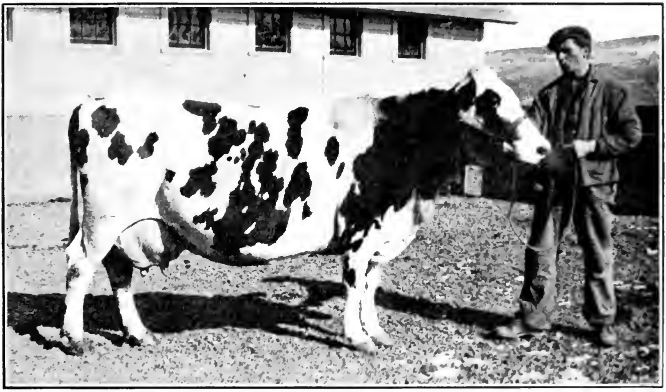


FIGURE 246. — MODEL DAIRY COW.

State Board of Health, which gives prompt and efficient attention to all questions concerning the health of the people of the state.

190. Quarantine. — When a person or a group of persons is suffering from a communicable disease, or when anyone has been exposed to the germs of the infection of any such disease, the Board of Health may place him under *quarantine*. The nature of the quarantine depends on the

[1] The Sanitary Code of the Public Health Council of the State of New York defines the health officer's duties in detail and may be had by writing to the State Department of Health at Albany. Selections from the Sanitary Code will be found in Appendix B.

specific disease and the laws of the town or state in which the persons reside.

The New York law on this subject is typical of the best state laws on quarantine. It says:

"The Board of Health shall prohibit and prevent all intercourse and communication with or use of infected premises, places, and things; and require and if necessary

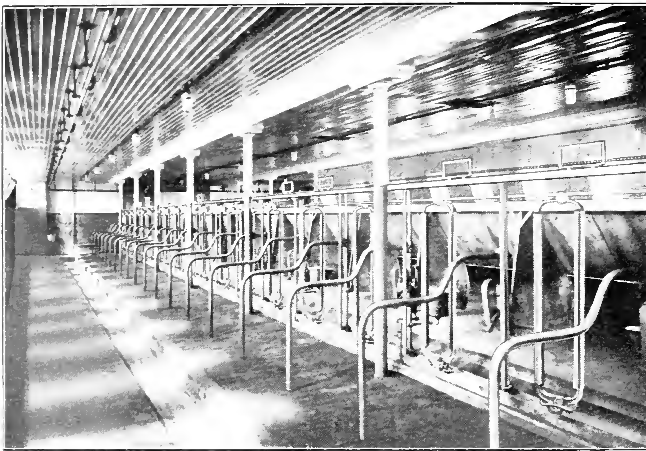


FIGURE 247. — MODEL DAIRY STABLE.

provide the means for the thorough purification and changing of the same before general intercourse with the same or use thereof shall be allowed." See Appendix B.

This means if an individual is suffering from scarlet fever or diphtheria, or some other communicable disease, he shall not associate with the general public until he has ceased to be a source of infection. His liberty is temporarily restricted by quarantine because he may be the cause of sickness and even death to others by spreading the germs of communicable disease.

It is interesting to know that the more highly civilized

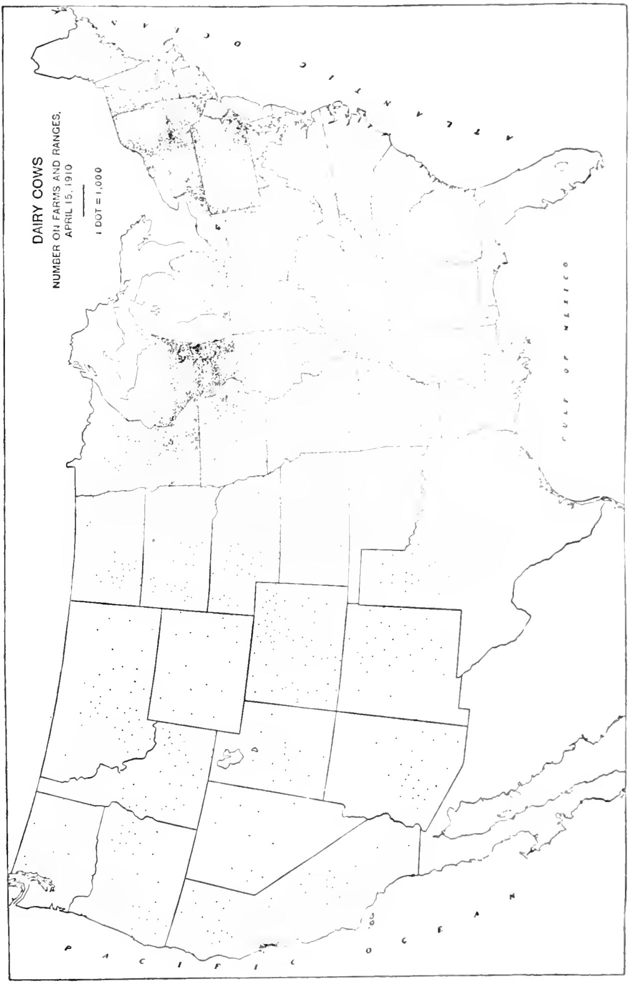


FIGURE 248. Which states furnish the most milk, butter, and cheese? Which the least?

a nation, state, or city becomes, the more specific and exacting are the quarantine regulations. There is every reason to believe that in the near future the present laws of quarantine will be extended. In addition to individuals being quarantined in a dwelling, all the inhabitants of a city or state may be quarantined in case of severe epidemics; or the transportation of stock from one state to another may be prohibited in the case of a serious communicable disease existing in cattle or sheep. The quarantine laws, for example, order from time to time that all dogs in the town or county shall be muzzled as a protective measure against rabies.

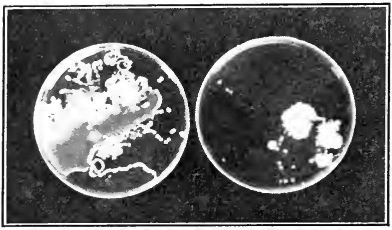


FIGURE 249. — AGAR PLATES.

Where a house fly was allowed to walk. White patches are bacterial growths.

Immigrants suffering from certain diseases are prohibited from landing in the United States. This means that there are national as well as state and city quarantine laws. The present quarantine laws are the most effective protective measures against the spread of disease known to man and are the product of a high degree of civilization.

191. **Vaccination.** — The success which has attended the efforts of man to overcome disease is well illustrated by smallpox. For centuries this disease was responsible for many deaths throughout the world. It is said to have existed in China centuries before Christ. Later it swept over Europe again and again. King Frederick William III of Prussia stated, in 1803, that 40,000 people succumbed annually in his kingdom. A famous French physician wrote in 1754 that every tenth death was due to smallpox, and that one fourth of mankind was either killed by it or disfigured for life. Smallpox was brought into the Western Hemisphere soon after the discovery

of America and killed thousands of the Indians. It also visited the colonies. In 1721, Boston was ravaged for the sixth time by this disease. Out of the 10,567 inhabitants, 5989 had the disease and 894 died.

In 1796, Jenner, an Englishman, demonstrated the fact that by inoculation of a person with cowpox, a disease peculiar to cows and in some way allied to smallpox, the patient would become immune to the dreaded disease. This was one of the greatest and most beneficial discoveries of medicine which has ever been made.

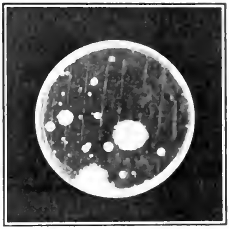


FIGURE 250. — BACTERIA AND MOLD.

One tenth of the number carried by one house fly.

By the result of vaccination smallpox has become a rare disease in the civilized nations of the world, and is least prevalent where the vaccination laws are the most stringent.

Vaccination for smallpox consists in the inoculation of the human patient with vaccine, a substance secured from a cow suffering from cowpox. This usually causes a slight illness, but during the illness the patient acquires a power which enables him to resist the germs of smallpox. This acquired power of resistance is called immunity.

Many people do not understand the theory of vaccination and its advantages, and have opposed its use through fear of acquiring lockjaw from the vaccine. It has been established that proper vaccine matter never contains the germs of lockjaw, and if this disease occurs, it is due to failure in keeping the arm clean during the period when the vaccination scar is forming.

Immunity to disease is now being produced through inoculation. The patient is inoculated, that is, there is introduced into his circulatory system a virus, or serum. Each disease has its own virus, as the vaccine in smallpox, and this virus produces a mild form of the disease. This causes the cells to become resistant to the germs or microbes of the specific disease. Inoculation is being widely used for the prevention of typhoid fever. All soldiers are required to take this treatment. It would be desirable for all people to become immunized against this disease, but those who travel extensively and thus have to drink all kinds of water and milk should certainly undergo this treatment.

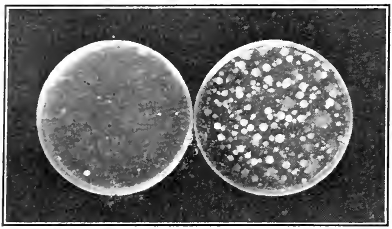


FIGURE 251. — MILK DILUTED TO $\frac{1}{1000}$. Left-hand culture from clean milk; right-hand culture from dirty milk.

Vaccination and immunization reduce the liability of death in case the disease is acquired, but they do not absolutely prevent the disease. If a vaccinated or immunized person gets an overwhelming number of germs, he may have an infection of a slight kind. But the liability of contagion is reduced to a minimum.

192. **Antitoxin.** — We cannot say definitely why vaccination and immunization act as they do. It is known that if a poison (toxin) produced during a case of diphtheria is gradually introduced into the blood of a horse, a substance is produced which destroys the injurious effects of the diphtheria poison. The serum from the blood of the horse is called antitoxin, and may be preserved for use at any time to destroy the influence of the diphtheria poison. A given amount of this antitoxin is introduced into the blood of the patient suffering from diphtheria, and this usually counteracts the disease. This treatment has

saved countless lives. It is estimated that in the ten years after the discovery of the diphtheria antitoxin the lives of a million children were saved in France alone. State boards of health usually furnish antitoxin for diphtheria and lockjaw.

LABORATORY STUDY

It takes five pounds of sulphur to disinfect a room which contains 1000 cubic feet of air. Three ounces of forty per cent formalin, to which is added two and one tenth ounces of potassium permanganate will also disinfect the same sized room. Compare the cost and ease with which each is used.

193. **Disinfection and Disinfectants**. — The time when disinfectants shall be used and the manner of disinfection have been considered important factors in preventing the spread of communicable diseases. The purpose of disinfection is to destroy the germs lodging on clothes, floors, carpets, and curtains. People who care for the sick should know where the germs are likely to be and how to disinfect places where they have found lodgment. The term *disinfectants* is sometimes incorrectly applied to deodorizers, substances which are used to destroy odors, but the word should be applied only to substances which destroy germs or bacteria.

Disinfectants are not expensive, and few of the patented preparations are as satisfactory as the common ones used by boards of health. Weak solutions of carbolic acid and bichloride of mercury are chiefly used for killing the germs on the hands and clothing, or for cleaning the woodwork in the sick room. Chloride of lime is used to kill the germs in the discharges of the body, and sulphur dioxide and formaldehyde gas for the final killing of the germs in the room or the whole house before it is occupied again.

Never use any methods of disinfection unless they have been personally recommended to you by a physician or an expert in the details of room disinfection. Do not rely upon patented solutions and methods. The latter are expensive and often practically worthless.[1]

194. **Results of Disease.** — In New York State for the year 1909 there were reported to the State Board of Health 138,315 cases of communicable diseases. There were many cases that were not reported, so that this is not to be taken as the highest estimate of the number of people who were sick with preventable diseases. During the years 1913, 1914, 1915 in the same state the following number of people died from these communicable diseases.

NUMBER OF DEATHS

1913–1915

	Diphtheria	Scarlet Fever	Whooping Cough	Measles	Typhoid Fever
1913	1853	837	818	1071	1018
1914	2015	687	730	839	878
1915	1754	409	749	834	750

It is difficult properly to measure the value of health to the community. When the wage earner is sick and is placed in quarantine, the loss of money is the amount he might have earned. In the case of a typhoid fever epidemic the total loss is many thousands of dollars. Further, there is no adequate measure of the sufferings of those who die, and the heartaches of those who survive. But both the suffering and the financial loss can be greatly lessened by improving our sanitary laws and aiming at a better state of health for all the people. An increase in

[1] When practicable, it is well to have the local health officer discuss such subjects as disinfection and quarantine.

taxes to provide cleaner streets, public playgrounds, proper sewage disposal, and adequate inspection of milk, meat, and water, is really an economy. For although such improvements cost money, they are not so expensive as epidemics of disease and the maintenance of hospitals and of orphan asylums.

195. **Heredity of Disease.** — The term heredity of disease is one which has been misunderstood by many people. By the term heredity we mean that which is handed on from parents to their offspring. In the case of biological diseases which are caused by some definite plant or animal, it is evident that they cannot be inherited. But when the parents are afflicted with a biological disease, their bodies become weakened and their offspring may have a poor constitution so that they are more easily affected by disease.

196. **Immunity.** — Immunity is a technical term which means that the body resists or is not susceptible to the germs of biological diseases. Many people do not become sick when there is an epidemic of typhoid fever, measles, malaria, or the like. Such people are said to possess a high degree of natural immunity to disease germs. People usually well frequently take germ diseases when the body happens to be exhausted by care or work. In such cases the immunity of the body has been weakened. Many of the germ diseases confer immunity against a second attack of the same disease, but this does not hold true for all persons or for all germ diseases. Vaccination against smallpox, in the case of most persons, confers immunity for about seven years. Inoculation with the typhoid serum confers immunity for from two to three years. Immunity, then, is a relative term, and depends in a large measure on the state of health of the individual and on his power of resisting the poisonous effects of disease germs.

STUDENT REPORT

Due to Some Plant or Animal			Treatment by			Prevented by				
	In the water	From contact	Nature	Medicine	Antitoxine	Personal care	Quarantine	Boiling the water	Fumigation	Killing flies
Cold			X	X			X	X	X	
Measles . . .										
Whooping cough										
Typhoid fever .	X	X	X	X	X	X	X	X	X	X
Tuberculosis . .										
Add others . .										

197. **What are you going to do and how are you going to do it?**— We have now learned some of the facts about how to keep well and how to do our life work effectively and efficiently. We all begin life as children with an unknown work to do. How well are we going to do it? Judge Lindsay says, "Children are the life blood of the states. They are better producers of energy than steam or electricity." Davenport in a new study emphasizes this point in the following words: "The human babies born each year constitute the world's most valuable crop. Taking the population of the globe to be one and one-half billion, probably about fifty million children are born each year. In the continental United States with over ninety million souls probably two and one-half million children are annually born. When we think of the influence of a Harriman, of an Edison, of a William James, the potentiality is far from being realized. Nearly half a million of these infants die before they attain the age of one year, and half of all are dead before they reach their 23d year

— before they have had much chance to affect the world one way or another. However, were only one and a quarter million of the children born each year in the United States destined to play an important part for the nation and humanity we could look with equanimity on the result. But alas! only a small part of this army will be fully effective in rendering productive our three million square miles of territory, in otherwise utilizing the unparalleled natural resources of the country, and in forming a united, altruistic, God-fearing, law-abiding, effective and productive nation. On the contrary, of the 1,200,000 who reach full maturity each year, forty thousand will be ineffectual through temporary sickness, four to five thousand will be segregated (placed apart) in the care of institutions, unknown thousands will be kept in poverty through mental inefficiency, other thousands will be the cause of social disorder, and still other thousands will be required to attend and control the weak and unruly. We may estimate at not far from 100,000, or eight per cent, the number of the non-productive or only slightly productive, and probably this proportion would hold for the 600,000 males considered by themselves. The great mass of the yearly increase, say 550,000 males, constitute a body of solid, intelligent workers of one class and another, engaged in occupations that require, in the different cases, various degrees of intelligence but are none the less valuable to the progress of humanity. Of course, in these gainful occupations the men are assisted by a large number of their sisters, but four-fifths of the women are still engaged in the no less useful work of home-making.

"It is a reproach to our intelligence that we as a people, proud in other respects of our control of nature, should have to support about half a million insane, feeble-minded, epileptic, blind, and deaf, 80,000 prisoners, and 100,000 paupers at a cost of over one hundred million dollars per year." — DAVENPORT.

SUMMARY

Disease prevents us from working as we do when we are well. Most diseases are unnecessary and preventable, especially all which are caused by some plant or animal living as a parasite in our bodies. In most of the biological diseases some definite poison produced by the parasite is taken into the body, and this is the chief cause of the disease. As a physician knows the nature of a disease and its effect upon the body, he can aid materially in overcoming the illness. Each biological disease is distinct and must have special treatment. Many of these diseases are taken from some one who has the disease. Vaccination, quarantine, and disinfection are measures which help to prevent the spread of germ diseases. It is our duty to keep well, and we can do much toward this by understanding how to avoid the biological diseases.

QUESTIONS

What are the biological diseases? How many biological diseases do you know? Name them. Describe a germ disease. Describe malaria. What is vaccination? What is quarantine? For what diseases are people quarantined? What is the work of the Board of Health? What is the purpose of disinfection? What are the chief disinfectants?

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PART III

PLANT BIOLOGY

CHAPTER XX

TYPICAL FLOWERING PLANTS

198. Introduction. — The study of plant biology may begin with any plant. The trees in the park, the grass in the lawn, and the hothouse geranium, all respire, use food, and grow. These are plant life processes, and they are similar to the same life processes in animals.

FIGURE 252. — BEAN PLANT.
For root details see Figure 261.

199. The Bean Plant. — We begin the study of plants with the bean, because it can be grown in the laboratory with little care and because its parts are easy to examine. The whole bean plant, Figure 252, is made up of many parts, the roots which hold the plant in the ground and absorb water, and the stem which supports the leaves, flowers, and pods. Each of these parts is called an organ, and each does a given work. While we are learning how the bean uses these organs, we shall compare them with similar organs in other flowering plants, and in this way come to understand how all plants of this kind live.

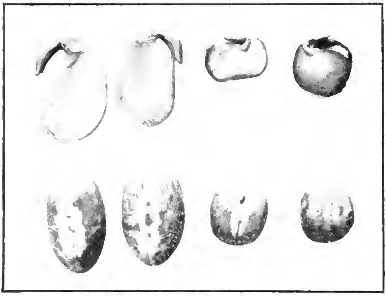

FIGURE 253. — PHOTOGRAPH OF BEAN AND PEA.

200. The Bean Seed. — The bean seed discussed in this study is the familiar dry bean, white or red in color. This seed contains the embryo or young plant which consists of three important parts, all inclosed in the seed coat (testa). These parts are: (1) the small *stem*, the hypocotyl (hȳ-pō-kŏt′′l: Greek, *hypo*, beneath; *kotyle*, cavity); (2) the seed *bud*, the plumule (plūm′ūl: Latin, *plumula*, feather); (3) the seed *leaves*, the cotyledons (kŏt-y̆-lē′dŏn: Greek, *kotyledon*, socket). See Figures 253 and 254.

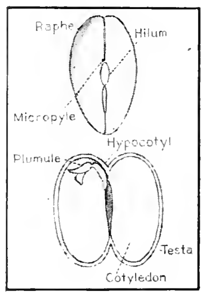

FIGURE 254. — PARTS OF BEAN SEED. Compare with Figure 253.

Every bean is attached at a definite point to the pod in which it grows, and a scar, called the *hilum* (hī′lŭm: Latin, *hilum*, a little body), shows where the point of attachment was. Through this hilum enters all the food material which makes the bean seed. The testa or coat of the bean is the hard outer layer, and beneath this may sometimes be seen a delicate inner layer, called *integument*. These two layers of the seed coat protect the young bean embryo. Other markings on the outside of the bean are the *micropyle* (mī′krō-pīl: Greek, *micro*, small; *pyle*, gate), a small dot at one end of the hilum, and the *raphe* (rā′fē: Greek, *raphe*, a seam), a band or ridge which extends lengthwise around the bean from the top of the hilum to the bottom.

The small stem or hypocotol is the part of the bean embryo that first escapes from the seed coat when the young bean begins to grow. One end of this small stem soon develops into a root which grows into the ground, and the other end develops into a stem which grows above the ground and lifts the seed leaves into the light.

The seed leaves or cotyledons are by far the largest part of the bean, and their size is due to the great amount of food stored in them. They are the parts of the bean seed which are important to man and animals as food.

The seed bud or plumule consists of two small leaves. The plumule is connected closely with the food stored in the seed leaves, which is taken up by the young plant and used in growing.

LABORATORY STUDY

Place a few beans in dry sand in a warm room. Why do not the beans grow and sprout? Place others in water in a warm room. What happens? Place other beans in moist earth (*a*) in a warm room; (*b*) in a cool place. Examine in a few days. These several experiments show the influence of temperatures, soil, and moisture on the sprouting of beans. Heat a few beans in an oven for ten minutes and then place them in a warm, moist soil. Why do they not grow? Soak beans for several hours. Remove the testa and place them beside dry beans for a few days. What happens? This experiment illustrates one use of the testa. Examine a dry bean. Split it along the back and observe (1) the two parts into which it divides. These are the cotyledons of the new plant. Note (2) the pair of small white leaves which are the plumule of the new plant; (3) the hypocotyl, below the cotyledons, from which the stem and roots will grow; (4) the hard covering or testa. Look for the micropyle and raphe on a bean not split.

201. Corn "Seed." — A grain or kernel of corn, commonly called a seed, is like a bean (1) in containing a young plant, the corn embryo; (2) in containing food for the use of the embryo when it first begins to grow; and (3) in having marks upon it. On the top of the kernel is a slight prominence, the scar which marks the place where one thread of the so-called silk was attached. On one side of the kernel is a depression beneath which the embryo lies, and at the base is a stalk by which the kernel is attached to the cob during its development (Figure 255).

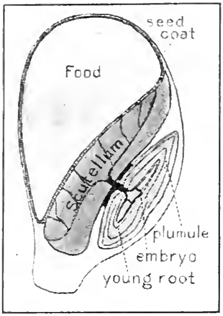

FIGURE 255. — DIAGRAM OF CORN SEED.

A corn grain differs from a bean in being a fruit, — that is, the seed case adheres to the seed coat as a second covering. A kernel of corn, therefore, corresponds to a bean pod containing but one seed. Corn differs from the bean also in the position of the embryo, which is at one side of the food supply. The latter is called the *endosperm* (ĕn′dō-spĕrm: Greek, *endo*, within; *sperma*, a seed). Another difference between the two is that the corn has a single modified cotyledon called the *scutellum* (skū-tĕl′lŭm: Latin, diminutive of *scutum*, a shield), the use of which is to absorb and digest the food and carry it to the embryo (Figure 255). The cotyledon of the corn never appears above ground. The corn embryo has its leaves rolled into a tight, pointed bud, which enables

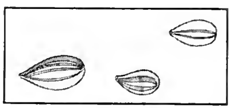

FIGURE 256. — SUNFLOWER "SEED."
A fruit.

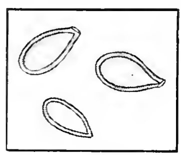

FIGURE 257. — SQUASH SEED.

it easily to pierce the earth above. The root is at the lower part of a short hypocotyl.

As the corn has but one cotyledon, it belongs to the class of plants known as *monocotyledons* (mŏn-ō-kŏt-ȳ-lē′-dŏn: Greek, *mono*, one; *kotyledon*, socket). The bean, having two cotyledons, belongs to the class *dicotyledons* (dī-kŏt-ȳ-lē′dŏn: Greek *di*, two; *kotyledon*, socket).

LABORATORY STUDY WITH CORN

Remove most of the endosperm from a few kernels, and plant them. How does the growth compare with that of a kernel retaining all its endosperm? Examine whole corn kernels, noting (1) silk scar on top; (2) depression on the side; (3) hard outer covering; (4) stalk by which it was attached. Cut crosswise a kernel which has been soaked in water and identify the embryo, scutellum, endosperm, and hard outer covering. Split a kernel lengthwise and find the same parts. Remove the embryo from another soaked kernel and study its attachment to the endosperm. Look for the plumule and root.

Examine such seeds as you can obtain and make a report, using the following table as guide.

	Size	Embryo easily Seen	Hilum at Side	Hilum on End	Two Cotyledons	One Cotyledon
Bean . .						
Pea . .						
Corn . .						
Squash .						
Etc. . .						

202. Classification of Seeds. — The comparative study of the bean and corn seeds shows the important parts of seeds and explains the chief differences between them. The common seeds are classified as follows: monocotyledons: grass, wheat, barley, oats, and rye; dicotyledons: squash, morning glory, tomato, radish, and beet.

203. **Growth of the Bean Embryo.** — As soon as the ground is warm in the spring, farmers plant beans in rows. After the bean seed has lain in the damp earth for about ten days, the moisture has softened the seed coat and food, and the shoots from the beans begin to show above the ground.

The first part of the bean embryo to show is grown in the little stem (hypocotyl). This curves sharply into an arch and begins to push upward through the particles of soil. At the same time delicate roots push downward into the soil (Figure 258). As soon as the arch of the hypocotyl has pushed through the soil into the light, it straightens up and pulls the seed leaves (cotyledons) out of the ground. The seed coats are usually left behind in the soil. As soon as the cotyledons are exposed to the light, they crack apart, slowly spread wide open, and in a few days become green. During these changes in the cotyledons, the leaves of the plumule have taken from them the food stored for the use of the growing bean embryo. As soon as this store of food is absorbed by the young bean plant, the cotyledons drop to the ground. The bean seedling is no longer dependent on the food in the seed, but is able to gain its food from the soil and air.

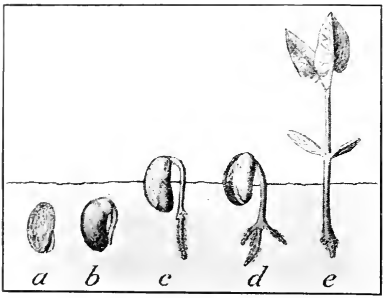

FIGURE 258. — GERMINATION OF BEAN.

During the summer the bean plant grows bean seeds, and the farmers harvest the beans and store the seeds in barrels, sacks, or wooden bins. The dry beans may be kept for years and still grow bean plants at any time when conditions are favorable.

LABORATORY STUDY

Examine germinating seeds and young seedlings of various kinds of plants, and note their peculiarities in sprouting as indicated below.

	Arch Prominent	Arch not Prominent	Cotyledons above Ground	Cotyledons not above Ground	Testa Brought Up	Etc.
Bean . .						
Corn . .						
Pea . .						
Tomato .						
Squash .						
Maple .						
Etc. . .						

204. **Foodstuffs in the Bean.** — The bean stores two kinds of stuffs: carbohydrates and proteins. Carbohydrate is the name of the foodstuff which includes such foods as sugar and starch. The term protein is applied to the foodstuff found in such foods as the lean of meat, the white of egg, and the curd of milk which we use as cheese.

The presence of these foodstuffs may be shown by applying the following chemical tests. Boil beans until they are soft and then place a small portion of them in a test tube. Add a drop of iodine. If starch is present, the mixture will turn purple in color. Add strong nitric acid to a second portion in a clean test tube, boil and cool. If protein is present, the mixture will be a clear yellow color which will become orange if ammonia is added. To a third portion add Fehling's[1] solution as a

[1]

1.	Copper sulphate	9 grams
	Water	500 cc.
2.	Rochelle salts	49 grams
	Caustic potash	30 grams
	Water	250 cc.

Take two volumes of 1, and one of 2, and add to the mixture 2 volumes of water. Do not mix 1 and 2 until ready to use.

test for sugar. If the latter is present, the mixture will become dull orange when heated. Test uncooked seed for oil (1) by heating it over a lamp on a sheet of linen paper; (2) by soaking it over night in ether. (This must not be near a flame at any time.) If oil is present, it will show on the paper as a clear spot, and in the second test the oil will appear on the surface of the ether in the test tube.

Make a record of the results as indicated below:

	Much Protein	Much Starch	Oil	Sugar
Bean				
Corn				
Wheat				
Walnut				
Pea				

205. Digestion of the Food in the Seed. — It may appear strange that the growing bean plant lives upon the food stored in the cotyledons, and yet such is the case. But this food must undergo a real digestion before the bean embryo can use it. We do not know just how this digestion takes place in the bean, but in the corn, as we have learned, there is a special structure, the scutellum, which helps to digest the food in the endosperm. This corn scutellum may be removed from the corn seed and made to digest other kinds of starch, for instance, that obtained from a finely grated potato. This should be kept warm and moist for several hours, after which it may be tested for sugar with Fehling's solution (See page 265). When scientists learn more about the digestive processes of plants they will probably find that they are similar to the digestive processes of animals.

206. The Bean Seedling — Each bean seedling is provided with a supply of food which gives it a start in life. But after this supply is exhausted, the young bean must be able to prepare its own food. The several parts of the bean seedling are the roots, stem, and leaves, all of which work in preparing the seedling's food.

207. Root System. — The first root to form on the bean is called the tap or primary root and grows straight downward. Many branches, known as secondary roots, grow from the taproot. These large secondary roots serve chiefly to hold the plant firmly in place. From the secondary roots smaller branches or *rootlets* grow, and on these, a short distance back from the tip, are numerous *root hairs*.

FIGURE 259. — BEAN PLANTS.

All the food these plants have used came from the cotyledons, as the jar contained only sawdust.

In order to understand the other great use of roots, we must be familiar with their structure. A cross section of a taproot shows three regions. In the central part is a woody portion called the *central cylinder*. Next to and outside of this is a layer known as the *endoderm* (Greek, *endo*, within ; *derm*, skin) which separates the central cylinder from the next region, the *cortex* (Latin, *cortex*, bark). Outside of all is a thin protective layer, the *epidermis*.

If we examine under the microscope a portion of the epidermis taken from near the center of an onion bulb, we find that it is made up of many small parts, called cells. Every cell consists of living matter (protoplasm) surrounded by a wall. Near the center of each cell is a small spherical body called the nucleus. See page 4.

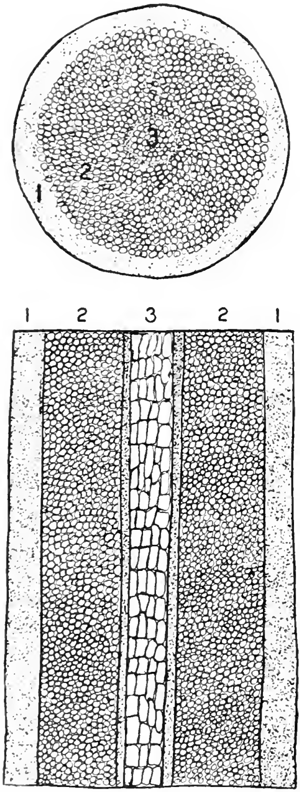

FIGURE 260. — SECTIONS OF BEAN ROOT.

1, epidermis; 2, cortex; 3, central cylinder.

All regions of the plant body are made of such cells, and the cells of each region are adapted to the special work of that region. Therefore the cells of a plant body vary in size and shape, but all the cells of any one region are nearly alike. Such a group of similar cells is called a tissue. See page 5.

A cross section of a taproot shows the tissues of all the layers in the plant. The central cylinder contains groups of cells called fibrovascular bundles. Some of these cells overlap in such a way that they make continuous tubes from the root, up through the stem, and into the leaves. In the leaves the vascular bundles are called veins. The cells which carry the liquids present in the plant are to the plant what veins and arteries are to animals. The inner part of a vascular bundle is made up of woody cells and is called the *xylem*. These cells carry water from the root upwards. The outer part of the bundle (the *phloëm*) is of a softer tissue and contains the sieve vessels which carry liquid food downward.

The epidermis of the rootlets is covered with root hairs, which are really much elongated cells (Figure 261). While root hairs help to hold a plant firmly in place, their main use is to take up water from the soil. The cell walls are thin and are lined with a thin layer of protoplasm. Water is taken in through the walls of the cells by osmosis (page 3). The root hairs which grow in soil apply themselves closely to particles of it, and take from them the thin film of water with which each is covered. On this account the hairs or rootlets grown in soil are much more irregular in shape than those grown in water or in moist air. Unless a plant is removed carefully, all the root hairs are broken off and remain in the ground.

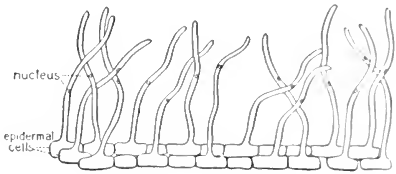

FIGURE 261. — ROOT HAIRS.

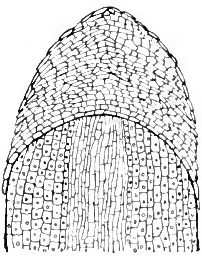
FIGURE 262. — ROOT CAP.

Another statement is frequently made in discussing the uses of root hairs, namely, that by means of an acid which they secrete, they dissolve minerals in the soil so that they can be taken up by water and carried into the plant. This is based on the fact that a seedling grown on a polished marble plate will corrode the surface, and on other experiments. Researches recently made prove conclusively that root hairs do not secrete acid.

Rootlets are protected on the end by a structure called a root cap (Figure 262). This cap is made up of loose cells which are constantly formed from the inside. As fast as the outer cells are destroyed by the pushing of the root through the soil, new cells are ready to take their place.

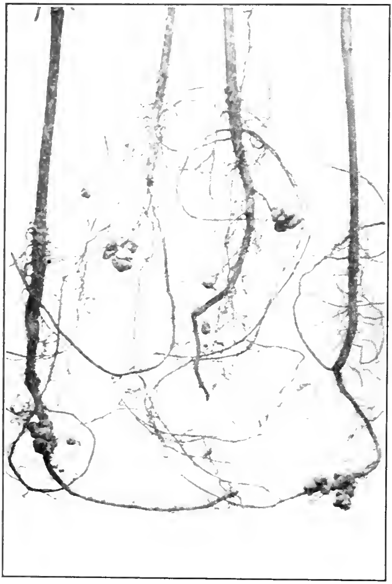

FIGURE 263. — BEAN ROOTS.
Showing tubercles.

Small bunches, called *tubercles* (Figure 263) are found on the rootlets of plants of the bean family. The tubercles are filled with bacteria which gather nitrogen from the air, use what they need, and leave the surplus in the roots. Some of this nitrogen is used by the growing plants themselves, and any that they do not use is left in the soil for the use of other plants. Most plants take from the soil more nitrogen than they add to it, but the opposite is the case with beans and their relatives. Thus clover and other relatives of the bean are used by farmers as a cover crop or for "green manure," so called, for the sake of replacing in the soil the nitrogen which other crops have used up. The practice of rotating crops depends on the fact that different kinds of plants use different material in the soil. In successive years crops of different kinds will grow better than crops of the same kind, unless the soil has been supplied with the used-up elements through the aid of fertilizers and chemicals.

When water containing minerals in solution is taken in through the root hairs, it is passed along by osmosis to the woody layer of the rootlets and thence to the primary root from which it is distributed to the parts of the plant above ground. Here it is made into food and carried by the phloëm of the vascular bundle to all parts of the plant.

FIGURE 264. — FIBROUS ROOTS OF BUTTERCUP.

How do they differ from the bean roots?

The root system of a plant, then, serves two main purposes: to hold it fast in the ground, and to absorb water from the earth. In passing through the soil this water has taken up mineral substances which will enter into the plant's food.

LABORATORY STUDY OF ROOTS

Cut a carrot crosswise and lengthwise, and note the central cylinder and cortex. Cut across one of the larger bean roots, noting (1) the central woody cylinder; (2) the softer ring surrounding it; (3) the outer epidermis. Cut a root lengthwise and find the same tissues. Examine sprouted barley for root hairs and root caps; also a radish seedling for root hairs. Stand a cut-off root in red ink for a few hours. Make cross and lengthwise sections, noting what part has been stained by the ink. This shows the routes through which absorbed water travels.

208. The Bean Stem. — The bean stem is made up of three parts: (1) a central pith where food is stored; (2) woody fiber which conducts water; and (3) a bark and an epidermis which cover and protect it. The stem as a whole holds up the leaves to the air and light, carries water and food materials gathered by the roots to the leaves, and distributes liquid foods to all parts of the plant.

LABORATORY STUDY OF A BEAN STEM

Make a cross section of a bean stem and find (*a*) the central pith; (*b*) the woody ring surrounding it; and (*c*) the outer green bark and the epidermis. Split a stem lengthwise and identify these parts. Stand the cut-off end of a stem in red ink for a few hours; then cut across and lengthwise, noting that the woody tissue is stained red. Compare the stem with the root.

209. **The Bean Leaves.** — A bean leaf consists of two parts: the stalk or *petiole* (Latin, *petiolus*, fruit stalk) by which it is attached to the stem, and the broad, green part, the *blade*. Petioles are longer in some parts of the plant than in others. Where are the longest ones? What reason can you give for this?

The blade of a leaf is in three parts, each of which has a prominent rib entering it from the petiole. From the rib many small branches extend to all parts of that division of the blade. The vascular bundles, or veins, are of use to the leaf, not only in carrying water to it from the root and food back to the root from the leaves, but also in giving firm support to the soft parts between them.

A leaf like the bean, which has many small veins running together, is called a net-veined leaf. All dicotyledonous plants have leaves with net veins.

A section through the blade of a leaf shows several distinct parts (Figure 265). The outermost layer is the epidermis, a layer of cells without much color, which serves as a protective skin. Below the epidermis is a layer of brick-shaped cells placed on end. These are called the *palisade cells*. They contain green coloring matter (*chlorophyll*) which is held in small bodies called *chloroplasts*, a word meaning color-bearers. The position of the palisade cells makes the upper surface of the leaf firmer than it would otherwise be. The arrangement of the cells in a compact layer regulates the amount of light that penetrates to the interior of the leaf and helps to prevent undue loss of water. Below the palisade cells are the loosely arranged cells of a spongy layer. They contain chlorophyll and are exposed to the air which enters through the holes in the lower epidermis. Most of the work of the leaf is done in this green tissue. Because this tissue lies in the middle of the leaf, it is known as *mesophyll* (mĕz′ō-fĭl: Greek, *mesos*, middle; *phyllos*, leaf).

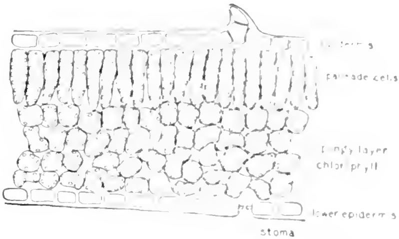

FIGURE 265. — CROSS SECTION OF BEAN LEAF.

How many tissues present?

The holes (*stomata*) in the lower epidermis are more than mere holes, for they can become larger or smaller according to the needs of the plant. Seen from the surface, each stoma is surrounded by two bean-shaped cells, containing some chlorophyll. These cells (Figure 267) called guard cells, have the power of absorbing water to a greater degree than the other cells of the epidermis. When the guard cells are full of water, or turgid, the opening between them is larger than when they are almost empty or flaccid. The size of the openings regulates the amount of air which passes in and out, and of the watery vapor which passes out.

FIGURE 266. — LEAF SKELETON.

Showing net veins.

The stomata are more numerous on the under side of leaves which grow with the blades in a horizontal position, because there the stomata are protected from water which would interfere with their action. Leaves which are nearly upright have the stomata on both sides, and leaves like a water lily that rest on the surface of the water have the stomata on the upper surface. Stomata are both small and numerous. A dozen or more are found in some leaves in a circle no larger than a period on this page.

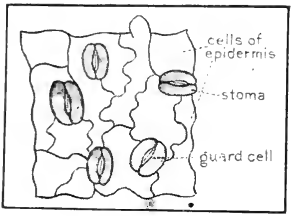

FIGURE 267. — EPIDERMIS OF LEAF.

During a season a large amount of water passes off through the stomata of any plant. The process of giving off this water is called *transpiration.* This process is unavoidable. The root hairs gather water almost continuously, and this is carried to the leaf by the fibrovascular bundles and distributed to the cells. The mesophyll in the leaf uses the minerals which the water contains, but it does not use all of the water. This excess is cast off into the spaces between the cells (intercellular spaces), which communicate with the outside through the stomata. Usually the transpiration takes place readily, but if the outside air is not in condition to take up moisture, the cells become too full and the excess is passed off through organs (*the hydathodes*) at the ends of the vascular bundles. The drops of water which escape from the ends of the hydathodes are called *guttation drops.* Grass blades and strawberry and nasturtium leaves show such drops almost every morning in the spring. House plants like fuchsia or impatiens will produce guttation drops if covered for a few hours with a bell jar. Cool a portion of the jar later, noting what happens. Give an explanation of what you see.

LABORATORY EXPERIMENTS

Hold the under side of a geranium leaf against a cool window pane and note the moisture which is condensed. Try other leaves in the same way. With clips fasten a watch crystal to a growing leaf and seal with vaseline. Note the moisture condensed. Try the upper side of the same leaves. Plunge a leaf into water and set the water in the sun. Do small bubbles appear on the surface of the leaf? Where?

Take leaves of the same plant and coat with paraffin one leaf on both sides, another on the upper side, and a third on the under side. Lay them aside for a few days. Then remove the paraffin and examine all the leaves. Which is in the best condition? Why?

Examine with a microscope the epidermis of a number of leaves from different plants. Note the irregular epidermal cells and the stomata cells. Are the stomata arranged regularly?

Hold a leaf up to the light and notice the arrangement of the veins and soft parts. Study a cross section of a fresh leaf and find: (1) the epidermal layer on top; (2) the palisade layer below it; (3) the wide, spongy layer; and (4) the lower epidermal layer with stomata.

Stand the petiole of a leaf in red ink and observe how the color spreads through the veins of the leaf.

210. The Work of the Bean Leaf. — As soon as the bean plant gets its plumule into the air, the pale leaves unfold, turn green, and increase in size. The stem elongates, branches, and other leaves appear. Each of these new leaves is held out from the stem or branch in a position which gives the leaf the greatest possible amount of air and light. The leaves of the plumule begin to be useful to the plant as soon as they become green. Their work is most important in the life processes of the plant.

Does the bean plant respire? When an animal respires, it takes oxygen into the cells of its body and gives off carbon dioxide. The presence of this gas is shown by forcing the air that comes from the lungs through a tube into limewater. The limewater becomes cloudy. This is a simple chemical test for carbon dioxide.

If a growing bean plant is kept tightly covered under a glass disk for twenty-four hours and then the inclosed air is forced through limewater, the clear limewater turns cloudy. Thus it is shown that the bean leaves have given off carbon dioxide. The only life process which is known to produce carbon dioxide is ***respiration.*** Therefore we can say that the plant respires and that this life process in the plant is similar to the same life process in animals. See pages 3 and 15.

The Manufacture of Food.—The words "manufacture of food" are often used in connection with plants. This process may be better understood by comparing it with the manufacture of some article in a factory. To manufacture an article, there must be a building with rooms; machines, and power to run them; and various substances, called raw materials, which are to enter into the finished product. In addition there must be a supply of water, pipes in which to carry it, and forces to move it. Besides the finished product, a factory always yields some waste material. When the product has been finished, it is usually packed for distribution and stored in a room to which it is carried on tracks.

In the leaf factory, the cells of the palisade and spongy layer are the rooms. The machines are chlorophyll bodies, and the power is furnished by the sun. The raw materials are water, containing a small amount of mineral matter obtained from the soil, and carbon dioxide obtained from the air. The pipes in which the water comes are the fibrovascular bundles, and the stomata are the places where the air enters.

The forces which move the raw material are largely osmosis, capillarity, and the suction caused by transpiration. The materials made are carbohydrates, in the form of starch and sugar, and protein. Waste material is oxygen. The material ready for carrying is usually in the form of sugar. The storehouse may be the stem, the roots, or the seeds of the plant, and the tracks for carrying the food to the storehouse are the sieve tubes of the

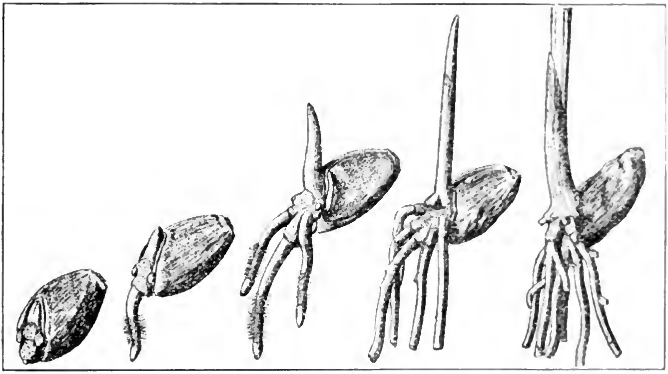

FIGURE 268. — GERMINATION OF A MONOCOTYLEDON.

fibrovascular bundles. Part of the carbon dioxide is furnished by the plant's own respiration. The plant takes from the carbon dioxide all of the carbon, but only a part of the oxygen, leaving some of it to be thrown off as waste.

The waste oxygen thus set free by the leaf in the manufacture of food can now be used by animals in respiration. Animals are constantly setting free carbon dioxide which plants must have if they are to make food. Animals will never be able to use up all of the oxygen in the air so

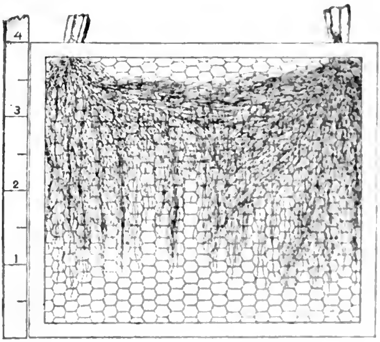

FIGURE 269. — ROOTLETS OF TWO CORN PLANTS.

Showing how they strive for food and moisture.

long as there are plenty of green plants, nor, for the same reason, will there ever be enough carbon dioxide to poison animals.

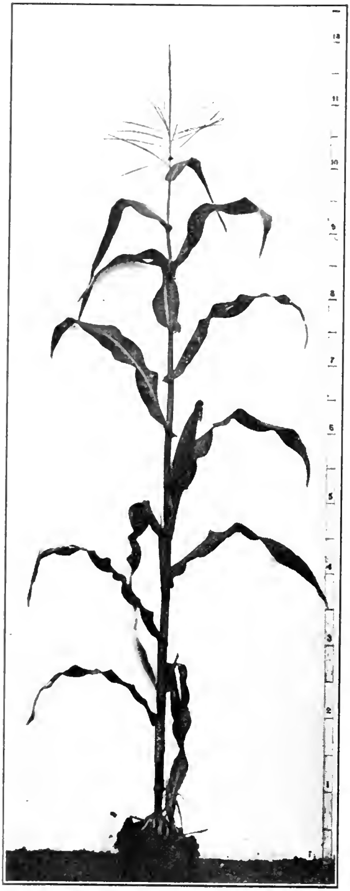

Figure 270. — Corn Plant.
Showing prop roots.

Another vital process which the leaf shows is digestion. It is difficult to explain how the food is digested in plants, but scientists have proved satisfactorily that digestion does take place.

After the food is digested, it is distributed by circulation. In the experiments it was shown that the plant has a vascular system, and that red ink was carried to all parts of the leaf. Evidently, then, a plant has circulation.

Food to be used by the plant cells must not only be prepared by digestion and distributed through circulation, but each cell must take from the sap what it lacks, and build this food into living plant protoplasm. This process is called assimilation and as a result of it cells grow, divide, and grow to full size again, thereby increasing the size of the plant.

Summary of the work of the bean leaf: (1) It performs respiration; (2) it performs transpiration; (3) it manufactures sugars and starches (a process technically known as photosynthesis), and proteins; (4) it digests some of the food that it has made; (5) it assimilates some of the digested food; (6) by circulation it carries some of the starch and protein to other parts of the plant and brings fresh raw materials into the leaf; (7) it gives off waste material in the form of oxygen.

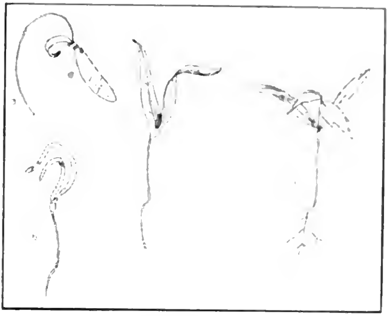

FIGURE 271. — MAPLE SEEDLINGS. Compare with Figure 274.

211. The Corn Seedling. — When the corn seedling begins to grow, its tightly rolled leaves which form the sharp plumule push up through the soil. Next the root grows. The primary root, instead of remaining the largest, as in the case of the bean, sends off a number of branches about the same size as itself. Like those of the bean, these branches have rootlets and root hairs. There is little difference between the roots of corn and beans so far as their structure goes, but corn roots have neither tubercles nor nitrogen-gathering bacteria. The first leaves of corn are like the later ones, except in size, be-

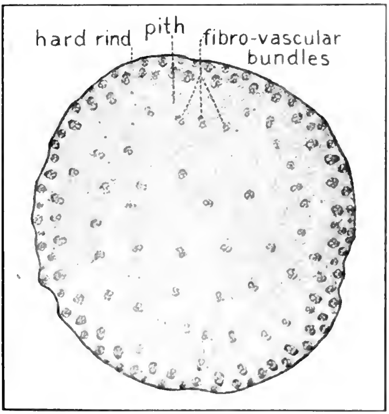

FIGURE 272. — MICROPHOTOGRAPH OF CORN STEM.

cause only the plumule comes above the ground. The kernel of the corn remaining in the ground shrinks as the plant grows and as the food is used. The modified cotyledon (scutellum) dies when it has served its purpose of

FIGURE 273.—STEM OF CORN.
Showing node and fibrovascular bundles.

transferring to the young seedling the food stored in the endosperm.

212. The Root System of Corn. — There are many fibrous roots of small size, which extend to a distance of several feet in every direction. Besides these underground roots, the corn plant has aërial roots growing from the lower joints of the stem, and these are known as *prop roots*. These roots are stout, straight, sometimes green, branching in the soil. They serve to hold the plant firmly in the soil.

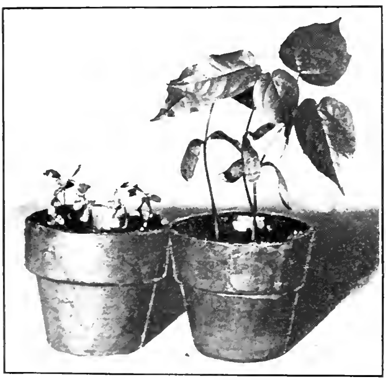

FIGURE 274.—ELM AND OLDER MAPLE SEEDLINGS.

213. The Corn Stem. — While the roots of the bean and corn are similar in structure, there are several differences in the stems of these plants. The corn stem has no central region filled with pith, but the pith makes up the greater part of the interior. Scattered through it are stringlike parts, fibrovascular bundles, each consisting of xylem and phloëm, but not arranged in any regular order (Figure 273). Surrounding the pith is a hard rind which gives the plant stiffness. The place where a leaf joins the stem is called a *node*. Some of the vascular bundles of the stem pass out through the nodes and as veins continue on into the leaves. The corn stem represents the structure of all monocotyledonous plants, as the bean stem represents all of the dicotyledons which live only one season.

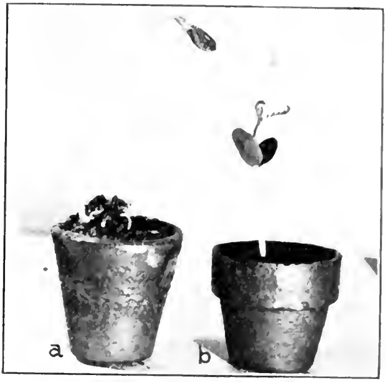

FIGURE 275. — SEEDLINGS.

a, Horse-chestnut seedling ; *b*, Honey locust.

FIGURE 276. — OLDER HORSE-CHESTNUT SEEDLINGS.

Note the palmately compound leaves.

214. The Corn Leaf. — The leaf of the corn has no petiole, but is attached to the stem by a clasping base. This base protects the tenderest part of the stalk, which is just above the node. At the point where the clasping part and the blade of the leaf meet, there is a collar which prevents water from running down inside the clasping base. The corn leaf is long and narrow; it curves, and has wavy edges. Veins run from the base to the tip without branching, giving the parallel venation characteristic of the monocotyledons.

FIGURE 277. — WHEAT SEEDLINGS.
a, grown in sunlight; *b*, grown in the dark.

A cross section of a corn leaf shows that it has the same structure as the bean leaf. The stomata are aided in preventing undue transpiration during dry, hot weather by the tight rolling of the leaf.

215. Other Seedlings. — All dicotyledonous plants are like the bean in having two cotyledons, but differ in other respects. Peas, for instance, do not bring their cotyledons above ground. Morning glories have their cotyledons folded in the middle; maple seedlings have theirs folded on each other. Many seedlings have leaves which differ in shape from those of the mature plant (Figure 271).

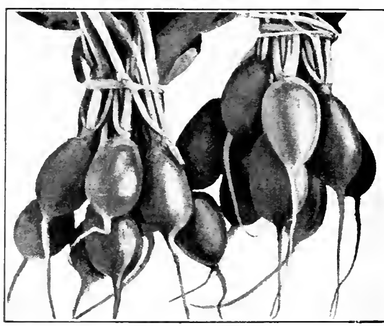

FIGURE 278. — ROOTS OF RADISH.
Containing stored-up food.

All monocotyledonous plants are alike in having only one cotyledon which usually remains in the soil during germination. The first seedling leaves look more like the later ones than in the dicotyledons.

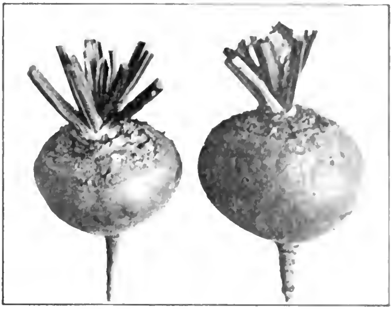

FIGURE 279. — ROOTS OF BEET.
A valuable food. See also Figure 296.

216. Other Roots. — All roots serve to hold the plant in place and to collect water. Some roots have other uses in addition. The roots of beets, turnips, carrots, parsnips, and radishes store up food the first year of their growth. If, however, they are planted a second year, they use the stored-up food to produce fruit and seeds (Figures 278 and 279).

Ivy has two kinds of roots, one in the ground, the other

FIGURE 280. — ALFALFA ROOT.
Compare with Figures 269, 281, and 283.

along the sides of the stem to help the plant cling to its support. Roots which grow in the air are called *aërial* (Latin, *aer*, air) roots (Figure 281).

Sometimes roots arise from the bottom of a stem which has been cut or broken from the main plant, as in the case of a geranium slip. Such roots are called *adventitious*. The willow is a tree which is easily grown from a twig, because it readily forms adventitious roots.

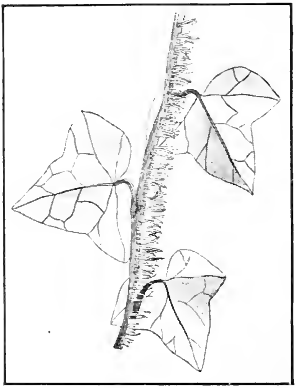

FIGURE 281. — AËRIAL ROOTS OF IVY.

Most roots grow downward in soil which is well cultivated. The stimulus which causes them to take this direction is gravity, or as scientists say, they are showing *geotropism* (gē-ŏt′rō-pĭzm: Greek, *ge*, earth; *tropos*, a turn).

Other influences governing the direction in which roots grow are the presence of water and obstacles. When a root turns in the direction which will give it the best supply of water, it is exhibiting *hydrotropism* (hī-drŏt′rō-pĭzm: Greek, *hydro*, water; *tropos*, a turn). When a root turns aside to avoid an obstacle it acts in response to the stimulus of touch or contact, showing *thigmotropism* (thĭg-mŏt′rō-pĭzm: Greek, *thigmos*, touch; *tropos*, a turn). The roots of poplar, willow, and soft maple trees, in seeking water, often clog sewer pipes by filling them with rootlets after they have gained an entrance through a joint, a habit which renders them objectionable as shade trees.

In agriculture, the soil is made fine and porous to help the roots of plants get food and moisture.

LABORATORY WORK ON ROOTS

Test the roots of beet, carrot, parsnip, radish, and turnip with iodine for starch; with Fehling's solution for sugar; with nitric acid for protein.

Examine a large number of roots and report.

	Roots All Underground	Roots not All Underground	Primary Roots	Fibrous Roots	Aërial Roots
Dandelion					
Plantain					
Carrot					
Dahlia					
Corn					
Ivy					

217. Other Stems. — The stems of all plants are like the stem of the bean in the work which they do, but some stems have additional uses. The stems of such plants as Solomon's seal, dogtooth violet, and Jack-in-the-Pulpit store up surplus food. These stems are thick and fleshy, and remain underground from year to year. For this reason they are often mistaken for roots, but they can always be

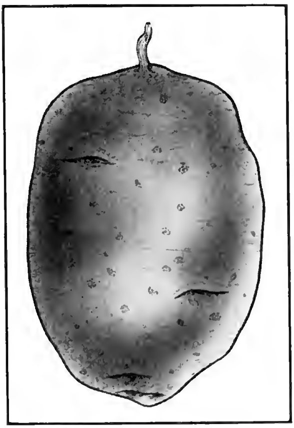

FIGURE 282. — POTATO.
The eyes are buds.

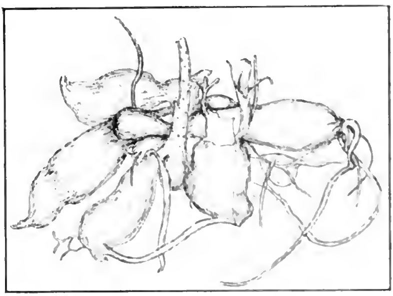

FIGURE 283. — DAHLIA "ROOTS."
An underground stem which stores food.

recognized as stems by the buds of new leaves, or the scars of former leaves. Underground stems, called *rhizomes* (rī′zōm) or rootstocks, send up aërial stems which live through one season.

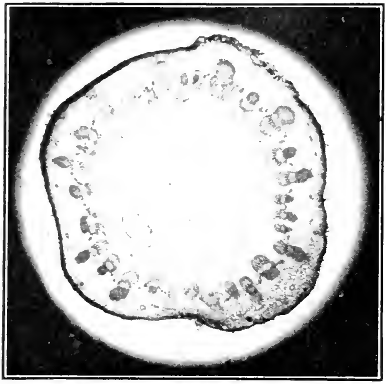

FIGURE 284. — MICROPHOTOGRAPH OF SUNFLOWER STEM.

Stems like the water lily, which grow in water, have large air spaces to carry air to the roots that lie in the mud at the bottom of the water.

The trunks of trees are stems. In evergreen trees (pine, spruce, etc.) the trunk puts out branches, but does not divide, and tapers from base to tip. Such trunks are called *excurrent* (Latin, *ex*, out; *curro*, to run). In the case of the elm tree and many others, the trunk itself divides again and again. Such a trunk is called *deliquescent* (Latin, *de*, from; *liquescere*, to become liquid).

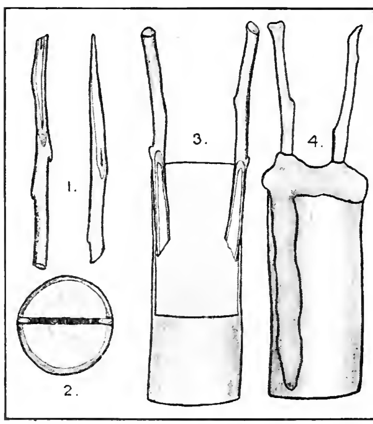

FIGURE 285. — CLEFT GRAFTING.

An interesting comparison is that between the climbing and twining stems of plants, especially vines, and the sturdy trunks of trees. The morning glory is a plant which twines around some support and thus is able to get sunlight for its many leaves. Twining plants of the same kind always curve in the same direction. In twining around any object they touch, climbing plants are responding to thigmotropism.

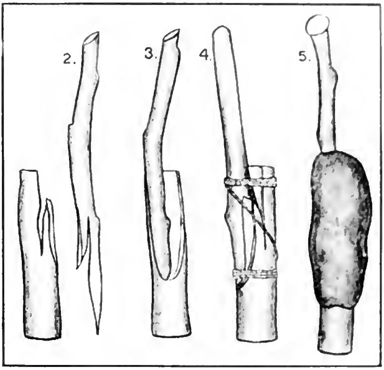

FIGURE 286. — WHIP GRAFTING.

The wild grapevine is a plant which climbs to the top of trees by means of a long, leafless stem. Such plants, common in the forests of tropical countries, are called *lianas*.

Woody stems have a structure which differs from that of the soft bean stem. On the outside is the brown bark in which are *lenticels*, holes which allow air to enter. Under this is a layer of green bark, the outer edge of the phloëm of the vascular bundles. Between the phloëm and the xylem of each vascular bundle is a region of rapidly dividing cells, which is called the *cambium*. When the vascular bundles are crowded close together the cambium of adjoining bundles touches, thus forming a ring around the tree (Figure 284). The outer edge of this cambium layer is always turning to phloëm, and the inner to xylem.

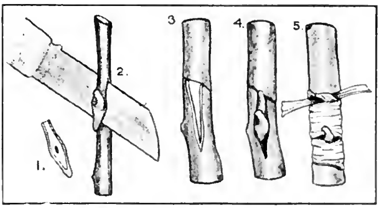

FIGURE 287. — BUDDING.

A woody twig like the horse-chestnut (Figure 290) has

FIGURE 288. — TWINING STEM OF DODDER.

FIGURE 289. — CREEPING STEM OF TRAILING ARBUTUS.

a bud at the end called a *terminal* bud, and along the branch are other buds, named *lateral* buds. These buds are covered with scales and contain the leaves of the next season arranged in a definite manner. Sometimes buds

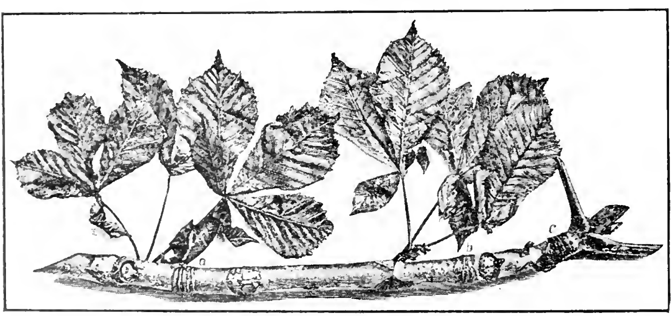

FIGURE 290. — HORSE-CHESTNUT.

contain both leaves and flowers. As a bud opens, the scales drop off leaving on the twig scars crowded together in indistinct rings. The growth of a twig in the preceding year can be seen by noting the distance between the tip of the twig and the first group of indistinct rings, which marks the position of the terminal bud of last year. A study of the buds on a branch shows where the new branches will form.

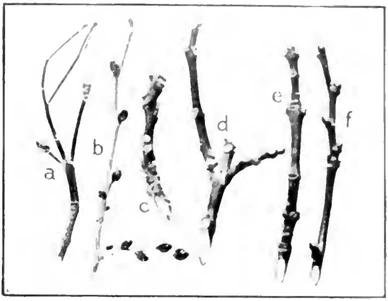

FIGURE 291. — TYPES OF TWIGS.
a, maple; *b*, elm; *c*, walnut; *d*, catalpa; *e*, ash; *f*, linden.

The place where the leaves of last year were attached shows on the bark as scars, called *leaf scars*. In each leaf scar are a number of small dots. These dots are the ends of the vascular bundles which grew from the stem into the leaf.

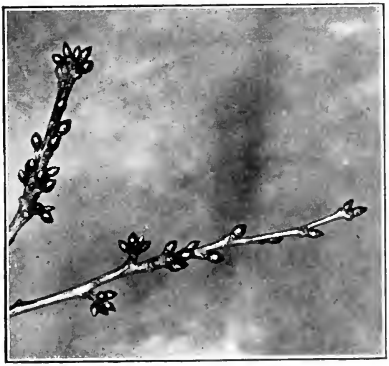

FIGURE 292. — CHERRY TWIGS.
Leaf buds and fruit buds.

A cross section of a woody stem shows a central pith surrounded by one or more rings of wood. The pith and the bark are connected by narrow lines of pith called medullary rays (Figure 293). A

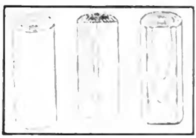

FIGURE 293. — SECTIONS OF WOODY STEM.

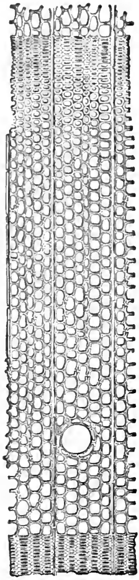

FIGURE 294. — WOOD OF SPRUCE. Greatly magnified.

woody layer examined under a microscope shows large cells on the inner side of each layer, and smaller, thick-walled cells on the outer side. The large cells are formed when conditions are favorable to rapid growth, and the smaller cells when conditions are less favorable (Figure 294). A dry season may check growth during the middle of the summer so that an indistinct ring will occur between two distinct ones. This makes it impossible to tell accurately the age of a tree by counting the rings.

Every part of the woody stem has a distinct use. The bark protects the tender growing parts within. The xylem carries water containing food materials from the roots to the leaves, and the phloëm carries to other parts of the plant for use or for storage the food which has been made from the raw materials. As the stem increases in thickness, only the outermost layers of xylem continue to carry water, for the inner layers fill up with a substance which hardens into wood. Although they are dead, these layers are still of use in giving stiffness to the tree. The work of the tree goes on without them, as is shown when a tree decays in the center. The pith in the center of a tree and in

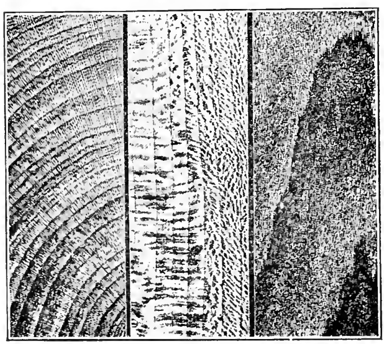

FIGURE 295. — PHOTOGRAPH OF SECTIONS OF WOOD.

the medullary rays serves as a storehouse for food and as lateral conductors of sap.

Liquids are always passing along the paths indicated, but this process is observed most readily in the spring when the sap runs from the broken end of a branch. When the leaves are grown, much of the water carried to them is lost by transpiration, and little is left to be carried back. In the spring, water is carried down, as well as up.

FIGURE 296. — FOOD STORAGE.
Creeping stem of Canada ginger.

Most of our common lumber is made by sawing the trunks of trees lengthwise. Sawing in this way shows the annual rings as long lines (Figure 295), but does not show the medullary rays except in a few boards. Lumber to be used in furniture is often cut so as to show as many medullary rays as possible. The rays are lighter in color and more glistening than the woody layers.

A tree grows by adding a layer of new wood each year. The branches of the current season have only a single ring of wood, while those of the season before have two rings, and so on.

LABORATORY STUDY OF TWIGS

Examine a twig from a horse-chestnut tree, and identify (1) the terminal buds; (2) lateral buds; (3) leaf scars; (4) dots in leaf scars; (5) rings; (6) scales covering buds; (7) breathing pores or lenticels. Dissect a bud to see what it contains. Make a cross section of a stem and find (1) the pith; (2) woody rings; (3) bark in two layers.

FIGURE 297. — CELERY PLANT.
Compare with Figures 279 and 282.

FIGURE 298. — CABBAGE PLANT.

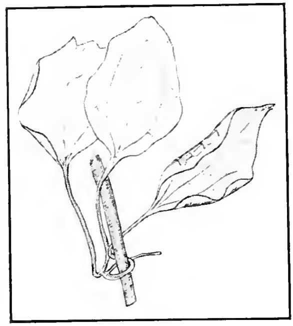

FIGURE 299. — TWINING PETIOLE OF CLEMATIS.

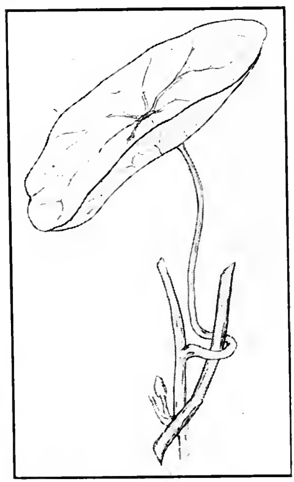

FIGURE 300. — TWINING PETIOLE OF NASTURTIUM.

Examine, with a microscope, a section of wood, looking for the pith, medullary rays, and annual rings. Examine the boards in the room and furniture to find the annual rings and medullary rays.

REPORT ON TWIGS

Record your observations in a report.

	Position of Buds	Arrangement of Buds	Contents of Buds	Distance between Leaf Scars	Number of Scales	Lenticels Prominent	Lenticels not Prominent	Lenticels Transverse	Lenticels Vertical	Shape of Scales	Color of Scales
Geranium .											
Horse-chestnut .											
Lilac . .											
Maple . .											

218. Other Leaves. — All leaves have the same work to do as the leaves of the bean, but some leaves have other

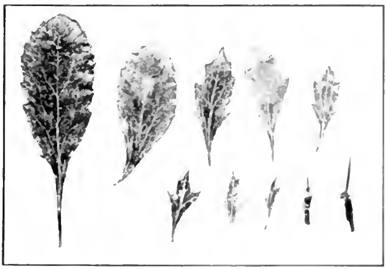

FIGURE 301. — BARBERRY LEAVES.
Showing how a leaf may become a thorn.

work in addition. The storage of food is one additional task. Celery and rhubarb (pieplant) store food in the

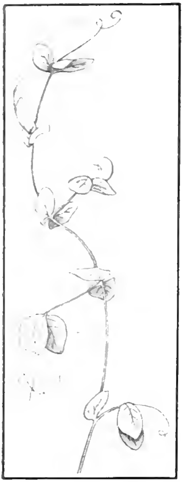

Figure 302. — Pea Plant.
Leaves modified into tendrils.

thick, fleshy stalks of their leaves. In cabbages, the blade of the leaf is the place of storage, while in onions it is the thick enlarged base of the leaves.

Clematis and nasturtiums climb by twining the petioles of their leaves around a support.

Pitcher plants have leaves which hold water and entrap insects. Venus's fly-trap and sundew both use their leaves to catch insects.

Plants which have leaves lasting more than one year are called *evergreen;* and those that shed their leaves every autumn are called *deciduous* (Latin, *deciduus*, falling off). The blade of some leaves is in one piece, as is the case with the geranium. Such leaves are called simple leaves to distinguish them from the compound leaves, like the rose or horse-chestnut, in which one petiole supports several leaflets.

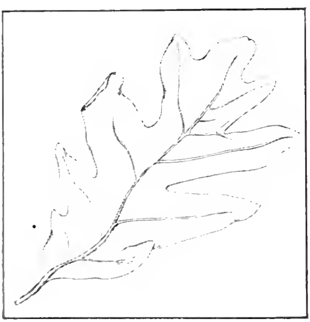

Figure 303. — Leaf of Oak.
Simple leaf.

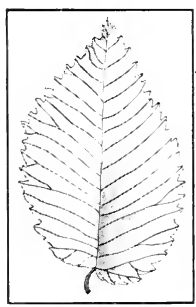

Figure 304. — Leaf of Elm.
Simple deciduous leaf.

LABORATORY EXPERIMENT TO PROVE THAT LEAVES GIVE OFF WATER

Wrap in waxed paper a jar containing a small plant, and cover the earth with half an inch of melted paraffine to prevent evaporation. Weigh the plant each day and note the amount of water lost by transpiration through the stomata.

LABORATORY STUDY OF LEAVES

Examine as many leaves as possible and record the facts which you have learned about them in a report like the following:

	Leaves Simple	Leaves Compound	Deciduous	Storage	Climbing
Cherry .					
Maple .					
Lilac . .					
Ash . .					
Rose . .					
Horse-chestnut .					
Etc. . .					

219. Comparison of a Monocotyledonous with a Dicotyledonous Plant. —

	Monocotyledon Corn	Dicotyledon Bean
Root.	Epidermis. Cortex. Endoderm. Central cylinder. Root caps. Root hairs.	Same structure.
Stem.	Hard outside.	Thin epidermis in young plants, bark in old.
	Much pith.	Pith confined to center and medullary rays.
	Scattered vascular bundles, no cambium.	Vascular bundles form ring, phloëm out, xylem in, cambium between.
	Vascular bundles given off from nodes, to leaves.	Vascular bundles pass to branches and to leaves.

	Monocotyledon Corn	Dicotyledon Bean
Leaves.	Long, simple, and narrow.	Broad, compound.
	No petiole, but clasping base.	Petiole.
	Parallel veins.	Netted veins.

220. The Bean Flower. — Just before the bean plant reaches full size, greenish buds appear in clusters on the ends of the branches. These green buds grow into the bean flower. This flower is made up of a number of parts, all of which have an important work to do in producing the bean seed.

The parts of the bean flower have technical names which it is necessary to learn in order thoroughly to understand flowers. The green, outermost part, called the *calyx* (Greek, *kalyx*, cover), is made up of separate *sepals* (Latin, *separ*, separate) which form a cup in which the rest of the flower is fastened. The calyx protects the delicate parts of a flower while they are small. Within the calyx is the white and much larger part called the *corolla* (Latin, *corolla*, crown). The corolla (Figures 305 and 307) is made up of irregular shaped structures called *petals* (Greek, *petalon*, leaf); within the corolla there is a group of *stamens* (Latin, *sto*, stand) which are recognized easily by their slender stalks, *filaments*, and enlarged tips or *anthers*. At the exact center of the bean

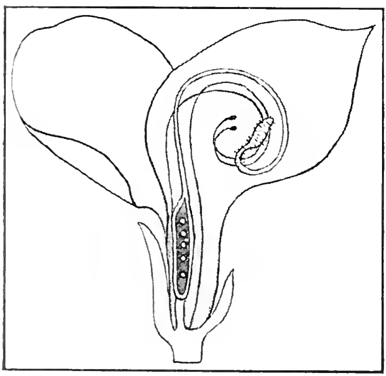

Figure 305. — Diagram of Bean Flower.

flower and within the group of stamens is the *pistil*. The stamens and pistil are the important parts of the bean flower because they produce the bean seed (Figures 306 and 307). The stamen bears in the enlarged tip many minute bodies which are known as *pollen* or pollen grains (Latin, *pollen*, fine flour). The pistil is divided into three parts: (1) a slightly expanded and sticky tip, the *stigma* (Greek, *stigma*, point); (2) a slender portion connecting the stigma with the much larger base, the *style* (Greek, *stylos*, pillar): (3) and the swollen base, the *ovary* (Latin, *ovum*, egg). See Figure 306. The ovary contains small, rounded bodies called *ovules* which ripen into seeds.

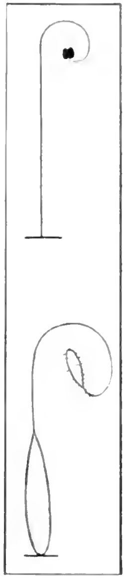

FIGURE 306. — DIAGRAM OF STAMEN (above) AND PISTIL (below).

The bean flower is a complete flower, because it has all of these parts: calyx, corolla, stamens, and pistil. It is also said to be perfect because it contains in the same flower the two organs needed to produce seeds, the pistil and stamens.

The word *pollination* is used to describe the carrying of the pollen from the anther of the stamen to the stigma of the pistil. This may be done by the wind, by insects, or by the contact of a stamen with a stigma. The bean flower secretes a sweet fluid, nectar, at its base, which is the fluid the bees gather to make into honey. When a bee alights on a bean flower, it pushes its head among the inner parts to get the nectar. In withdrawing its head, pollen is brushed off and the hairy body of the bee, especially the head, is covered with it. When the bee puts its head into the next bean flower, some of this pollen is caught by the sticky stigma past which the bee has to push to get the nectar. Thus the

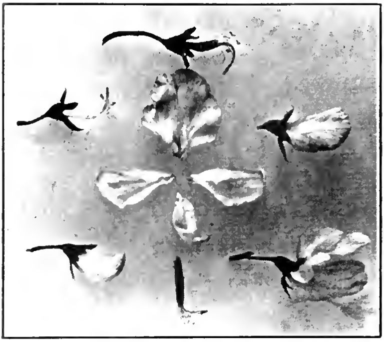

FIGURE 307. — SWEET PEA FLOWER.

stigma is covered or *pollinated* with pollen from the stamens of another flower, and the first step is taken which results in the formation of a bean.

221. The Corn Flower. — The flower of the corn is imperfect, for it lacks one of the two parts necessary to make a seed. Both parts, however, are found on the same plant, the stamens in the "tassel" (Figure 270) at the top of the stalk, and the pistils on the "ear" (Figure 310) at the side

FIGURE 308. — FLY POLLINATING WILD CARROT.

of the stalk. The style of each pistil protrudes from the ear of corn as a long green thread, called the silk. The pollen is light and abundant, and falls from the stamen with every stir caused by the wind. The stigma at the end of the style is sticky, as in the bean. In a field of corn where many plants are shedding pollen at the same time, it is almost certain that every pistil will receive at least one grain of pollen. It is to secure thorough pollination that corn is planted in fields, with the plants close together.

FIGURE 309. — SWALLOW-TAIL BUTTERFLY POLLINATING PERSIAN LILACS.

Plants which have both stamens and pistils on them, but on different flowers, are called *monœcious* (mŏ′nē′shŭs: Greek, *monos*, one; *oikus*, house). Plants which have only staminate or only pistillate flowers are called *diœcious* (dī-ē′shŭs: *di*, two: *oikus*).

FIGURE 310. — CORN FLOWER WITH PISTILS.

222. **Fertilization.** — The second step in the production of a seed is fertilization. By this we mean the union of the sperm nucleus of the pollen cell (male parent) with that of the egg cell in the ovule (female parent).

The pollen grain has two coats, an outer and an inner. The outer is thicker than the inner, but it has thin spots in it. When a pollen grain falls on a sticky stigma, the inner coat pushes out through one of the thin places, forming a tube into which all the contents of the pollen grain flow. The contents, at this time, consist of two nuclei and a small amount of protoplasm. The pollen tube grows and pushes its way through the loose tissue of the stigma till it reaches the ovary containing the ovules (Figure 311, *a*, *b*).

The ovules are attached to the sides of the ovary. Each has a thick coat called the integument which does not quite meet at one spot, known as the *micropyle.* Inside the ovule is the embryo sac containing the egg cell and a few other cells.

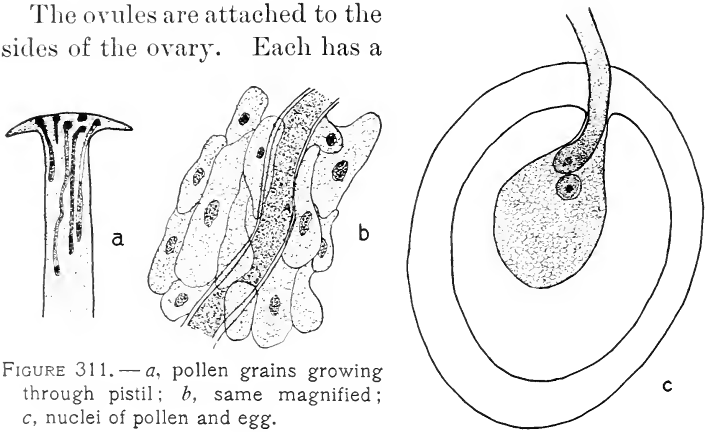

FIGURE 311. — *a*, pollen grains growing through pistil; *b*, same magnified; *c*, nuclei of pollen and egg.

When the pollen tube reaches the micropyle of an ovule it enters, touches the egg cell, and bursts. The male nucleus unites with the nucleus of the egg, and fertilization is accomplished (Figure 311, *c*). The other nucleus of the pollen tube usually unites with a nucleus near the center of the embryo sac and helps to form tissue which may be of use to the growing embryo or may form a part of the mature seed.

The fertilized egg cell soon begins to divide and grow, and

FIGURE 312. — PISTILLATE AND STAMINATE FLOWERS OF WILLOW.

finally it develops into the embryo, consisting of plumule, hypocotyl, root, and cotyledons. The integument changes to testa, food is stored up for the embryo, and the seed is ripe, ready to start a new plant, although it may have to wait for years before conditions allow it to sprout.

223. Other Flowers. — Flowers like the bean which have all the parts usually found in a flower — sepals,

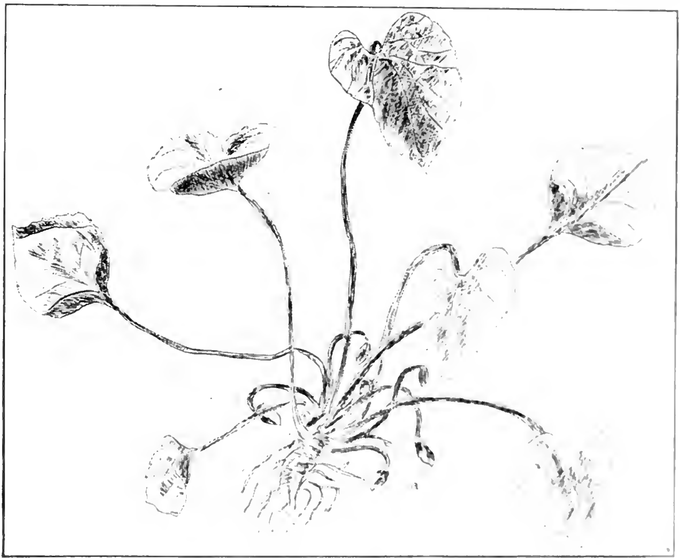

FIGURE 313. VIOLET.
a, cleistogamous flowers.

petals, stamens, and pistil — are complete. As we have seen, they are also perfect because they have in the same flower stamens and pistil, the parts necessary for the production of seed. An imperfect flower may be staminate, having only stamens, like the tassel of the corn, or pistillate, having only pistils, like the ear of the corn (Figure 312). So an incomplete flower may lack either sepals or, as is more common, petals. Hepatica is an example of a flower which has no petals, but its sepals are colored.

Regular flowers are those in which all the parts of the same kind are the same size and shape, as in the blossom of the apple. In irregular flowers all the petals or sepals are not of the same shape. The bean is an irregular flower, and so is the violet.

Cleistogamous flowers (klīs-tŏg′ȧ-mŭs: Greek, *klistos*, closed; *gamos*, marriage) are found in the violet (Figure 313) and pansy in addition to the flowers of the ordinary type. These are formed underground near the surface, have no colored parts, usually only one stamen, and they never open. They produce many seeds, however.

FIELD AND LABORATORY STUDY

Study flowers in field and laboratory, and record the results, using the following table as guide.

	Corolla Regular	Corolla Irregular	Corolla Lacking	Stamens only in a Flower	Pistils only in a Flower	Flower Perfect
Geranium	X					
Castor bean						
Salvia		X				
Nasturtium						X
Pansy		X				
Etc.						

Carolus Linnæus (the Latinized form of the name Karl von Linne) was born in 1707 and died in 1778. He was a celebrated Swedish botanist and naturalist.

Linnæus went to the University of Upsala in 1728, attracted by the fame of Rudbeck, the Professor of Botany, whose assistant he became.

In 1732 he explored Lapland. Later, while studying in Holland, he wrote works on botany which attracted wide attention. In 1741 he became Professor of Botany at Upsala, whither his fame attracted students from many foreign countries. Linnæus' system of plant classification greatly promoted the study of botany in his day.

The *classification of plants* by stamens and pistils was originated by Linnæus, the usual name given to Carl von Linné (1707–1778), the Swedish botanist. During the period of his studies many new plants were being brought to the attention of botanists by the traders who were constantly penetrating to parts of the world hitherto but little known. In 1737 Linnæus published his famous book, *Genera Plantarum*, in which he gave special names in the nomenclature of plants, and also first enunciated the principles of defining general species and the use of specific names. For his achievements in the field of botany Linnaeus was elevated to the nobility.

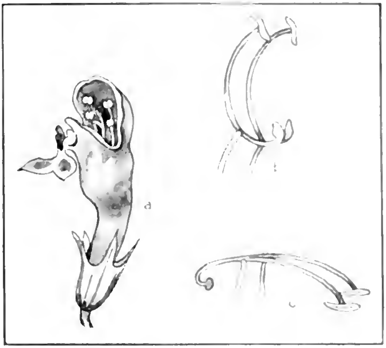

FIGURE 314. — TWO-PARTED FLOWER OF MINT.

Note the convenient place for the bee to alight; *b*, stamens in usual position; *c*, stamens bent down by bees. Pollen will be shaken on to the bee and carried to another flower.

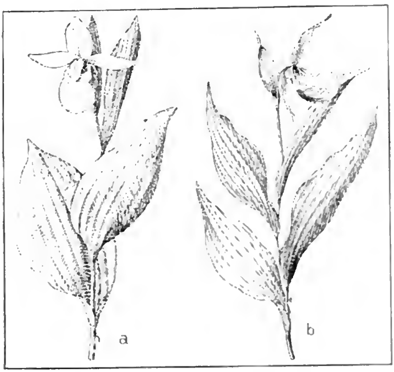

FIGURE 315. — LADY SLIPPER.

Pollinated by insects.

Flowers are also classified according to their method of pollination, that is, whether by insects or by the wind. Insects have an object in visiting flowers, for in them they find the nectar which they make into honey, or they find pollen, which they eat and feed to their young. Insects are attracted to flowers by their strong odor or bright colors, or by both.

One of the most interesting studies in biology is the relation which exists between certain flowers and the insects which pollinate them. In the case of salvia or flowering sage, for example, the irregular corolla offers the bee a convenient place to alight. To suck up the nectar the bee must push its head into the cup of the flower where it is forced to brush against the stigma which becomes covered with the pollen from the last salvia flower which the bee visited. When the bee withdraws its head it becomes dusted with pollen from the anthers which bend down and touch the back of the insect. The stamens and pistil of salvia do not mature at the same time (Figure 317), so that the bee can carry pollen only from flowers in which the stamens are ripe; and the pistil will receive pollen only in the flowers that have a ripe pistil.

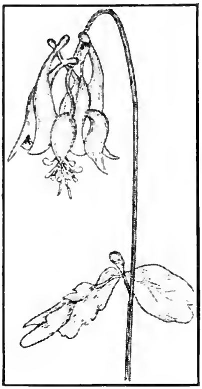

FIGURE 316. — FLOWER OF COLUMBINE.

Showing spurred petals. Only a long-tongued insect can reach the nectar. Note the bunch of stamens upon which the insect alights.

Certain orchids have deep tubes from which the nectar can be drawn only by insects like large moths which have long sucking organs. Many orchids have their pollen in masses. These masses stick to the head of the insect visitor, and hang down while it is passing to another flower. In this position the mass is almost certain to be rubbed off on the stigma of the second flower. Red clover is dependent on bumble bees for pollination, for they have a tongue of the length to get the nectar. The pollen is carried as in the case of the bean.

Flowers which are pollinated by wind have no need of color or of odor, but they have pollen which is light, abundant (for much of it is lost), and easily shed from the anthers. The stigma is feathery, thus offering more surface for the grains of pollen. Grass and corn, as we have seen, are examples of flowers pollinated by the wind. It is an advantage in securing proper pollination for such plants to grow close together.

LABORATORY STUDY

Pollination of Flowers. — As soon as flowers come, observe them closely and note which have many insect visitors, and which few or none. Fill out a report as suggested below and add any points which interest you further.

	Color Conspicuous	Color Not Conspicuous	Odor Strong	Odor Not Strong	Nectar Abundant	Nectar Not Abundant	Insects Many	Insects Few	Etc.
Sweet pea .									
Dandelion .									
Hepatica .									
Buttercup .									

224. Cross- and Self-Pollination. — All plants which receive pollen from another plant of the same kind are said to be cross-pollinated. Darwin found that plants which grow from seeds resulting from cross-pollination produce a greater number of seeds and that these seeds have more vigorous embryos than those resulting from self-pollination. Since this has been known, nursery men and gardeners have taken advantage of cross-pollination to improve their stock and to produce new varieties of fruits and vegetables. Much of Luther Burbank's work has been based on cross-pollination.

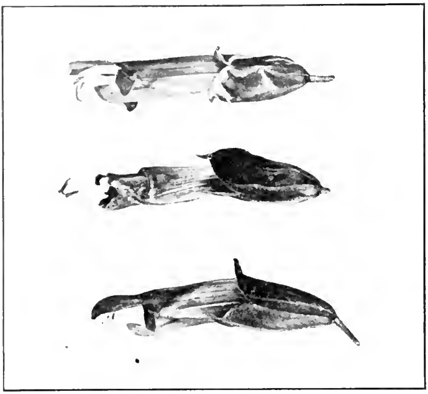

FIGURE 317. — SALVIA.
A flower in which the stamens mature at one time and the pistils at another.

Plants have a number of devices for preventing self-pollination. The anthers, for instance, may be turned away from the stigma; or the pistil may be so tall that no pollen can get on it from the stamens of the same flower; or the stigma may be ripe and the ovules started to develop before the stamens of the flower are ready to shed their pollen (Figure 317).

While it is the rule that plants avoid self-pollination and self-fertilization, a few have no other way of producing

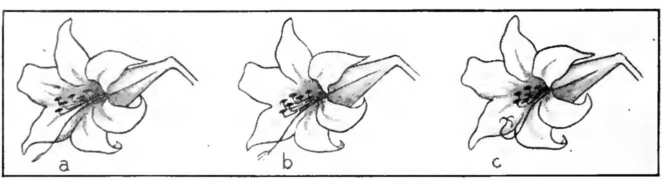

FIGURE 318. — EASTER LILY.

seeds. This is true of cleistogamous flowers. The one or two stamens which they develop contain sufficient pollen to fertilize all their ovules, for none is lost, and the pistil and stamen are placed in such a position that pollination is sure to occur.

FIGURE 319. — FRUIT OF THE BEAN.
A pod.

Other plants, as some of the lilies, are arranged for cross-fertilization, but if that fails, they can pollinate themselves. An Easter lily at first keeps its three-parted stigma carefully closed until it is well out of the way of the anthers (Figure 318, *a*). Then the stigma opens out, exposing its sticky surfaces to the air and to insects which may visit the flower (Figure 318, *b*). If no pollen is brought to the stigma, however, the plant brings the pistil up until the stigmas almost touch some of its own anthers

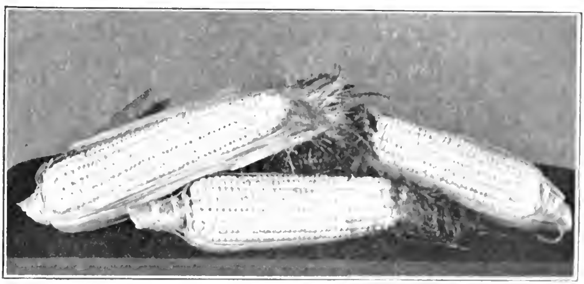

FIGURE 320. — FRUIT OF THE CORN.
Kernels or grains.

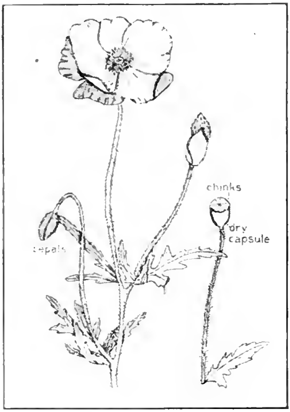

FIGURE 321. — FRUIT OF THE POPPY.

A capsule.

from which pollen is received for the fertilization of the lily's own egg cells in the ovules (Figure 318, *c*).

225. The Fruit of the Bean and Corn. — In science the term *fruit* includes much more than the meaning we usually give it when we refer to apples, oranges, or berries. By *fruit* the botanist means the ripened ovary of a plant and its contents. The first step in the production of fruit is the pollination of the stigma of a flower. Next comes the fertilization of the egg cell in the ovule. Finally the ovule develops into a seed, and at the same time, the ovary grows to protect and to provide nourishment for the seed until it is mature.

In the bean plant the pod begins to develop from the pistil as soon as fertilization has taken

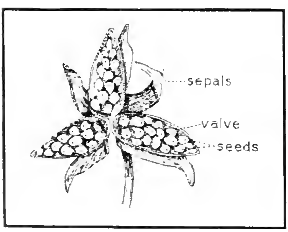

FIGURE 322. — CAPSULE OF VIOLET.

FIGURE 323. — CHESTNUTS.

A dry fruit.

place. Each ovule remains attached to the pod until the former changes into a seed and becomes mature. In bean pods and string beans, ovules are often present which have not developed owing to a lack of fertilization of the egg cell. When a bean pod is ripe, it splits and sometimes curls up, thus helping to scatter the seeds. From seed to seed again makes up the life history of the plant.

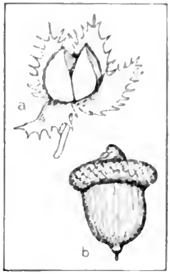

FIGURE 324. — DRY FRUITS.

a, beechnuts; *b*, acorn.

In the corn, as in the bean, each ovule develops into a grain of corn, if the egg cell has been fertilized. The ovary adheres so closely to the egg cell that it cannot be seen as a separate organ like the pod of the bean. All the maturing grains of corn receive nourishment through the cob to which they remain attached, and they are protected by the modified leaves or husks. Undeveloped ovules are sometimes found in ears of corn.

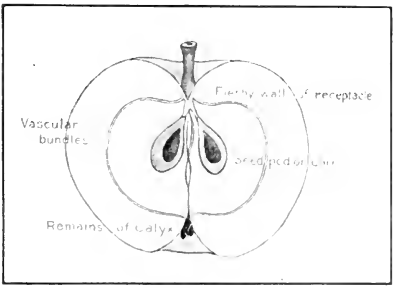

FIGURE 325. — VERTICAL SECTION OF APPLE.

A pome.

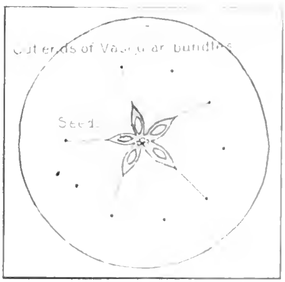

FIGURE 326. CROSS SECTION OF APPLE.

A pome.

226. Other Fruits. — The ripened ovary and its contents take many forms, so that we have the fleshy fruits, such

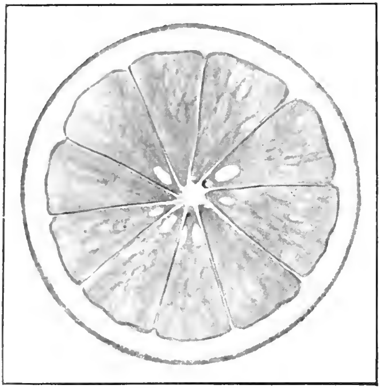

FIGURE 327. — CROSS SECTION OF ORANGE. A berry.

as the apple, or dry fruits, like the bean. Pods and other fruits which open in a definite way are called *dehiscent* (Latin, *dehisco*, to split open) fruits. Poppies, pansies, and violets have dehiscent fruits called *capsules*. Nuts, corn, and wheat are examples of *indehiscent* fruits (Figures 323 and 324).

Fleshy fruits fall into three groups: (1) *pome fruits*, apples and pears which have the seeds in a core in the middle surrounded by a thick, fleshy part (Figure 325); (2) *drupes*, or stone fruits represented by the plum, which has the seed inclosed in a hard stone surrounded by soft pulp; and (3) *berries*, fruits in which the seeds are scattered through the pulp, as in the grape, currant, or orange (Figure 327). Most of the fruits commonly called berries are really collections of small drupes. In the strawberry each "seed" is a fruit, and the fleshy substance is the receptacle of the flower, which has been greatly enlarged. In the case of the blackberry, as well, the receptacle is eaten, for the drupes cling to it as it is removed from the bush. Melons, cucumbers,

FIGURE 328. — FORMS OF DEHISCENT FRUITS.

pumpkins, and squashes are a special kind of berry called *pepo.* Such fruits have a hard rind.

FIGURE 329. — FRUITS WITH HOOKS. Distributed by animals.

The use of fruits to plants is simply to protect the seeds while they are maturing, and to secure their distribution later. But the fruits of the cereal grains and of beans furnish the highest form of vegetable food for man and domestic animals. The fleshy fruits, on the other hand, furnish many of man's luxuries in the way of food.

One of the most interesting studies about plants is how their fruits may be improved by supplying the best possible conditions for their growth; how their flavor may be improved, the skins made thicker or thinner, the seeds grown larger or smaller, or such other changes made as to cause the fruits to be more desirable to man. Many of these changes may be brought about through cross-fertilization.

FIGURE 330. — BURDOCK IN BLOSSOM.

227. Seed Distribution. — Seeds must be scattered or distributed to "spread" the plant, and the fruit helps to do this. If all the seeds merely fell to the ground and germinated there,

FIGURE 331.—FRUITS DISTRIBUTED BY WIND.

but little range would be added to the plant's territory, and a small increase in the number of plants would take place. Such plants as the dandelion and burdock have developed the most successful means for gaining the distribution of seed, and are, therefore, the most common and most widely distributed.

Seeds may be distributed by an explosion of the fruit case or through the agency of the wind, water, or animals. Some plants, like the witch-hazel or jewel-weed, have a fruit the tissue of which is so strained at the time of ripening that the seed case bursts with an explosion which throws the seeds some distance from the parent plant.

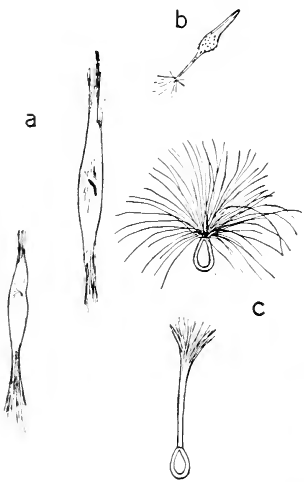

FIGURE 332.—OTHER FRUITS DISTRIBUTED BY WIND.

a, catalpa; *b*, dandelion; *c*, milkweed.

FIGURE 333.—FRUITS AND SEEDS.

FIGURE 334. — MILKWEED PLANT. Distributing seeds.

FIGURE 335. — SEED OF COTTON.

Frequently plants develop special structures which help to secure the distribution of seeds through the agency of an animal. Fruits like the burdock, for example, are provided with hooks which catch firmly to a passing animal, and the fruit is carried long distances before the seeds are dropped. Other fruits, like the cherry, have an edible pulp which causes the fruit to be picked up and carried away. A bird may fly with the fruit to a fence post, and there eat the pulp and drop the seed. In many cases, as in the raspberry, the whole fruit is eaten, but the seeds are indigestible and are carried far from the parent plant before they are thrown out by the animal.

Other fruits are fitted for distribution by water. In such cases the fruit is surrounded by a light, buoyant substance, as in the bur reed and the cocoanut, and so may be carried hundreds of miles without injury. In the case of still other fruits, like grains, the whole fruit is eaten, but enough are produced by the plant so that many may be destroyed and yet some be left to serve as seed, and thus prevent the plant from becoming extinct. Squirrels, in storing up food for the winter often bury nuts which are not used, and some of these are sure to grow.

LABORATORY STUDY OF SEED DISPERSAL

Every season of the year affords material for this phase of plant study. Record your result as follows:

	Agencies					Devices				
	Wind	Water	Animals	Explosions	Wings	Pappus	Hooks	Edible	Explosive Tissue	Etc.
Dandelion										
Maple										
Burdock										
Cherry										
Etc.										

228. **The Struggle for Existence.** — In the process of distribution, six or eight seeds from a plant may fall in almost exactly the same place. It is probable that all will begin to grow, but only one or two will live, because there will not be sufficient light, food, or moisture for all. In this case the plants which get the best start or have the most vigor crowd out the others. In biology this effort to secure the conditions necessary for life is known as *the struggle for existence.* The result of this struggle is spoken of as *the survival of the fittest.*

229. Enemies of the Bean. — Besides this struggle to get its share of light, food, and moisture, the bean plant has to contend with enemies. One enemy is a plant or bacterium (Chapter XXIII) which lives upon the tissues of the bean. This bacterium causes the disease known as bean blight, one of the most destructive diseases of beans, and one which scientists have been unable to prevent or cure. The plants having bean blight appear wilted, and have clear watery spots in the leaves which, after a time, turn brown, dry up, and drop out, leaving a hole in the leaf where each spot was. The bacteria which cause the disease enter through the stomata, appear first in the cotyledons, then work into the stem, and finally kill the plant by stopping up the sap tubes. The bacteria are carried by insects from one plant to another.

FIGURE 336. — BEAN PLANT INJURED BY BACTERIA.

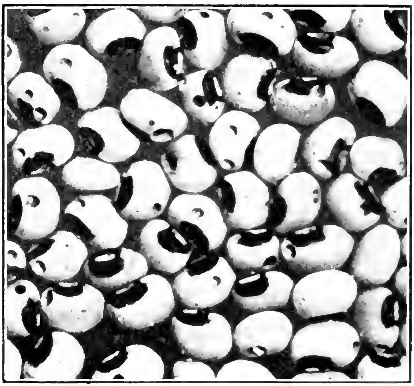

FIGURE 337. — BEANS DAMAGED BY WEEVILS.

Any insect which carries these bacteria is indirectly an enemy of the bean plant, but bean weevils injure it directly (Figure 337). The female weevil gnaws holes through the young pod and pushes her eggs into the pod or into the young beans. The eggs develop into grubs or larvæ, which get their food from the substances of the bean seed. If the grubs mature, the weevils may crawl out, thus leaving large holes in the bean. The loss to the farmer comes not only in the food actually eaten by the weevils, but also in spoiling the beans as food for man.

If the pods show that the beans have been pierced by weevils, the development of the eggs can be prevented by storing the beans in a cold place. A test for the presence of weevils is to place the beans in water, where those that contain weevils will float.

230. **Enemies of Corn.** — One great enemy of corn is a fungus (see page 360) called *corn smut.* This fungus destroys the corn kernels by living on the food in them and filling the whole kernel with black, sticky spores.

Grasshoppers injure the corn plant by eating the leaves, and plant lice by sucking its juices.

In speaking of an animal as a friend or an enemy of a plant or of man, we should remember that every plant and animal is only endeavoring to maintain its own life. We regard them as enemies when they destroy or injure something which we are trying to raise to maintain our own lives, and as friends when they destroy our enemies.

231. **The Raising of Beans.** — Beans are raised in large quantities for food. In New York, Michigan, and California more than nine million bushels were raised in the year 1915. Michigan raised four and a quarter million bushels, and New York one and a quarter million bushels.

A crop of beans can be planted, cultivated, harvested, and threshed by tools and machinery. But before beans can be used as food they must be examined by some one so that all those discolored or specked by weevils may be discarded. Beans unfit for human food can be eaten by such animals as hogs and sheep. So we find that where the raising of beans is an important industry, the raising of hogs and sheep is also practiced extensively. Sheep eat not only the rejected dry beans, but also the pods.

Certain varieties of beans are eaten when young and green, the pod itself being used as an article of food.

FIGURE 338. — A FIELD OF BEANS.

These "string beans" are raised extensively in some localities and are canned for the market. In this industry much of the work has to be done by hand.

232. The Value of Beans as Food. — Beans furnish more protein and yield more energy than any other kind of plant food except wheat. Compared with the cost of meat or of eggs, vegetable forms of protein are much cheaper, and beans are the cheapest of all. String beans do not contain so much nourishment as dry beans. Beans properly cooked are both digestible and palatable and should form an even more important part of our diet than at present.

233. History of the Bean Plant. — The bean and the members of the bean family (beans, peas, clover) are known to have been cultivated from the earliest times of human history. They are spoken of in the Bible under the name of *pulse* (Daniel i. 12), and mention is made of them in the records of the Egyptians, Greeks, and Romans. When America was discovered, the Indians were cultivating pole beans. Beans are now widely distributed, one or more varieties being grown in all temperate regions.

The value to the soil of the plants of the Pulse family has long been known, but the reasons for it have not been understood until recently. As we have seen, bacteria in the roots of beans gather nitrogen which goes to replace that drawn from the soil by other plants. Soils which lack nitrogen may be improved by growing on them a crop of the pulse family and then plowing it under. This method of enriching the soil is known as "green manuring." See page 270.

Figure 339. — Peanuts.

The bean family includes such well-known plants as peas, peanuts, clover, and alfalfa. The peanut has the peculiar habit of thrusting its blossoms into the ground after they have been pollinated. The pods mature there and are harvested by digging.

234. **The Raising of Corn.** — Most of the work of planting, cultivating, and harvesting corn is done by machinery. Hand work is necessary only in removing the ears from the stalk and the husk from the ears. Because corn is so valuable a food for men and animals and because so much of the work necessary in raising it can be done by machinery, corn raising has become one of the most important industries on the easily cultivated level prairies of the Middle West.

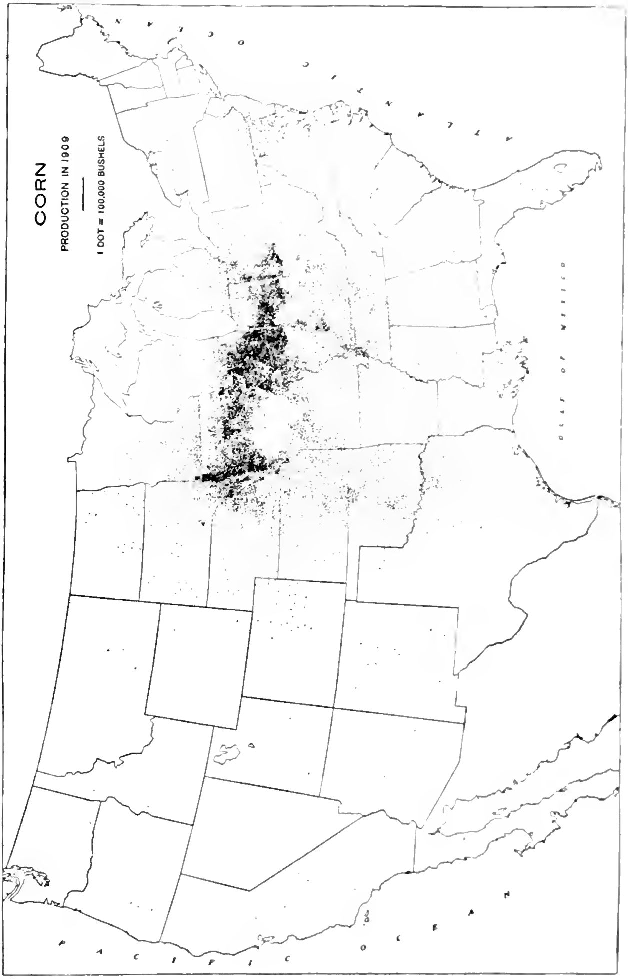

FIGURE 340. — MAP OF CORN PRODUCTION.

235. **History of the Corn Plant.** — The corn plant was found growing in America when the New World was discovered, and it was one of the principal foods of the Indians. Now corn is grown wherever the climate is not too cold for it to come to maturity.

236. **Economic Importance of Plants.** — From a biological point of view much of the study of plants is concerned with the life of the plant itself, considered as an organism; what its problems are, and what peculiarities it has developed which have aided it in the struggle for existence. There is, however, another point of view, — the importance of plants to man as the source of his food supply. Within recent years, this has come to be more fully recognized than ever before, and as a result, agriculture as an industry has been almost revolutionized by the application of scientific methods.

Man has learned to take a wild plant and, by cultivation, selection, and cross-pollination, to improve any part of the plant he wishes. Man is the only animal intelligent enough to do this, and his success depends upon his following such natural laws as he has been able to discover. Students are constantly endeavoring to learn the conditions under which each plant thrives best, — the kind of food, soil-temperature, amount and kind of cultivation; what diseases it is likely to have, and how to prevent and cure them.

SUMMARY OF THE BEAN

The bean is a typical flowering plant and is representative of the dicotyledons. The bean seed contains an embryo which is nourished by the food in the cotyledons. A bean plant has roots to hold it firmly in place and to gather the water which contains part of the plant's food. It has a stem to hold the leaves to the light and air, and to carry water and food. The leaves are the part of the plant where most of the vital processes are carried on. The vital processes which occur in the leaf are respiration, photo-synthesis, or the making of food, excretion, and assimilation.

The bean flower contains the organs necessary for reproduction. A seed is formed when the nucleus of a pollen grain unites with the nucleus of the egg cell in the ovule. The fruit of the bean is the pod which contains the seeds. The bean depends upon insects for cross-pollination.

The raising of beans is an important industry. Beans probably once grew wild, but now they are widely cultivated. Their chief value as food is due to the large amount of protein in the seed.

A bean plant which has successfully completed its life work has added to the sum total of the solid matter on earth, and has left stored-up material which may be used either as food for animals or for the new plant which the seed contains. The plant has added to the supply of oxygen in the air, and by decomposition through the aid of bacteria leaves the soil richer in nitrogen.

SUMMARY OF THE CORN

The corn is a typical monocotyledonous plant. Food for the embryo is stored at one side of the grain. This embryo is supplied with food prepared in a modified cotyledon. A corn plant has many roots, all of about the same size, which gather for it water and inorganic matter and hold the plant in the soil. In addition to the regular roots, there are prop-roots. The leaves of corn have parallel veins and clasping bases. The leaves perform most of the vital processes of the plant. The stem has a hard rind and scattered fibro-vascular bundles. The fruit consists of grains in which the ovary adheres closely to the seed. Corn depends upon the wind for pollination. The stamens are in the tassels and the style of the pistil is the silk. It is a monœcious plant.

QUESTIONS

How does the bean plant begin life? Explain the work of each part of the plant. What is the importance of photo-synthesis? What is the difference between pollination and fertilization? Why are beans valuable? What is a food? How can you show that any given substance is a food? How do roots help the leaves? How do the stems help the leaves? Compare the corn plant with the bean in structure, importance, etc.

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CHAPTER XXI

OTHER FLOWERING PLANTS

237. The Flowering Plants. — True flowering plants are the most highly developed of all. They are numerous, it being estimated that there are 120,000 kinds. Some varieties are so small as hardly to be noticed, while others, like the hardwood trees, are very large. Some live submerged in the water, while others are found only in deserts.

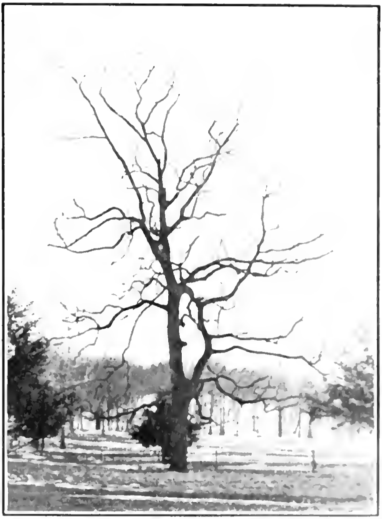

FIGURE 341. — WALNUT TREE.

The flowering plants are of special interest on account of their intimate relation to our daily life, and on account of this close relationship we should study some of the most common families, such as the grass, rose, mustard, and the like, all of which are easily recognized.

The Grass Family. — The grass family has long narrow leaves with clasping bases and parallel veins, fibrous roots, and inconspicuous flowers which are pollinated by the wind. The grasses are the most important of all

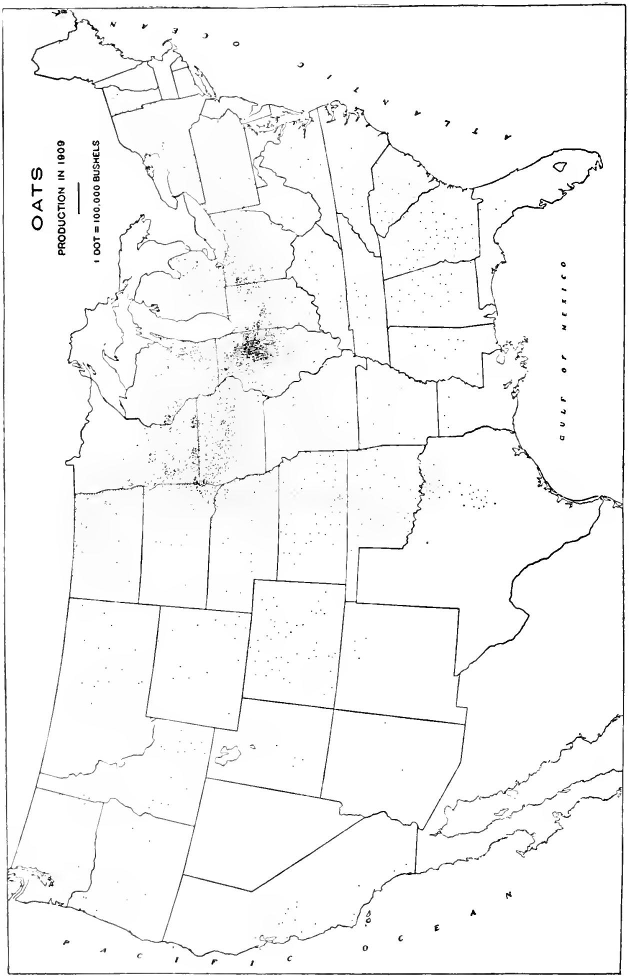

FIGURE 342. — MAP OF PRODUCTION OF OATS.

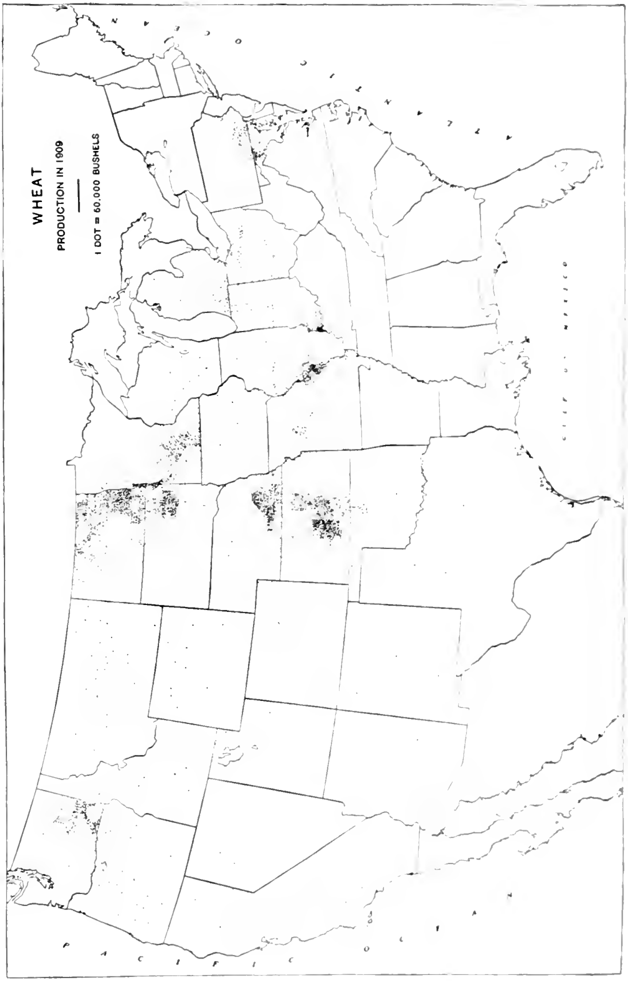

FIGURE 343. — MAP OF WHEAT PRODUCTION.

FIGURE 344. — THE CEREALS.

a, wheat; *b*, oats; *c*, barley; *d*, rye.

plants as food for man and the animals which he uses. This family includes corn, wheat, oats, barley, rye, rice, and similar grains. Wheat and barley are mentioned in the earliest literature and were among the first plants cultivated for food. As men learned to till the soil and harvest these grains, agriculture became established and a marked step towards civilization was made. In China and India millions to-day depend very largely upon rice. In 1915 the United States produced 3,054,535,000 bushels of corn, 1,011,505,000 bushels of wheat, and 28,974,000 bushels of rice.

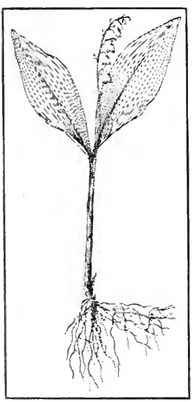

FIGURE 345. — LILY-OF-THE-VALLEY.

Lily Family. — Lilies have parallel-veined leaves. The flowers are made up of a six-parted *perianth* (calyx and corolla taken together), six stamens, and

Figure 346. — X-ray of Easter Lily.

a three-parted pistil. The fruit is a capsule. Lilies are cultivated chiefly for decorative purposes.

Walnut Family. — The trees of this family furnish us with nuts and valuable lumber. The monœcious flowers are grouped in catkins. The leaves are alternate and pinnately compound. All the walnuts and hickories belong to this very useful family (Figure 341).

Beech Family. — Like the walnut family, this group consists of trees, of which the beech, oak, and chestnut are the most common. All are valuable for lumber and firewood. The leaves are simple, alternate, and straight-veined. The flowers are monœcious.

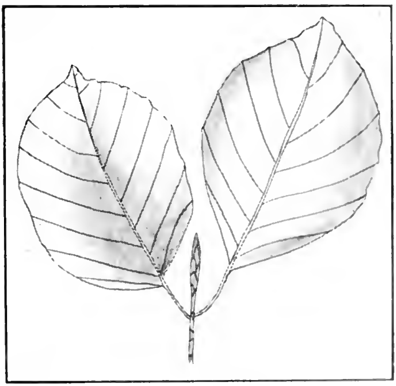

Figure 347. — Leaves and Bud of Beech.

Crowfoot Family. — This large family is valuable to us for the medicines (mostly poisonous) which it furnishes. The medicinal members of this family are hydrastis, aconite, hellebore, and larkspur; while other members, as clematis, peony, and columbine, are cultivated for ornament. The common buttercup shows most

FIGURE 348. — WILD COLUMBINE.

of the characteristics of the crowfoot family. The leaves are commonly dissected; the petals, sepals, and pistil are all disconnected. The juice of the buttercup is colorless and is biting to the taste.

Mustard Family. — Garden vegetables such as the turnip, radish, cabbage, horse-radish, and mustard belong to this family. All have regular flowers consisting of four sepals, four petals, and six stamens. The corolla is in the form of a Greek cross. These plants have a pungent, watery juice which is non-poisonous. The fruit is a kind of pod called a *silique.*

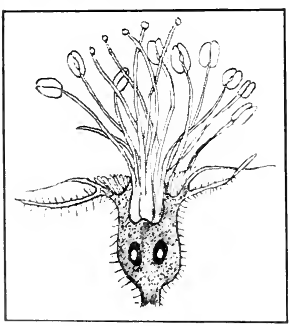

FIGURE 349. — STAMENS AND PISTILS OF ROSE.

Rose Family. — The flowers are regular with the calyx usually of five sepals and the corolla of five petals. The leaves are alternate and usually serrate on the edge. The rose family is as important in furnishing the luxuries of our food as the grass family is for the necessaries. To this group belong all of the common orchard fruits, such as apples, peaches, and plums, and many of the common berries, such as the raspberry and strawberry. Many of the members of this family are also cultivated for ornament.

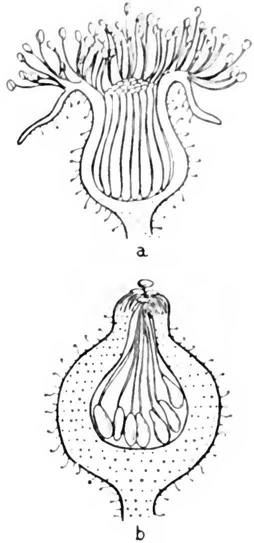

FIGURE 350. — ROSE FLOWER TURNING INTO A FRUIT.

a, early stage; *b*, later stage.

Pulse Family. — Beans, peas, vetch, alfalfa, peanuts, clover, and the like are members of this family. These plants may be recognized by their irregular, papilionaceous flowers, alternate leaves with stipules, and by their having the fruit in the form of a pod. This family furnishes us with most of our vegetable protein food. The plants improve the soil by the aid of bacteria. Wisteria, red bud, and the locusts are cultivated for ornamental purposes.

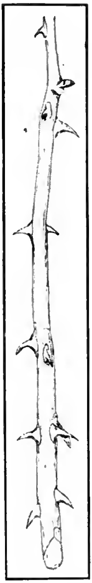

FIGURE 351. — THORNS OF ROSE.

Flax Family. — While this is not a large family, yet it furnishes all of our linen. Flax rarely grows wild, but requires cultivation.

Mallow Family. — This family is also important in furnishing material for our clothing, as the cotton plant belongs here. Hollyhock and althæa are forms cultivated for ornament.

Parsley Family. — This family includes such garden vegetables as parsnip, parsley, and carrots, and plants like fennel, dill, coriander, and caraway used for medicine and for flavoring food. These plants

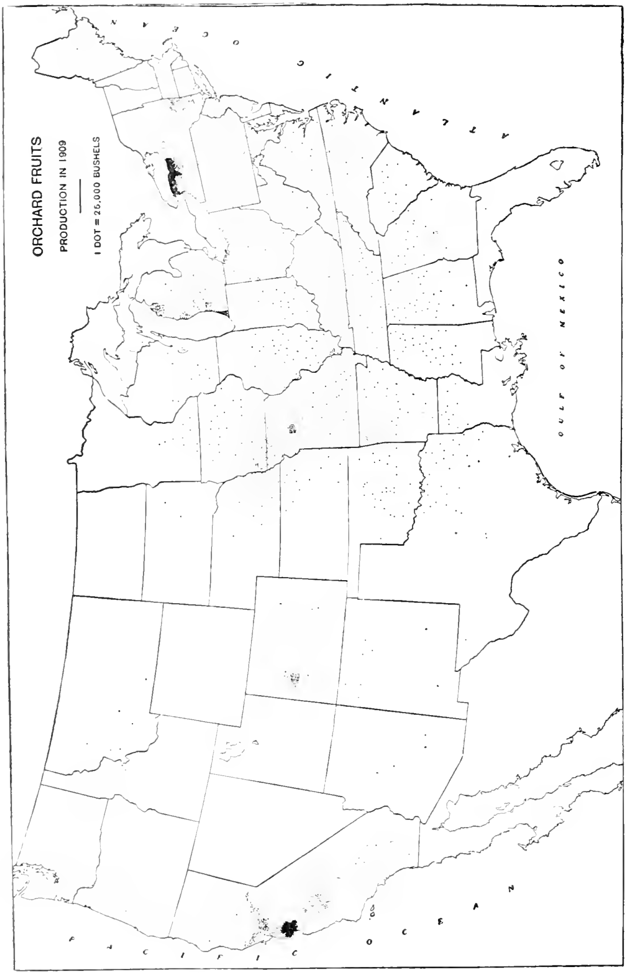

FIGURE 352. — MAP OF PRODUCTION OF ORCHARD FRUITS.

have hollow, ribbed stems; alternate, compound leaves, and flowers in an *umbel*. See Figure 308.

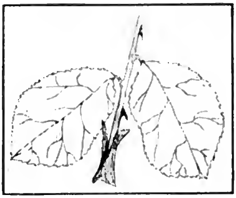

FIGURE 353. — STIPULES OF ROSE LEAF.

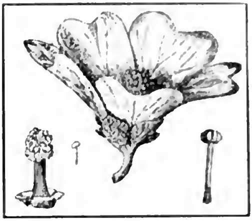

FIGURE 354. — FLOWER OF MALLOW.

Mint Family. — The members of this family are easily recognized by their square stems, opposite leaves with crenate margins, and bilabiate flowers (an irregular flower divided into two parts). Peppermint, spearmint, catnip, horehound, pennyroyal, sage, savory, and thyme are some of the mints used for medicine and in food.

FIGURE 355. — WATER HOREHOUND.

Nightshade family. — Here are found many poisonous plants, as tobacco and Jimson weed from which stramonium (similar to belladonna but more powerful) is obtained. The tomato, potato, and egg-plant are used for food. Petunias are cultivated

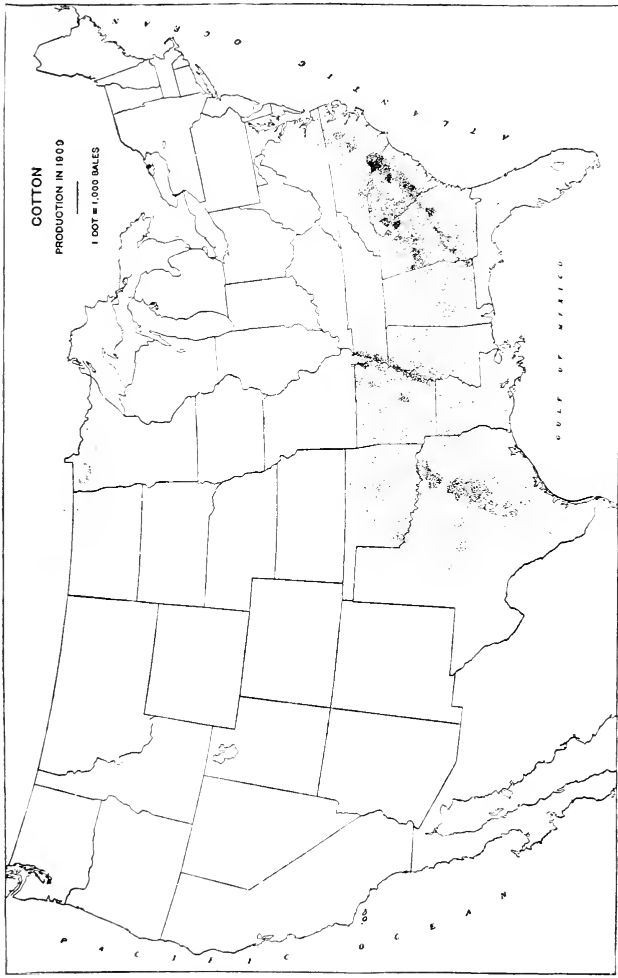

FIGURE 356. — MAP OF COTTON PRODUCTION.
The mallow family.

Figure 357. — Self-heal

A common weed.

Figure 358. — Hedge Nettle

Figure 359. — Common White Daisy.

for ornament. The foliage of all these plants is rank-scented, the leaves are alternate, and the flower five-parted.

The Composite Family. — This family is typified by the common daisy and dandelion. They have their flowers in heads and are of two kinds, ray-flowers and disk-flowers. This is one of the largest families of plants, and from the standpoint of the botanist, the most complex. It contains our common weeds, such as the daisy, dandelion, golden rod, aster, burdock, thistle, and hawkweed.

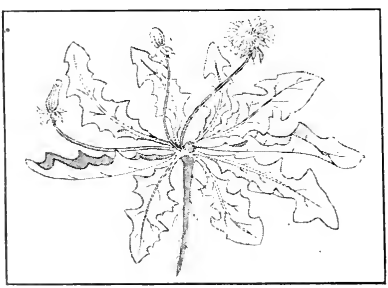

Figure 360. — Dandelion.

Not all the flowering

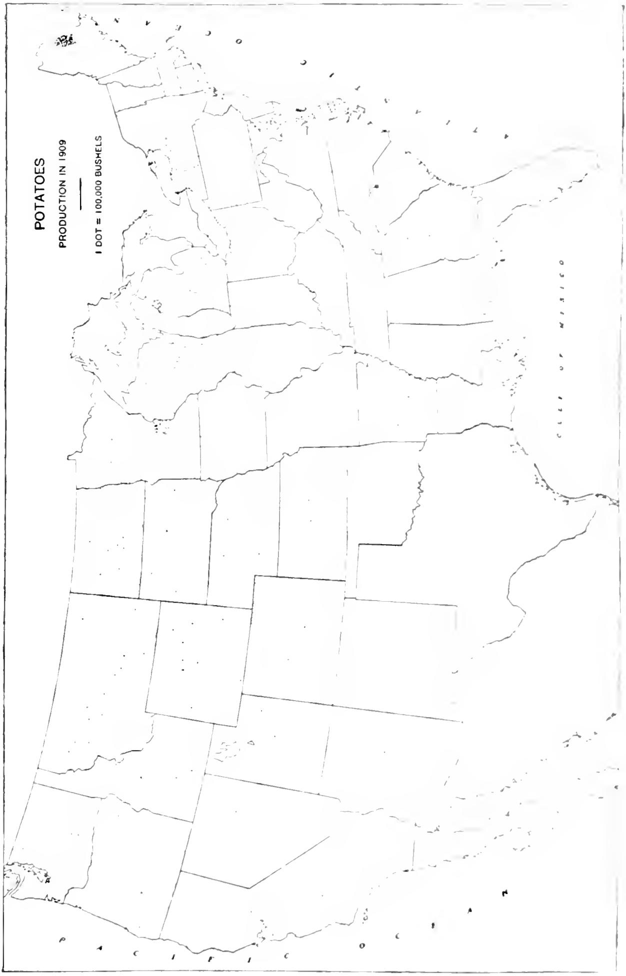

FIGURE 361. — MAP OF POTATO PRODUCTION.
The nightshade family.

plants are beneficial to man, and every farmer and gardener has to struggle with the weeds.[1] Some of the members of the composite family, like the goldenrod and daisy, lend a charm to the fields, and many people dislike to think of them as obnoxious plants. But they prevent the grass from growing, and cattle will not eat them either in the winter or in the summer, so that they are a nuisance to the farmer. A weed, then, may be defined as a plant which interferes with the growth of some useful plant. Weeds are successful in growing and in living, because they have strong roots, produce many seeds, and have numerous devices for distributing their seeds.

FIGURE 362. — CANADA THISTLE.

SUMMARY

The flowering plants are the most highly developed of all the plants and bear an intimate relation to mankind. The many grasses and cereals furnish animals and man with much of their food. The cultivation of these plants has aided the development of civilization.

[1] Thompson, "Distribution of Weeds by Means of Farm Seeds." School Science and Mathematics, December, 1915, page 770. Georgia, A Book of Weeds.

QUESTIONS

What plants furnished part of your food to-day? In what part of the plant was this food made? In what part stored? What fruits do you eat? Which plants grow these fruits? Where do these plants live? Name plants, parts of which are used in medicine. What plants are used in making paper? What parts of a plant are used in making houses? What kinds of cloth are made from cotton? from linen? from silk? from wool? What are the common weeds?

CHAPTER XXII

THE SIMPLEST PLANTS

238. Introduction. — Many plants when full grown never have more than one cell and are so small that they can be studied only through a microscope. All of these minute plants have long scientific names, often hard to remember, but they are the same names which the English, German, or Japanese children have to learn when they study these plants.

The two plants discussed in this chapter belong to the group known as the *Green Algæ* (Latin, *algæ*, seaweed). The names of these two plants are *Pleurococcus* (plū-rō-kŏk′ŭs) and *Spirogyra* (spī-rō-jī′rȧ).

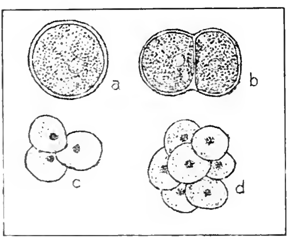

FIGURE 363. — PLEUROCOCCUS. *a*, single cell; *b*, cell dividing; *c* and *d*, groups of cells.

We are now to compare these microscopic plants with the bean plant with its many parts composed of hundreds of cells, which is able to respire, make its own food, and grow bean seeds.

239. Pleurococcus. — Pleurococcus is a widely distributed, single-celled plant which grows in great abundance upon the shady side of trees, old buildings, and rocks. After a rain it is conspicuous in these places as green patches. A bit of this green substance examined with a microscope shows many green cells. Each plant, or we may say, each cell is a somewhat roundish structure with a clearly defined cell wall. The contents of the cell are green, due to the chlorophyll which conceals all parts of the cell except the nucleus. The nucleus usually lies near the center of the cell. As long as the cell is full of chlorophyll, the cytoplasm cannot be seen (Figure 363).

Pleurococcus makes its own food as the bean does, and apparently it is able to digest the starch and protein which it makes in a manner similar to that of the bean. Whenever a number of pleurococcus cells are examined, some are found to be dividing. In this division the nucleus forms two nuclei which move apart. A partition wall forms and two cells take the place of the old or parent cell. This method is called *fission* (Latin, *fissus*, cleft), and is the simplest form of reproduction. In pleurococcus the cells do not always separate at once, but form groups of two, three, or four cells (Figure 363).

SUMMARY

This simple unicellular (one-celled) green plant, pleurococcus, lives and makes its own food and grows new cells. While there are no flowers and seeds as in the bean, yet this plant is able to reproduce itself. All of the important life processes found in the bean take place in the simple, single cell.

LABORATORY STUDY OF PLEUROCOCCUS

Study this as an example of a plant which consists of a single cell, but still performs all the processes common to higher plants. Soak a bit of bark and scrape it gently to get the pleurococci cells, some of which may be in groups. Draw a single cell and a group of cells.

240. Spirogyra. — This plant is best known as the "pond scum" which grows in most fresh water ponds and in slow running streams. It may be kept for some time in glass dishes in a laboratory. Instead of being made up of single cells or clusters of cells, the cells of spirogyra are cylindrical in shape and are attached end to end. This results in long, fine threads which float in the water in large masses.

The individual cells of spirogyra are provided with one or more narrow green bands arranged spirally within the

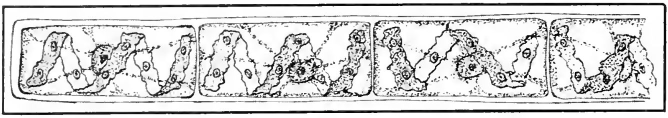

FIGURE 364. — SPIROGYRA.

protoplasm. These spiral bands of chlorophyll are the special structures which manufacture food (Figure 364). The cells of the filament increase rapidly in size and divide, and thus the filaments increase in length. As each cell divides, the cell wall grows in at right angles to the length of the plant. Spirogyra grows so rapidly in the spring that in a short time the water may become polluted. The bubbles found among a mass of spirogyra are the oxygen which the cells give off during photosynthesis.

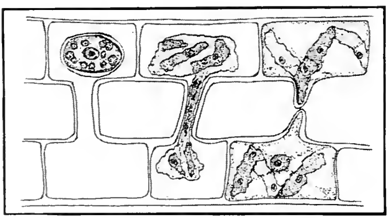

FIGURE 365. — SPIROGYRA CONJUGATING.

During the summer there are times when spirogyra reproduces in another manner (Figures 365 and 366). Two cells of adjacent plants join by putting forth tubes which fuse on meeting. The contents of one cell pass through the tube, and flow into and unite with the contents of the other cell. Thus there is formed a single roundish mass of protoplasm surrounded by a thick wall. This mass of protoplasm is called a sexual spore, because two cells unite to form it. The two cells which thus unite are called *gametes* and are identical in all their parts. This spore, therefore, is known as a *zygospore* (Greek, *zygos*, yoke; *spora*, seed). In the formation of a zygospore, the cells are joined permanently and a form of sexual reproduction is present.

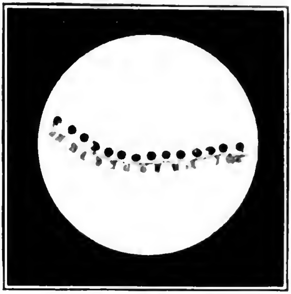

FIGURE 366. — MICROPHOTOGRAPH OF CONJUGATING SPIROGYRA.

As a zygospore, spirogyra can live in a resting condition during periods unfavorable to its growth, as in winter or during a drought. When conditions again become favorable the zygospore germinates and grows into a filament. The spirogyra is able to do the same things which a pleurococcus does and has the same life processes.

LABORATORY STUDY OF SPIROGYRA

Notice: (1) the clear outer part called the cell wall; (2) the main mass of the cell, a substance called cytoplasm. (This can be seen easily by putting a strong sugar solution under the cover glass. The cytoplasm draws away from the cell wall into a compact mass in the center of the cell.) (3) The darker portion of the nucleus, in or near the center of the cell. (This can be seen clearly by putting a drop of weak iodine under the cover glass, using fresh material for this test.) (4) A spiral band of green coloring matter, chlorophyll, containing bright spots.

Examine spirogyra in a mass, floated out in water in a glass or on a plate. Feel of it and observe that it is slimy. Note its color and delicacy. After it has been in the sun for a time, note the bubbles of gas entangled in the spirogyra, which help to make it float. With a microscope examine filaments which are joined in places by outgrowths from other filaments. Such filaments are said to be in conjugation. Draw the outgrowing tubes, the empty cell, and the zygospore or zygote.

SUMMARY

Both pleurococcus and spirogyra are called algæ, and each is typical of many other plants of the same kind. Our chief interests in them are that they are adapted to life in the water from which they obtain most of their food and that each cell is capable of carrying on all the life processes for itself. Plants like pleurococcus are called unicellular; those like spirogyra, which consist of many cells joined end to end thus forming a strand, are called *filamentous algæ.* Pleurococcus is found on old buildings, fences, posts, rocks, and on the bark of trees. It shows more plainly in wet weather than in dry, for then it is growing. Spirogyra grows in running water, attached to objects on the bottom, or floats in masses on the surface of ponds, ditches, and sluggish streams. Neither of these plants has any economic value.

Algæ are simple plants which grow in water or in moist places. Fresh water algæ are usually small. Algæ illustrate how a plant cell carries on the life processes. The cell is the unit of plant structure, and plant cells are similar to animal cells in all essential respects.

QUESTIONS

What is a cell? Compare plant with animal cells. Explain the process of conjugation. In what respects is the formation of a zygospore similar to the process of fertilization in the bean?

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CHAPTER XXIII

THE SMALLEST PLANTS (BACTERIA)

241. Bacteria. — Bacteria are the smallest of all plants and can be seen singly only through the aid of a powerful microscope. We do not know all about their life processes, but we have learned much about their effect. We constantly hear about these plants, either under their correct name, *bacteria*, or under the names of *germs* or *microbes*. Two incorrect ideas concerning bacteria are prevalent, — one, that bacteria are animals, and the other, that all of them are harmful. It is definitely known that bacteria are plants; that small as they are, they are among the most important plants in the world; that most of them are helpful, and only a few harmful. They are, however, so much like the one-celled animals (protozoa) that the word *germ* is not unnaturally used to cover both.

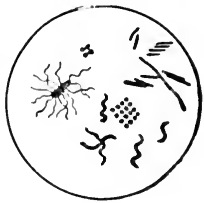

FIGURE 367. — FORMS OF BACTERIA.

242. Shape and Size of Bacteria. — Bacteria, according to their shape, are grouped into three classes: (1) round (the cocci); (2) rod-shaped, like an unsharpened pencil (the bacilli); (3) those that are shaped like a corkscrew (the spirilla). Most of the names for the different bacteria contain one or another of these words, thus indicating the shape of the bacterium[1] under discussion. The spirilla and the bacilli often have on one or both ends tiny thread-

[1] Bacterium, singular of bacteria.

like hairs by which they move, so that the first observers not unnaturally thought they were animals.

An indication of the minuteness of these plants is that fifteen hundred of the rod-shaped bacteria will hardly reach across the head of a pin. When bacteria are grown in the proper kind of substance, there are so many in a cluster that they appear as tiny spots or points, often tinged with a faint color. When seen alone under the microscope, they are clear, almost transparent, and colorless, and often have a bright, shining spot on the inside.

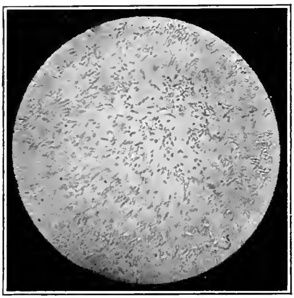

FIGURE 368. — SOIL BACTERIA.

243. **Where Bacteria are Found.** — Bacteria are everywhere, — in the air, as invisible dust; in the upper layers of the soil; and in water. We breathe in the microbes of the air with every breath, but generally with no injurious result. Every bacterium has its own work to do, and a healthy body gives little opportunity for most kinds of bacteria to do harm.

244. **Conditions Necessary for the Growth of Bacteria.** — Like all other plants, bacteria must have all the proper conditions before they can grow and multiply. Their food is chiefly plant or animal matter, but they cannot make use of food except in the presence of warmth and moisture, and most of them require oxygen in addition. They get the oxygen from the surrounding air.

245. **Life Processes.** — In the preparation of their food bacteria break up substances or decompose them, causing the condition known as decay. They use some of the material resulting from decay; some they set free in the air; and the remainder is left on the earth to be used by

higher plants. In changing dead matter — plants, leaves, and animals — to a form which again becomes a part of the earth, bacteria perform a service valuable to man.

Reproduction occurs in bacteria through simple fission. Sometimes bacteria break entirely apart, while in other cases they remain connected, forming a chain. Under favorable conditions each cell can grow to full size in half an hour and be ready to divide again. It is this ability to multiply rapidly which makes them of so great importance, for a few hundred bacteria, even of the harmful ones, could produce little effect.

In the process of growth, bacteria produce two substances, *enzyme* (see page 172) and *toxin* (tŏx'ĭn: Greek, *toxicum*, poison). Enzymes produce fermentation, a breaking-up process of which man makes use to secure certain flavors and odors, as well as to soften hard materials. Toxins are usually poisonous to living organisms, including the bacteria which produce them.

Enzymes cause the pleasant flavor of such articles of food as cheese and butter. The quality of tobacco depends largely upon the kinds of bacteria which have been at work upon it. Such bacteria are classed as helpful, as are those which gather nitrogen for the plants of the bean family. Other helpful bacteria are those which make it possible for man to use sponges by ridding them of the soft, slimy substance with which they are filled when alive, as well as the bacteria which soften the useless parts of the flax plant so that the rest of it may be separated and made into linen.

When food, air, warmth, or moisture is not sufficient, bacteria cease to grow and go into a resting state. That is, they change their form, and surround themselves with a substance which protects the soft protoplasm from being harmed by freezing, heating, or drying. The simple plants all do this, but the simpler the plant, the more easily does it resist. It is this ability to withstand unfavorable conditions and to resume growth when conditions change for the better that makes bacteria such "good friends and such bad foes."

LABORATORY STUDY OF BACTERIA

Prepare culture plates of agar-agar from the following formula:

Agar-agar Formula for 1000 c.c.

Agar-agar[1]	15 grams
Beef extract	3 grams
Peptone	10 grams
Salt	5 grams
Water	1000 grams

Boil material for the agar-agar formula; add sodium hydrate till the color of litmus paper is not changed; cool to about 56 C., and beat into this one whole egg, including the shell. Warm slowly to the boiling point and continue till the egg is firmly coagulated; then strain the clear medium through a cheese-cloth on to moist cotton in a filter funnel.

Work rapidly. Cool, and then boil once more. Filter through cotton into test tubes. Each tube should not be more than a quarter full. Plug the tubes with cotton. Then sterilize this mixture in the test tubes by placing them upright in water and boiling twenty minutes on each of three successive days. Let part of the test tubes cool, having the plugged end elevated half an inch. These are called slant agar tubes. When petri[2] cultures are needed, melt up a sterile agar tube and pour into a sterile petri dish.

1. To show that bacteria are present on one's hands. Draw the fingers of the unwashed hand across the surface of the agar-agar in petri dish. Cover and set away for four days at room temperature or two days at body temperature.

2. To show that fewer bacteria are present on freshly washed hands. Draw the fingers of the washed hand across the surface of the agar-agar. Cover and set away.

3. To show that bacteria lodge under the nails. Place on culture plates scrapings from under finger nails, (1) before washing the hands, (2) after washing the hands.

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[1] Secured at most drug stores.

[2] Flat, round dish with cover.

4. To show that heating milk reduces the number of active bacteria. Sprinkle drops of milk and water on agar-agar petri dish, (1) natural milk, (2) pasteurized, (3) boiled. (Use one tenth milk and nine tenths sterilized water.)

5. To show that bacteria change the medium in which they grow. Besides the number, form, size, and color of the colonies, note whether any change takes place in the agar-agar.

6. To show that bacteria grow best in the presence of warmth and moisture, compare those grown under such conditions with those grown in a dry or a cold place. Note the influence (*a*) of warmth, (*b*) of cold, on the rapidity of growth.

7. To show that bacteria are in the air, expose the surface of the culture plate for a few seconds.

8. To show that flies distribute bacteria. Let a fly walk across the surface of the agar-agar in the petri dish.

If bacteria have an opportunity, they work on everything which is capable of decay, and so we need to know how to prevent their working upon food and other things which we do not wish to "spoil." Several ways in common use are: (1) cold storage, where there is not warmth sufficient for the growth of bacteria; (2) the use of salt and other chemicals to prevent their getting a start, as in the curing and smoking of meat; (3) drying fruit and meat, thus removing water, a necessary condition for growth; and (4) heating fruit, vegetables, milk, etc., and sealing them in cans or jars while hot, thus killing any bacteria the substances may contain and keeping all others out. Anything prepared in this way is preserved by being made *sterile* or *aseptic* (Greek, *sepein*, to make putrid).

246. **Bacteria in Relation to Milk.** — (See also Part II.) Milk as it comes from the healthy cow is practically free from bacteria of any kind. The number of bacteria present, however, is not of so much importance as the kind. But if a large number of bacteria are allowed to get into the milk, some of them are sure to be harmful and may find

conditions so favorable for their growth as to make trouble for the person using the milk.

A high grade of milk will not contain more than 500 to 1000 bacteria per cubic centimeter. Such milk has been well cared for and comes from healthy cows. Some cities permit milk to be sold that contains as many as 100,000 and some even more bacteria per cubic centimeter. Such milk comes from unhealthy cows or dirty barns, or has been kept too long, or has "changed hands" too many times. To deliver pure milk to the consumer costs the producer time, care, and money, and consumers should be willing to pay more for milk which has had proper care.

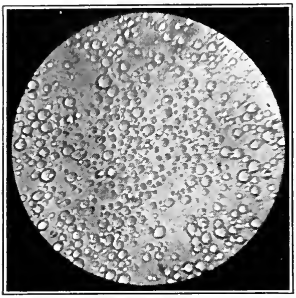

FIGURE 369. — CLEAN MILK. Showing oil globules.

Ice prevents harmful bacteria from multiplying sufficiently to make milk dangerous, unless the milk is kept for too long a time. Preservatives, soda, borax, boric acid, formaldehyde, and the like are sometimes used to prevent the growth of bacteria. In some cases no immediate harm seems to come to the persons using milk thus preserved, but some of these substances are poisonous, and pure milk, properly cared for, does not need them. So the use of any milk in which preservatives are found should be avoided.

A harmless bacterium gets into milk kept too long and forms lactic acid, thus giving the milk a sour taste and causing it to curdle. Sour milk is perfectly wholesome for food, but the taste is disagreeable. In 1857 Pasteur discovered this bacterium. He also found that milk could be kept for several days without becoming sour, after it had been heated sufficiently to kill this bacterium.

Louis Pasteur (1822–1895) was a celebrated French chemist and biologist.

After filling various academic positions, Pasteur was appointed Professor of Chemistry at the Sorbonne, in Paris, in 1867

Pasteur is especially famous for his researches in bacteria. In 1884 he discovered a method of curing or preventing hydrophobia by inoculating with the poisonous virus in an attenuated form.

In 1874 the French government gave Pasteur a pension of twenty thousand francs, which they increased the following year, in consideration of his services in science and industry.

This process, called after its discoverer *pasteurization*, consists in heating milk for twenty minutes at a temperature of 60° C., or to a higher degree for a shorter time, and then cooling it rapidly. This procedure kills nearly all the bacteria in the milk and does not change the taste or make it hard to digest. Milk is not rendered absolutely sterile, but it is a much safer food, especially for infants. At best pasteurization is only a corrective or precautionary measure, and we should demand that milk be kept clean and thus free from bacteria.

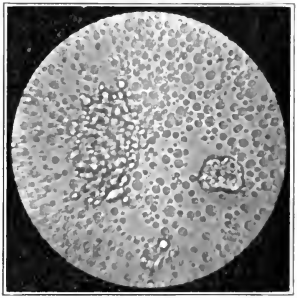

FIGURE 370. — DIRTY MILK.

Most raw milk products have their own forms of bacteria, but most of these forms are helpful. The flavor of June butter is imparted by a bacterium different from the one in January butter. So with cheese, each brand or flavor receives its taste through the action of a special bacterium. At every step in the use and manufacture of milk, it is necessary to know the conditions under which the helpful bacteria work best, and how to keep out the harmful ones.

247. Sources of Danger in Milk. — The cow herself may be unhealthy and her disease transmitted through the milk. Of the several diseases which this animal may give, tuberculosis is the most common. Children are more liable than adults to take the disease in this way. There is no necessity to be in doubt about a cow's being infected with tuberculosis, for in 1890 Koch discovered the tuberculin test, which enables the dairyman to detect the disease. This test is now commonly applied and in some cities owners of herds which have been tested and found free from disease are allowed to sell their milk as "certified," though the meaning of this term varies. Not only is the raw milk from tubercular cows dangerous, but also the butter and cheese made from it.

Bacteria multiply rapidly and remain active while milk is warm, and so it should be cooled as soon as possible after it has been taken from the cow. Milk should not be used when it is too old, for in that case the harmless bacteria may all have died and harmful ones taken their places. Milk should not be left in a metal container, nor open to the air, nor placed in an ice chamber where it can absorb the odors of other foods.

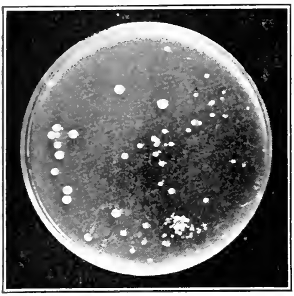

FIGURE 371.—BEEF JELLY. Exposed in sanitary dairy.

Ice cream should be eaten only when fresh, for poisons (ptomaines) are formed by the action of bacteria, especially in ice cream which has been melted and then refrozen. Ice cream should be made under clean and healthful conditions, and should never be exposed to the air of the street.

Men who made the Study of Bacteria Possible. — The inventor of the microscope should be placed at the head of the list of men who made the study of bacteria possible, for without this instrument we should not know that such plants exist. We do not know who the actual inventor was, but the microscope was little more than a toy until it was improved by a Dutch naturalist, Leeuwenhoek (Lŭ′wĕn-hook) in the latter part of the seventeenth century. Next in the study of bacteria comes Pasteur, who discovered and studied them in their relation to the souring of milk and in other fermentations.

Finally comes Koch, who discovered a way of separating bacteria so that each kind may be studied by itself, a method called getting a "pure culture," and who also invented the tuberculin test. Most of our facts about bacteria have been learned during the past thirty-five years.

248. **Healthy Bodies and Bacteria.** — So much has been said about harmful bacteria that a word of caution is needed. Two facts should make us take a sane view of the situation: (1) for every harmful bacterium there are thousands of helpful ones; and (2) harmful ones cannot do their work, or even live, in a perfectly healthy body, for such a body is constantly preparing a substance (antitoxin) which neutralizes the bacterial poison (toxin). Our chief aim, then, should be to keep well, and a few simple rules of hygiene will accomplish this. (1) Spend as much time as possible exercising in the open air. (2) Sleep as many as eight hours out of twenty-four in a well-ventilated room or out of doors. (3) Eat only food which agrees with you, and not too much of that. (4) Wear seasonable clothing. (5) Keep the skin clean through frequent bathing. (6) Have a definite occupation, work faithfully at it, do your best, and don't worry.

FIGURE 372. — BEEF JELLY. Exposed in unsanitary dairy.

SUMMARY

The smallest and simplest of all the plants are the bacteria. Most of them are helpful, ridding the earth of waste material, giving flavor to food, gathering nitrogen from the air for plants, and aiding in the making of linen and sponges. Some bacteria are harmful and cause diseases in plants and animals. Bacteria are spherical, spiral, or rod-shaped. They are found everywhere, unless special pains have been taken to remove them. If they have plenty of food, air, moisture, and warmth, they multiply rapidly, and they go into the resting state, in which they can remain for a long time if any or all of the necessary conditions of growth are lacking. The harmful bacteria by their growth secrete a poisonous substance. When there are enough bacteria present to make a large quantity of toxin, the animal or plant host is made ill. Some bacteria, especially in the resting state, can bear freezing or boiling without being killed. In order to make anything "keep," it is necessary either to kill all the bacteria by making the substance sterile or aseptic, or we must put into it a preservative in which the bacteria cannot grow. We should exercise great care to avoid the bacteria known to produce disease.

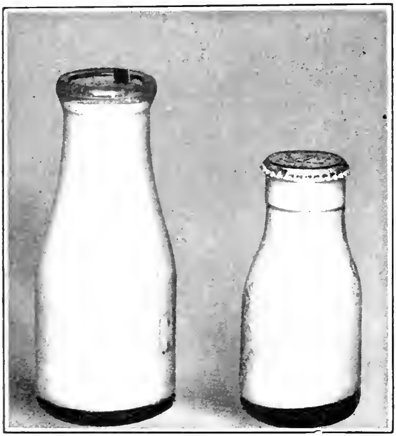

FIGURE 373. — BAD AND GOOD BOTTLING.
The metal cap keeps out dirt which can get by the paper stopper.

Milk, one of the most important articles of food, is a possible source of danger from harmful bacteria which may get into it in various ways. Milk should be kept cold, and should be used before it is too old. The harmless bacteria in milk form lactic acid and cause the milk to sour. The growth of these bacteria can be checked by pasteurizing the milk. Ice cream, if too old, is dangerous, for the slow-growing bacteria have had a chance to develop.

The men who did the most to make the study of bacteria possible were Leeuwenhoek, who improved the microscope; Pasteur, who discovered bacteria in milk, and Koch, who found the way to make a pure culture and to test cows for tuberculosis. Many students are devoting their lives to finding out about the various bacteria.

Every one should know the main facts about bacteria so that he may not have a foolish fear of them, but may be able to take reasonable precautions against the harmful kinds. Since a healthy body is the best safeguard against harmful bacteria, we should observe the laws of hygiene in order to keep well, and at the same time, avoid, when possible, the bacteria which produce disease.

QUESTIONS

What are the main points of likeness between a bacterium and a bean plant? What has the pleurococcus which the bacterium lacks? How can food be protected from harmful bacteria? In what respects are bacteria harmful to milk? In what respects helpful? Why are a few harmful bacteria not injurious in a healthy body? If one bacterium divides every half hour, and all live, how many will there be at the end of twenty-four hours? (Solve by arithmetic or by algebra.) Why does an apple with a broken skin decay more rapidly than one in which the skin is not broken? Why should one not put ice into water to cool it?

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CHAPTER XXIV

FUNGI

249. **Fungi.** — The Fungi are of importance to us because: (1) some can be used as food (the so-called mushrooms); (2) one of them, the yeast plant, is used in making bread, beer, and wine; (3) others spoil our food when they grow on bread and cake; (4) they cause many diseases in plants.

Fungi differ from the higher plants in two respects. They are colorless, or nearly so, chiefly because they have no chlorophyll. They are dependent for food on plant or animal substances, either dead or alive, because they lack chlorophyll and hence cannot make their own foods as the green plants do.

Fungi which live on the substances or juices of live plants or of animals are called *parasites* (Greek, *para*, beside; *sitos*, food); and those that live on dead objects are called *saprophytes* (Greek, *sapros*, rotten; *phyton*, plant).

250. **The Yeast Plant.** — This plant is a unicellular fungus, too small to be seen by the naked eye. It is oval or almost round in shape, and is nearly colorless. It has all the parts of a typical cell, although the nucleus cannot be seen without a special stain. Because it lives upon dead vegetable matter, it is a saprophyte.

The Work of the Yeast Plant. — In the making of bread, we know that: (1) yeast secretes an enzyme which breaks up sugar into simpler substances; (2) in this process alcohol is formed and carbon dioxide is set free; (3) the yeast lives on the proteid substances in the flour; (4) both the gas which makes bread light and the alcohol are driven off by the heat of the oven when the bread is baked.

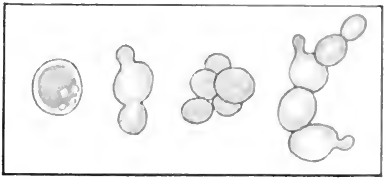

FIGURE 374. — YEAST.

Use is made of the enzymes and yeast in the making of beer, ale, and porter. The process of the manufacture of these products is as follows: The grain, usually barley, is soaked in water to soften it. The grain is kept warm and moist until it sprouts, and in this condition is called malt. It is then heated and crushed. Fermentation takes place when warmth and moisture are supplied, the enzyme *diastase* breaking up the starch into sugars. The liquid or wort from this process is boiled with hops. The wort is again fermented, this time by the aid of yeast, the action of which is to break up the sugars into carbon dioxide and alcohol. Yeast of only one kind is used (a pure culture) and care is taken to keep the temperature favorable to its most rapid growth. As the yeast grows and breaks up the sugar, it forms quantities of gas and alcohol. In bread these are temporary by-products which are lost in the baking, but in the manufacture of

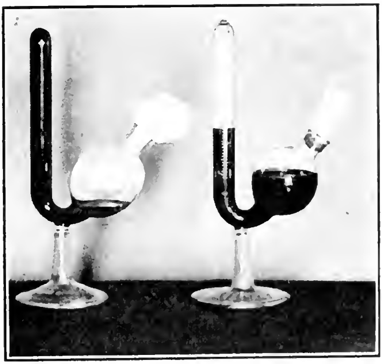

FIGURE 375. — FERMENTATION TUBES.

beer they are the product sought, and every means is taken to retain them.

Before the action of bacteria and yeast were understood, much trouble was experienced in getting uniform products, owing to the presence of undesirable bacteria and yeasts. The possibility of making pure cultures, the use of the microscope, as well as the tests which are made in the laboratories at every step of the manufacture, have placed the industries of bread-making and brewing on a scientific basis.

251. **Reproduction of the Yeast Plant.** — The method of reproduction of the yeast plant is similar to that of the bacterium, but differs from it in that instead of dividing exactly in two, a bud usually pushes out from the side of the mature plant. Sometimes the second plant will form a bud before it breaks away from the first, and so a chain is made. Oftentimes a single plant puts forth more than one bud (Figure 374).

LABORATORY STUDY

Prepare a Pasteur solution, a good food for yeast, as follows:

Potassium phosphate	10 parts
Calcium phosphate	1 part
Magnesium sulphate	50 parts
Ammonium tartrate	50 parts
Cane sugar	750 parts

Sufficient water to make a total of 5000 parts. (This may be used for the culture of other molds than yeast and also for bacteria.)

Yeast. — Examine yeast cells under low power. Note their glistening appearance and their number. Under the high power try to find all parts of a typical cell. Label and draw. Look for budding cells and chains of cells. Draw. Make a thick paste of water, yeast, and flour. Put an equal amount into each of three tumblers. Place one tumbler in a cool place. Into one of the remaining stir a teaspoonful of sugar and set both tumblers in a warm place. Examine several times a day and write down all the differences you observe in the three mixtures. Try to give a reason for everything you observe.

252. Bread Mold. — When examined with the naked eye, bread mold appears like a thick mass of felt, made up

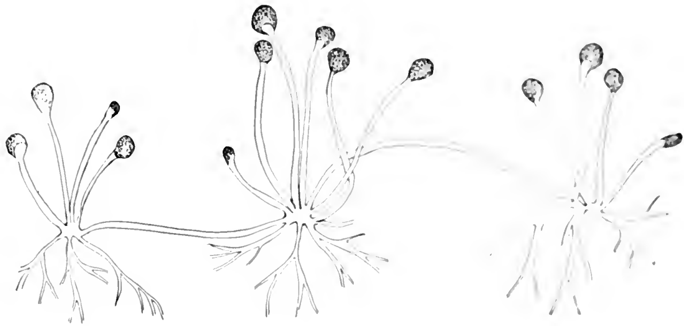

FIGURE 376. — BREAD MOLD.

of colorless, closely interwoven threads. These threads are called *hyphæ* (hī′fē: Greek, *hyphe*, web) and are of two kinds, one lying on the surface of the bread or just below it, and the other standing upright above the surface. The first are the nutritive hyphæ, and

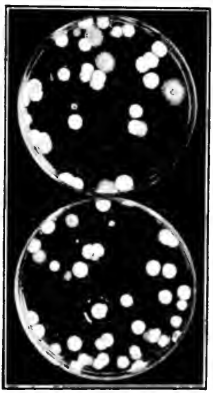

FIGURE 377. — MOLD GROWN FROM WATER.

FIGURE 378. — CAP FUNGI.

the second the reproductive. On the ends of the latter are round black bodies which are full of spores, each of which is capable of producing a new mold plant, if it falls into a place where conditions are favorable for growth, — that is, where it has plenty of food, the right degree of warmth, and sufficient moisture. Other kinds of fungi may usually be found on a loaf of bread after a day or two, as spores of many kinds of molds are floating in the air at all times (Figure 376).

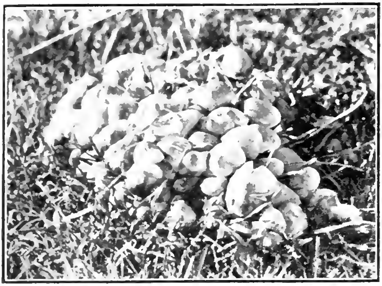

FIGURE 379. — PUFFBALLS.

253. **Other Fungi.** — A common fungus is the one that kills flies in the fall. At that time a dead fly is often observed on a window or mirror, the body surrounded by a whitish ring. Such a fly has been killed by fungus hyphæ which have filled the body. The ring is composed

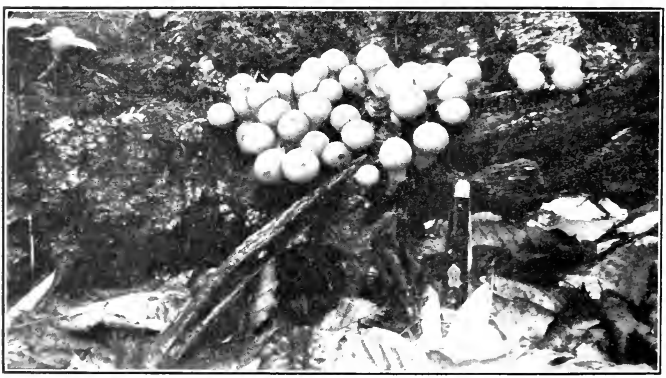

FIGURE 380. — PUFFBALLS.

of spores thrown off from the ends of the hyphæ which have burst through thin places between the segments of the fly's body.

FIGURE 381. — BRACKET FUNGUS.
The fruiting body of the fungus.

FIGURE 383. — PEAR SCAB.

FIGURE 382. — TREE KILLED BY BRACKET FUNGUS.

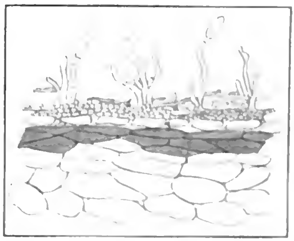

FIGURE 384. — SECTION THROUGH THE SCAB.

Other common fungi are potato blight, red rust of wheat, corn smut, which produces the black mass found in an ear of corn, and the bracket fungi, which grow in large numbers on the trunks of trees and whose hyphæ cause the death of the tree (Figures 381 and 382).

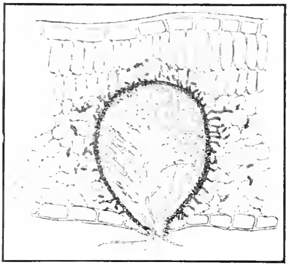

FIGURE 385. — SPORES. Section through a leaf injured by fungus.

The fungi used for food are nourishing, but there is a prejudice against their use because other fungi which resemble them closely are poisonous. As a matter of fact, it is an easy task to learn to distinguish the edible from the poisonous fungi. While the harmless fungi are now used as food much more than formerly, only a few varieties are raised for trade purposes (Figures 378–380).

LABORATORY STUDY

Wet a piece of bread, put a tumbler over it, and set it in a warm place for three or four days. Examine without the microscope to get the general appearance. With the microscope note (1) the clear, colorless threads (hyphæ) making up the mass; (2) the groups of spore-bearing bodies, black and round, on the ends of the upright stalks; (3) the spores coming out of them.

254. **Lichens.** — Lichens (lī′kĕns) are grayish green plants which look like scales. They grow on old fences, rocks, trees, and the like and are especially noticeable after a rain. A lichen is made up of the hyphæ of a fungus, which inclose the cells of an alga. The algal cells in a flat lichen are usually near the top and bottom, and the fungus is in the middle of the plant. The alga uses the moisture which the fungus collects and brings to the plant, and, by the use of its chlorophyll, makes food, a

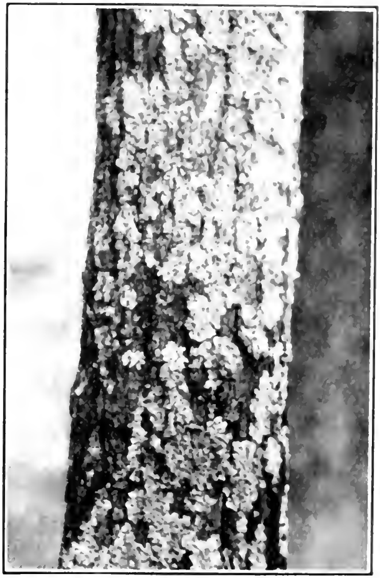

FIGURE 386. — LICHENS.

part of which is used by the fungus. The latter, after it has become accustomed to the alga, cannot live apart from it, and the alga, while it can live by itself, appears plump and prosperous when it is found surrounded by fungal threads. The partnership, therefore, seems to be helpful to both plants. Such a relation between organisms is known as *symbiosis* (sĭm-bī-ō'sĭs: life together; Greek, *syn*, with; *bios*, life). (Figures 386 and 387.)

Lichens are interesting chiefly as representing this peculiar interdependence of plants. They have little or no economic importance, although in the Arctic Regions they furnish a supply of food for the reindeer.

FIGURE 387. — SECTION OF LICHEN.

We close the study of the simplest plants with the fungi. As in the case of the bacteria, men have spent their lives studying the fungi, especially those which cause disease. Much has been accomplished, but a great deal remains to be done in finding out the cure for certain fungus diseases, especially those that attack vegetables which we use for food.

FIELD TRIP FOR THE STUDY OF LICHENS

After a rainy period, examine trees, rocks, old fences, posts, and similar places for lichens. Note the form, color, and kinds of trees having the greatest number of lichens; the trees having the smallest number, and the side of the tree having the greatest number. Make the same examination during a dry period.

SUMMARY

Fungi are plants similar in structure to the algæ, but they lack chlorophyll. On this account fungi cannot make their own food, but always have to use that prepared by another organism. As they lack chlorophyll, fungi cannot use carbon dioxide, and as a result that which they produce by respiration is cast off into the air, as is the case with animals and with green plants placed in the dark.

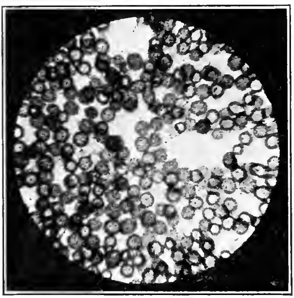

FIGURE 388. — SPORES OF CORN SMUT.
A farm fungus.

The fungi which are most important economically are the yeasts used in making bread, or beer and other fermented liquors; the edible mushrooms; those that spoil food, as bread mold, and those which cause plant diseases, such as corn smut and wheat rust. Fungi reproduce by means of spores. The mutually helpful relation in which fungi and algæ live in the lichen is called symbiosis. Animals which show the same relation are of little economic importance in this country.

QUESTIONS

What is the color of fungi? Are they ever green? Why not? How does their food differ from that of green plants? How does the yeast plant produce changes in flour? In malt? How does the work of bread mold and yeast compare with that of the bean? What are lichens? Do lichens grow equally well on all sides of a tree? On all trees? How do they appear when wet? When dry? What colors do you find among them?

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CHAPTER XXV

MOSSES AND THEIR ALLIES

255. **General Features.** — The plants in this group have more parts, stems, leaves, etc., than the fungi and algæ have; the chlorophyll is evenly distributed, and they tend to grow erect. The life history of the mosses is more complex than that of the simple algæ (Figure 390).

If a cushion of moss is examined, it is found to be made up of small plants packed closely together. At certain times of the year some of these plants have a stiff, wiry, brownish stalk, surmounted by a boxlike capsule, on top of which may be a shaggy cap or cover (Figures 389 and 390).

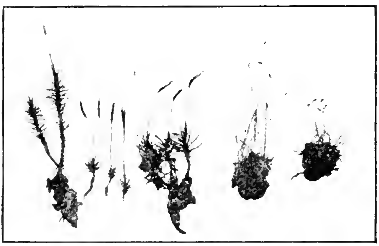

FIGURE 389. — TYPES OF MOSSES.

256. **Habitat.** — Mosses grow in moist places, for their rootlike rhizoids are not sufficiently developed to gather water from the soil. They thrive best in shady woods, on decaying logs, and on stones wet by spray. Another reason for their need of moisture will appear in the study of their reproduction.

257. **Life History.** — If a dry moss capsule is shaken, powdery spores, much like the "smoke" from a puffball, float off in the air. When these spores fall on moist ground, each sends out a mass of very small, alga-like

threads which are called the *protonema* (prō-tō-nē′mȧ: Greek, *protos*, first; *nema*, thread). These threads produce buds from which leafy moss plants grow. The latter produce gametes (reproductive cells which reproduce sexually) and so the moss plants are called *gametophytes* (gamete plants).

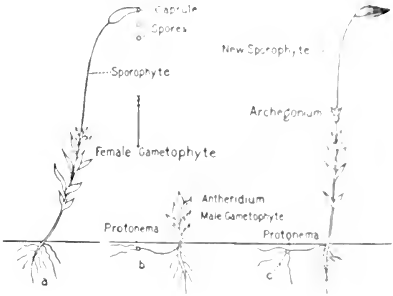

FIGURE 390. — DIAGRAM.
Life history of moss.

These gametes are of two kinds, eggs (large non-motile cells) and sperms (motile cells). The egg cells are produced in special vase-shaped organs called *archegonia* (ar-kē-gō′ni-a), and the sperm cells in other organs called *antheridia.*

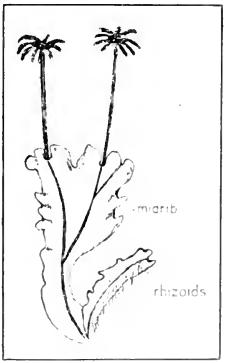

FIGURE 391.
ANTHERIDIAL PLANT.

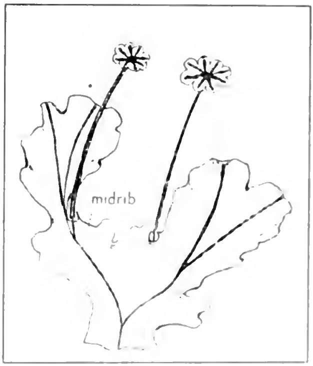

FIGURE 392.
ARCHEGONIAL PLANT.

When moss plants are reproducing, both of the reproductive organs are found surrounded by sterile hairs at the top of the stems. Some mosses have both antheridia and archegonia on the same plant, while other mosses have only one kind on each plant. The moss plant which bears the antheridia is usually short and has on the top a rosette of leaves, in the center of which is the sex organ.

Many sperms come from each of the antheridia, which move by the use of cilia when water is present, a film of dew being sufficient. The female moss plant has on its upper end one or more archegonia, each of which contains an egg cell. When the egg is ripe or ready to be fertilized, sperms may swim to it if water is present. A sperm enters the archegonium and fuses with the egg cell, thus forming a sexual cell, known as the fertilized egg cell.

From this fertilized egg cell a sporophyte (spore plant) grows out of the archegonium. The sporophyte consists of a foot, a pad by which it gets its food from the gametophyte, the seta, a slender stalk, and the capsule or spore-case. While every mature gametophyte leads an independent existence, the sporophyte is a parasite.

Thus in its life history the moss plant has two distinct generations, the gametophyte or sexual and the sporophyte which reproduces asexually (Figure 390).

258. **Economic Value.** — Mosses have little economic value, except in cold regions where some kinds are dug from under the snow for food for the reindeer. They are interesting as showing a stage of development of the higher plants.

LABORATORY STUDY

Moss (Polytrichum). Study moss plants and note the difference in size between the male and female plants. Make a drawing to show the difference in size and in the arrangement of the leaves. Select a female gametophyte which has a sporophyte. Draw and label the seta or stalk, and the capsule, the box at the top. Look for moss plants on trees, along the edges of sidewalks, and on damp soil. With the microscope examine archegonia and antheridia. When antheridia from fresh material are used, the sperms can usually be seen escaping from the antheridium.

259. Marchantia. — Marchantia is a plant belonging to the moss group, which grows in very moist places. It has a thin, broad body or *thallus* (thăl′lŭs: Greek, *thallos*, a young shoot), which is green on the upper surface and brown or gray on the under side. In the middle of the thallus is a midrib. On the upper surface are diamond-shaped markings, each of which has an opening which leads to an air chamber below. On the under side are rhizoids, which hold the plant loosely to the soil.

FIGURE 393. — MARCHANTIA.

The marchantias are adapting themselves to a life on land, but they are still dependent upon water. Their reproductive habits are like those of the mosses (Figures 391 and 392).

LABORATORY STUDY OF MARCHANTIA

Examine pieces of the plant and identify the thallus, midrib, rhizoids, and markings. Examine the umbrella-shaped, upright branches which bear the antheridia or male reproductive organs, the branches with slender projections which bear the archegonia or female reproductive organs. With a microscope examine a cross section of the thallus, and observe the openings and air chambers.

SUMMARY

Mosses are much more complex than algæ and fungi. Specialization is shown in the cells which gather and conduct water, the beginning of the absorptive and conductive systems of plants. There is also the beginning of a system of getting oxygen. The life history of a moss represents the alternation of generations, a generation which reproduces by spore (asexually), and one which reproduces by egg and sperm (sexually). The generation which bears spores is the sporophyte, and that which bears eggs and sperms, the gametophyte.

QUESTIONS

In what respects are mosses more highly developed than algæ, fungi, and lichens? Why do mosses require so much moisture? Give the life history of a moss.

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CHAPTER XXVI

FERNS AND THEIR ALLIES

260. The Group. — The ferns are the best known members of this group, but club-mosses and rushes (horsetails) also belong to the fern family. The study of coal mines has shown us that ferns are very old plants and that they were formerly much more numerous than at the present time. The plants of this group have real stems, roots, and leaves, and most of them are larger than the mosses. While the ferns are not so dependent upon water as the mosses, they grow best in cool, moist woods and in rich soil.

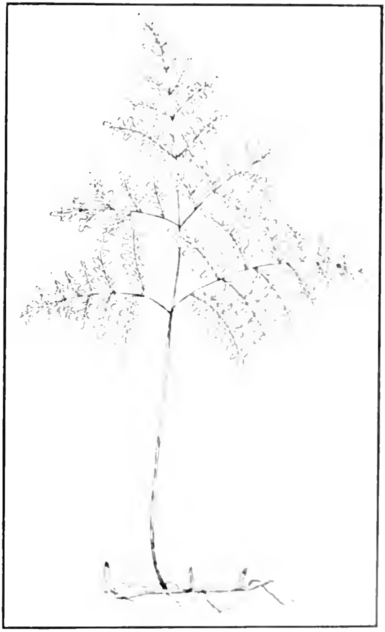

FIGURE 394. PTERIS.

261. A Typical Fern. — The fern named pteris (Figure 394) is the best known and most widely distributed. The stem proper is underground and lives on from year to year, while the part above earth renews itself annually. Some of these stems reach a length of ten or fifteen feet. They branch out and give off many fine roots. Leaves, termed *fronds*, form from the upper surface of the stem and grow up through the soil into the air.

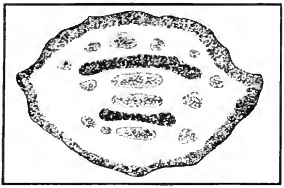

FIGURE 395. — PTERIS STEM.

The stem of the pteris fern is composed of well-defined clusters of cells which are grouped into tissues. These tissues are: (1) the epidermal on the outside, which protect the stem; (2) the fundamental, which make up the body of the stem and carry on most of the vital processes; (3) the mechanical tissues, variously grouped, which by means of their thick-walled cells give the stem firmness;

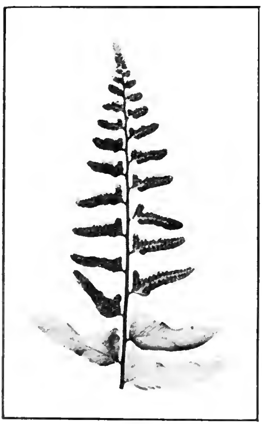

FIGURE 396. — FERN FROND SHOWING SORI.

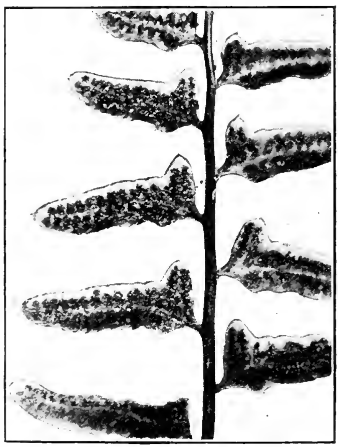

FIGURE 397. — SORI ENLARGED.

and (4) the conducting tissue, which is made up of several different kinds of cells, all of which carry liquids (Figure 395). The conducting tissue extends into the leaves and is the vein of the leaf. During certain seasons of the year, lines form along the margin of the under surfaces of the leaves. These lines are made up of many minute reproductive bodies, the *sporangia* (spōr-ăn′jĭ-à: Greek, *spore*, seed; *angeion*, vessel). Each sporangium contains numerous spores. In some ferns the sporangia occur in dots, the *sori* (singular, *sorus;* Greek, *soros*, heap). See Figures 396 and 397.

FIGURE 398. — FORKED VEINS OF FERN.

262. Life History of the Fern. — The fern plant just described forms spores in the sporangia. These spores fall to the ground and soon begin to grow. The sprout from the spore is in the form of a single thread and is a protonema. From the fern protonema there develops a small, flat, heart-shaped body called the *prothallium* (Greek, *pro*, before; *thallos*, twig) which is indispensable to the life of the fern. On the under surface of the prothallium grow small bodies, the antheridia and archegonia. The antheridia produce numerous motile sperm cells, and each archegonium a single egg cell. A sperm cell, on finding an archegonium, enters, fuses with the egg cell, and forms the fertilized egg cell. The prothallium is the fern gametophyte. See section 257.

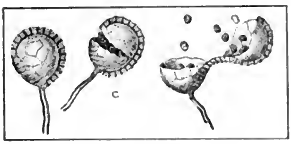

FIGURE 399. — SPORANGIA.

When an egg cell is fertilized, it begins to grow and a new fern plant is soon formed. The young plant remains attached to the prothallium and gains nourishment from

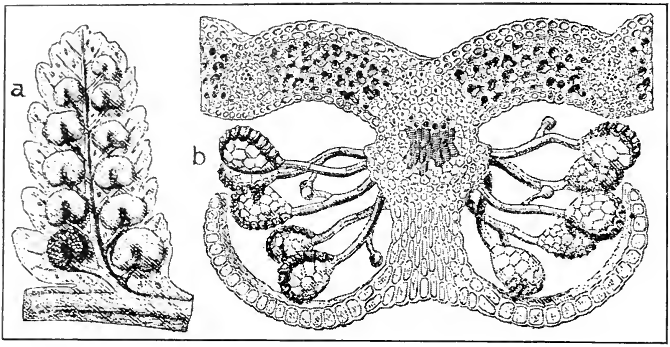

FIGURE 400. — *a*, POSITION OF SORI; *b*, SECTION OF SORUS.

it. As soon as the young fern is able to get nourishment by its own roots, it begins life as an independent plant and the prothallium dies. There is the same alternation of generations in the fern that occurs in the mosses, the

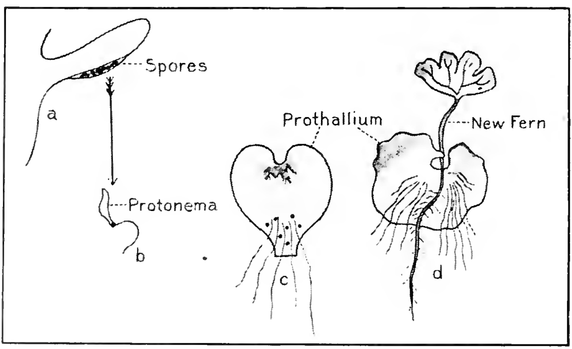

FIGURE 401. — LIFE HISTORY OF FERN.

prothallium being the gametophyte and the "fern" the sporophyte, but the latter is the longer lived and much the larger plant (Figure 401).

FIELD TRIP TO GREENHOUSE OR WOODS TO STUDY FERNS

Note the color of the plants, the characteristic fern leaf with its stipe or central stalk, its pinnæ or leaflets, and also the method of unrolling from the base to the tip. Note the fruiting dots (sori) on the back of the leaves. In what kind of soil are ferns found? Do they grow best in the sun or in the shade? Do the leaves remain green during the winter? Note the underground stem and its roots. Look for buds and young leaves. Note the forked veins.

LABORATORY STUDY

Examine the cross section of a stem and note the different kinds of tissue. Draw and label: (1) epidermal tissue on the outside; (2) mechanical, dark brown tissue in masses near the center; (3) conductive tissue, large openings; (4) fundamental tissue filling the rest of the space. With a microscope examine the epidermis on the under side of the leaf, noting the shape of the cells and the stomata. Pull off a bit of the epidermis and try to distinguish the green guard cells. Examine a sorus with low power of the microscope and see how it is made up of sporangia on stalks.

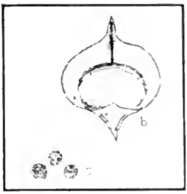

FIGURE 402. *b*, SPORANGIUM; *c*, SPORES.

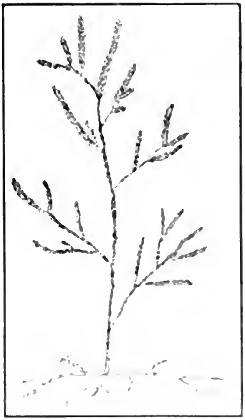

FIGURE 403. *a*. CLUB MOSS.

263. Related Forms. — Club mosses, horsetails, and selaginella (sē-lăj-ĭn-ĕl′lȧ) are plants which belong to the fern group. Club mosses bear their spores in a spike on scales which are modified leaves. In appearance these plants are more like mosses than ferns (Figures 402 and 403).

Horsetail, or equisetum, grows in waste or damp places.

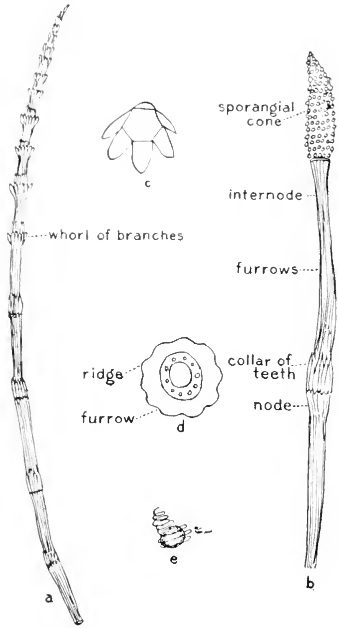

FIGURE 404. — HORSETAIL.

It is a hollow stem, with joints, a mineral coating on the outside of the stem, and the branches in a circle around each joint. The conductive tissue in this plant is arranged near the surface of the stem (Figure 404).

Selaginella is seldom seen in northern latitudes, except in greenhouses (Figure 405).

264. Economic Importance. — The fern group, like the mosses, have little economic importance. The spores of the club mosses are used in making certain kinds of fireworks (especially those used indoors); also in drug stores to keep pills from sticking together. The plant itself is used in Christmas decoration. Horsetail, so named from its appearance, was formerly cut, tied in bundles, and used for scouring, and this accounts for its other name, the "scouring rush."

265. The Formation of Coal. — Ages ago ferns were more numerous than they are now and many of them grew to be as large as our present trees. Geologists tell us that the climate was warmer and more moist than it is now, and conditions especially

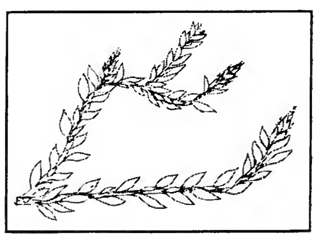

FIGURE 405. — SELAGINELLA.

favored the growth of fern plants. Where these large ferns died and fell to the ground, great masses accumulated.

As the earth's surface changed, these masses became covered with soil or water, and under the influence of heat and pressure they changed into coal. At the same time natural gas and petroleum, or rock oil, were formed. No coal is being formed at the present time, and when our present supply is exhausted, we shall have to find other sources of heat and power.

SUMMARY

Ferns and their allies are less dependent on water than are the algæ, fungi, and mosses. They are more highly organized, as they have epidermis, stomata, mechanical tissue, conductive tissue, stem, roots, and leaves. Their life history shows the alternation of generations, consisting of spore, protonema, prothallium, and sporophyte. Club mosses, horsetail, and selaginella are closely related forms. Coal was formed when ferns grew to the size of trees in regions which were then hot and moist.

QUESTIONS

What parts of the flowering plant are found in the fern? In an animal what corresponds to epidermal tissue? to conductive tissue? to fundamental tissue? to mechanical tissue? Compare the life history of a moss and a fern. Why can ferns do with less water than mosses? Illustrate by diagrams or sketches the life history of a fern. What plants are related to ferns? Tell how coal beds were formed.

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Campbell, A University Textbook of Botany, Bryophytes, page 200, Pteridophytes, page 241.

Curtis, A Textbook of General Botany, Chapters VII and VIII.

Leavitt, Outlines of Botany, Bryophytes, page 198, Pteridophytes, page 204.

CHAPTER XXVII

THE CONIFERS (GYMNOSPERMS)

266. **General Characteristics.** — In passing from the ferns to the conifers, usually known as evergreens, we go from a

FIGURE 406. — CONIFERS.
At center and left. Note their undivided trunks.

lower to a higher order of plants. With the exception of the corn and bean, none of the plants studied up to this time bears seeds, but all reproduce by spores or by fertilized eggs. Most of the evergreens are seed-bearing trees which vary in size, but which are alike in having trunks that taper from the base to tip without dividing. Such trunks are called *excurrent*. The evergreen group contains the largest plants in the world and those which live to the greatest age. Their foliage is usually composed of dark green, needle-like leaves which remain attached to the tree for two or three years. Thus the trees always have some foliage and so are termed "evergreen."

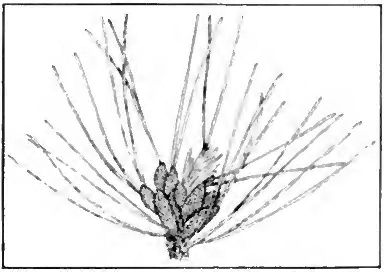

FIGURE 407. — STAMINATE STROBILI OF PINE.

267. Pine Tree. — The pine illustrates the plants of this family. The pine has all the parts of a flowering plant — stem (trunk), branches, roots, leaves, seed-producing organs, and fruit (cones).

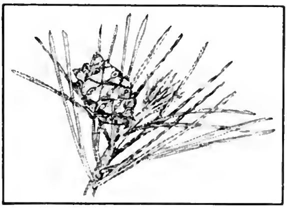

FIGURE 408. — YOUNG CONE OF PINE.

Stem. — The trunk does not divide, — a marked characteristic of evergreens. In a forest where trees are crowded together and there is in consequence a struggle to get light, the trunks grow tall and most of the branches are near the top.

A cross section of a stem shows a series of rings, known as annual rings, by which the approximate age of the tree can be told. In the spring when all the conditions are at their best and growth is rapid, the cells of the tree are large and thin-walled, strength being sacrificed to size.

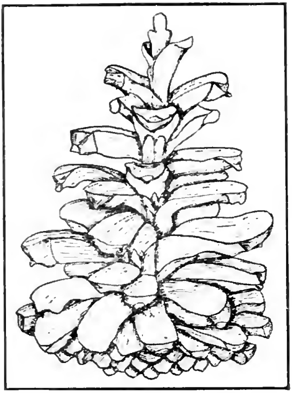

FIGURE 409. — RIPE CONE OF PINE.

But in the fall or during a dry time in summer, the cells formed are much smaller and the walls thicker. These small cells which show most plainly make up the annual ring. During a season in which long, dry periods occur, more than one ring may be made. From the center to the bark extend lines which are made of pith and are known as medullary rays. The part of the stem where increase in thickness takes place is just under the bark.

Branches. — The branches leave the stem almost horizontally and nearly in a circle around the trunk of the tree. In the pine they curve upward, but each kind of evergreen has its own habit of curvature in its branches.

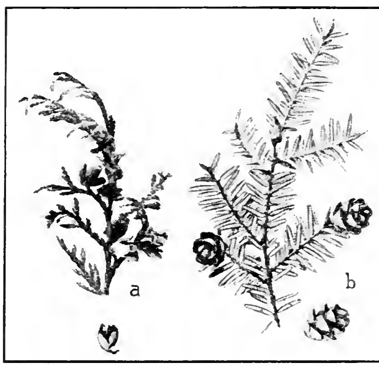

FIGURE 410. — OTHER CONES.

a, arbor vitæ; *b*, hemlock.

Leaves. — The leaves, called needles, are long, slender, and flattened on one side. They grow in bundles of two, three, four, or five needles, according to the kind of pine. The leaves, which are borne but once in a place, remain on the tree from two to five years and then fall off, leaving the branches bare except near the ends.

Roots. — The roots of the pine vary according to the kind of pine and according to the soil, but they are always extensive.

Seed-producing Organs. — Early in the spring, two kinds of cones are found on the new shoots which grow from the terminal buds. One kind looks like short catkins, and these cones are borne in clusters near the base of the shoot. They consist of scales arranged spirally around the central axis. Each scale bears two pollen sacs. These are the staminate cones (Latin *sta*, stand) or strobili. They wither soon after shedding their pollen, although they may remain on the tree for a year. The other kind of cone is short and thick, and is found at the tip of the shoot or on the side of the shoot near the tip. This is the carpellate cone (female strobilus), which is made up of scales arranged spirally around a central axis. Each scale near its base bears two ovules. When the pollen is ripe, each grain, being provided with winglike air sacs, is easily blown about by the wind. Some of the pollen sifts into the carpellate cone through the spaces between the scales, which at this time

FIGURE 411. — A VIRGIN FOREST OF MIXED HARD WOODS AND CONIFERS IN NORTHERN PENNSYLVANIA.

The splendid trunk in the middle ground is that of a cucumber tree. (Hugh P. Baker.)

FIGURE 412. — LUMBERING IN NEW YORK.

FIGURE 413. — FIRE SLASH.

The scene of a great destructive fire in 1908.

are separated slightly. Then the scales close together, the cones turn downward, and continue to grow for several months (Figures 407–410).

Figure 414. — Waste Land in Pennsylvania.

The year previous to the taking of this photograph this land was covered with a virgin forest as shown in Figure 411. Logging has been followed by fire, which destroyed the humus and much of the surface soil, making the tract a barren waste upon which it will be impossible to grow another such forest for many years. Pennsylvania alone has several millions of acres of such waste land covered formerly by splendid virgin forest.

Fruit. — During the next year, the pollen grains which are shut up inside the scales grow into pollen tubes and fertilize the egg cells which develop in the ovules. From the fertilized eggs the embryo pines develop.

When the cones are about two years old the scales open, and allow the seeds to drop out. Each seed is provided with a wing by which it is blown about, for the pine depends on the wind to scatter its seeds as well as its pollen. Because the seeds lie on the scale without being inclosed in an ovary, all these plants are called *gymnosperms* (Greek, *gymnos*, naked; *sperma*, seed).

Figure 415. — Waste Land.

After the fire had passed over the region shown in Figure 413.

268. **Habitat.** — The evergreens grow in sandy soil in temperate

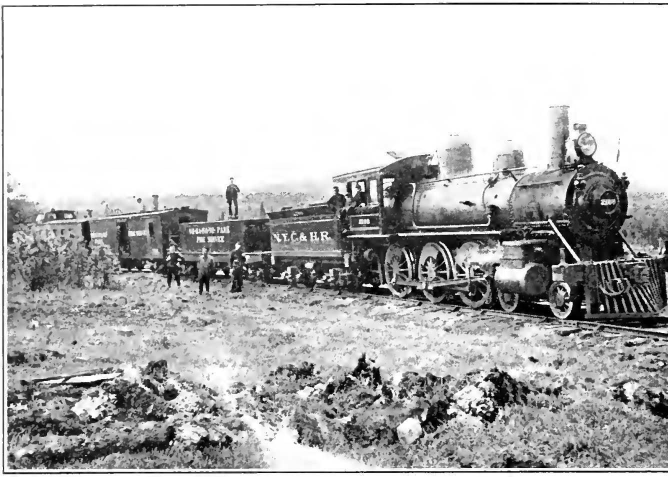

FIGURE 416. — FIRE TRAIN IN THE ADIRONDACKS.

FIGURE 417. — NURSERY WHERE YOUNG TREES ARE STARTED.

or in cold climates, but a few of them occur where it is very warm. The finest evergreen forests in the world are found in the western part of North America, on the slopes facing the Pacific Ocean.

269. **Related Forms of Conifers.** — Hemlocks, spruces, firs, and balsams have smaller, flatter needles than the pines and they are not arranged in bundles. Cedars have scale-like leaves. Larch and cypress trees shed their leaves in the fall, but in other respects are much like the pines.

FIELD STUDY OF GYMNOSPERMS

Most of the work in connection with gymnosperms should be done out of doors. The student should learn to know by sight all the local native evergreens and those commonly planted for ornament. He should note the method of branching and the character of the trunk compared with other trees. He should observe the position of the cones on the branches and be able to give the reasons therefor. In the spring he should look for the male and female cones or strobili, and for leaf buds in the winter. He should examine the leaf scars and the external rings which mark a year's growth, and decide how many years each tree keeps its leaves. He should note the arrangement of the leaves on the branches, the annual rings in the wood and their relation to the grain of the wood, the resin on wounds, the curvature of the branches, and the other features readily observed.

STUDENT REPORT

	Needles Single Alternate	Needles Scale-like	Needles in Bundles	Cones Large	Cones Small
Hemlock .					
White Pine					
Larch .					
Cedar . .					
Spruce . .					
Etc. . . .					

LABORATORY

In the laboratory examine a cross section of the stem to see the difference in the cells grown in the early and in the late part of a season. Note the pith and medullary rays. If specimens are available, examine sections of wood from different trees. Make a collection of the woods found in the vicinity. Examine scales from staminate and carpellate cones. With the microscope examine pollen of pine. Draw and describe all the rays.

270. **Economic Importance.** — The value of the gymnosperms can scarcely be overestimated. Most of the

FIGURE 418. — PLANTING YOUNG TREES IN THE ADIRONDACKS.

trees are sawed into lumber for building purposes, but some of them are used in their natural form for telegraph poles, masts of ships, and timbers of mines. Wood pulp, from which most of our paper is made, is produced from small spruce trees. The by-products of this group of trees are of great value. From the pine come tar, pitch, turpentine, and resin, while the bark of the hemlock was formerly extensively used in tanning leather.

The forests of the United States cover about 550,000,000 acres, or more than one fifth of the total area.

"Generally speaking, countries having over twenty per cent of wood lands have forest resources sufficient to supply their lumber industries and their firewood consumption, provided that such area is properly stocked and conserved." — Schenck, "Forest Policy," page 71.

Yellow pine, which supplies one third of the lumber consumed in the United States, ranks first in value: white

FIGURE 419. — YOUNG PLANTATION IN THE ADIRONDACKS.

pine, which formerly supplied the greatest amount, ranks second; and Douglas fir, third.

271. Related Topics. — Hardwood forests are composed of trees which have broad leaves and flowers with typical stamens and pistils. Such trees grow either alone or in tracts containing many evergreens. Maple trees supply sugar and syrup, the industry being important in Ohio and Vermont. Other hardwood trees yield fuel, lumber, and nuts.

272. Importance of Forests. — Forests are of the greatest importance in preventing floods caused by the rapid melting of ice and snow. The snow melts more slowly in the woods, not only during a midwinter thaw, but also in the spring, and the soft, porous character of soil causes it to absorb much water. This results in springs and rivers being fed uniformly during the summer. Floods and freshets can often be traced largely to denuded hills along the streams, because hills without forests have soil poorly

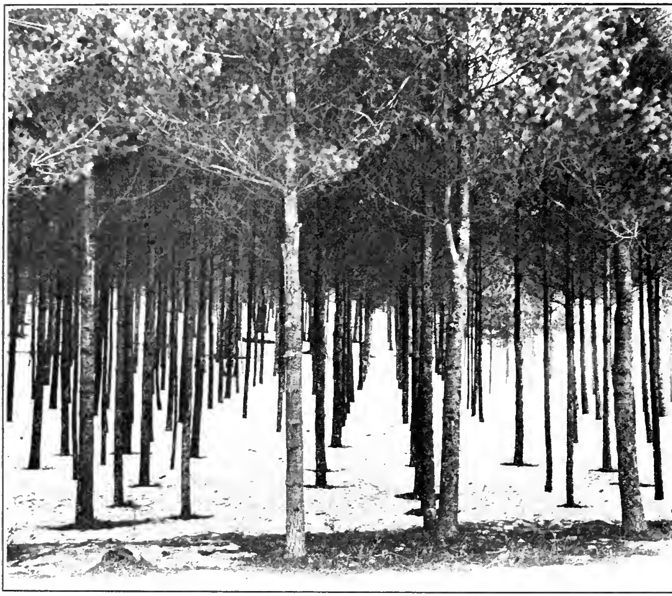

FIGURE 420.—YOUNG PLANTATION 16 YEARS AFTER PLANTING.

fitted to prevent the water from running down faster than it can be carried away. Floods and freshets each year do millions of dollars' worth of damage in the destruction of bridges, buildings, and other property.

Another loss occurs in the washing away of the most valuable form of soil from the hills, when the water flows off rapidly. Not only is the soil that is left useless for agriculture for many years, but that carried into the streams clogs harbors and channels, making it necessary to spend large sums in dredging.

Forests are destroyed not only by lumbering operations, but also by fires, many of which are caused by carelessness. Forest fires, in addition to destroying the trees, render large territories useless for agriculture by burning up the humus, or organic part of the soil. So great is the destruction and waste caused by forest fires, that the national and state governments have taken measures to prevent them. Forests are now patrolled daily during parts of the year and apparatus for fighting fires is always in readiness.

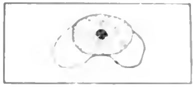

FIGURE 421. — POLLEN OF PINE.

In addition, the government is setting out thousands of young trees and protecting them in an effort to re-forest bare territory, especially around the headwaters of rivers. Where forests still exist, the government is buying them in order that they may not be destroyed. Such tracts are called forest reserves.

In European countries the study of forestry has been carried on for a long time. Their forests are made a source of revenue, but all the trees are never cut in a single season, and planting keeps pace with cutting. Scientific forestry is now practiced on about 90% of the public forests of the United States and on about 2% of the woodlands privately owned. Only about one fifth of the wooded area of the United States is under government control. New York State is taking steps to preserve her forests and also to re-forest large tracts which have been cut over (Figures 418–420).

FIGURE 422. — SEED OF PINE.

SUMMARY

The conifers belong to a class of the higher plants. They have periods of active and less active growth, both together resulting in the appearance of annual rings. Because their seeds are not entirely inclosed in an ovary, but lie uncovered on a scale, they are called gymnosperms. Conifers are of great economic importance, for they supply much of our lumber, tar, pitch, and all our turpentine and resin. Hardwood trees grow with the evergreens. They belong to many families of flowering plants and furnish lumber, fuel, and nuts. Forests help to regulate the flow of streams and they prevent the washing away of the soil.

QUESTIONS

How are gymnosperms like other plants? How do they differ from other plants? What kind of a trunk is characteristic of gymnosperms? How does a tree which grows in a forest differ from one which grows in an open field? Why? What are annual rings? How are they formed? Describe the branches; the leaves; the roots; the cones or strobili; the fruit. What is a sporophyte? Name the gymnosperms. Make a list of the uses to which lumber is put. What other products come from the evergreen forests? In what ways are forests beneficial? What are the governments doing to protect them? What regions in your own state are covered with forests?

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CHAPTER XXVIII

PECULIARITIES OF PLANT LIFE

273. Unusual Plants. — In order to live, all plants must have conditions favorable to their vital processes, and many of them develop special modifications which aid the plant in the struggle for existence. Some of the modifications already studied in this book are the arrangement of leaves or the length of petioles to secure air and light; the presence of color, odor, and nectar, devices to attract insects and thus secure the pollination of flowers; and the use of wings, pappus, and hooks to secure the distribution of seeds. Many of the carnivorous and parasitic plants are remarkable for the modifications which make it possible for them to obtain nitrogen, an element lacking in the food supply of their particular environment.

FIGURE 423. — PHOTOGRAPH OF PITCHER PLANT.

The Pitcher Plant. — The leaves of this plant form a sort of vase which retains water in the bottom. When insects crawl into the leaf, their escape is prevented by hairs which grow around the opening on the inside and point downward, and the unfortunate victim, exhausted

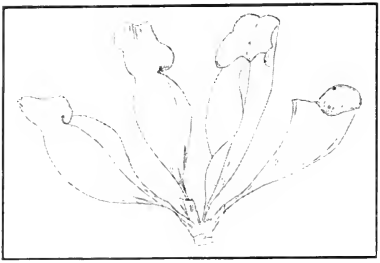

FIGURE 424. — LEAVES OF PITCHER PLANT.

by his struggles to get out, falls into the water and is drowned. When the bodies decay, the plants secure the nitrogen which they are unable to get through their roots.

The Sundew. — This plant has round leaves covered with long glandular hairs which secrete a sticky substance. When an insect alights on a leaf, the hairs bend over and hold the victim until it dies, the secretions of the plant meanwhile digesting the soft parts of the insect. When the leaf has

FIGURE 425. — PHOTOGRAPH OF SUNDEW.

absorbed this digested food, the hairs release the remaining parts, which then fall off, and the hairs resume their usual position.

Venus's Fly-trap. — This plant has another way to catch insects. The leaves end in a traplike device in two parts which lie flat like the leaves of a book. When an insect alights on one side, the other closes quickly and confines the fly by hairs on the edge which interlock. Digestion and absorption soon take place, after which the leaves lie flat again, ready for another insect visitor.

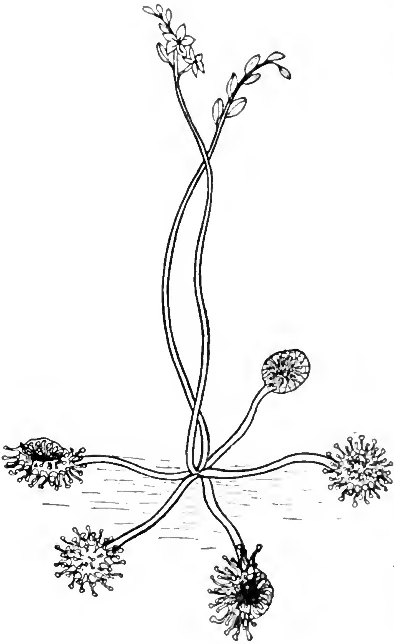

FIGURE 426. — DIAGRAM OF SUNDEW.

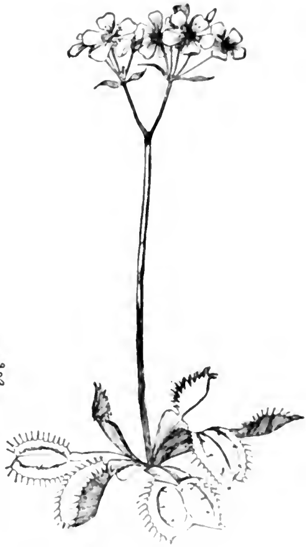

FIGURE 427. VENUS'S FLY-TRAP.

Indian Pipe. — Although it produces flowers and seeds, this plant has no chlorophyll and so is a waxy white in appearance. It gets its nourishment from decayed organic

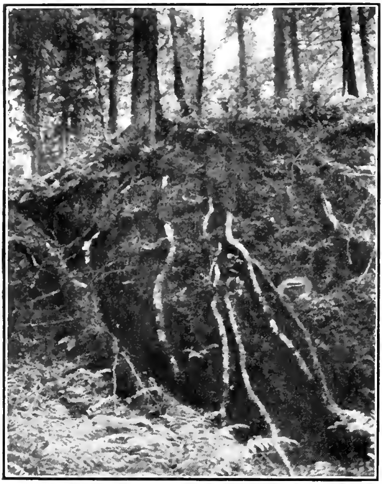

FIGURE 428. — PHOTOGRAPH OF BIRCH ROOTS.
Growing over the surface of a boulder.

matter, usually wood, just below the soil. A fungus which grows on the roots helps them to absorb this prepared food.

Mistletoe. — We are most familiar with this plant as a part of our Christmas decorations. Mistletoe has chlorophyll and so is able to manufacture its own food, but it has no roots for absorbing water, making it dependent on a larger plant for this necessary part of its vital conditions. The plant possesses absorbing organs which pierce the bark of the trees upon which it grows. As a result it does much injury to the trees by using the water which they need for their own life processes. In the South, for instance, the mistletoe is regarded as a great pest.

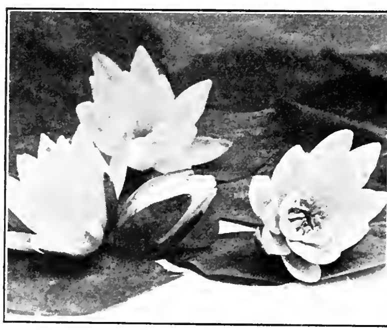

FIGURE 429. — WHITE WATERLILY.

274. **Movements of Plants.** — Most plants move slowly and only in response to one of several stimuli. Touch, or contact, is the stimulus in the case of sundew and Venus's flytrap, both of which are

peculiar in moving quickly. Tendrils curve under the influence of the same stimulus, but they move slowly.

Light and darkness are universal stimuli. Flowering plants move toward the light, if it does not surround them evenly on all sides. Window-growing plants show this. Plants like potatoes, which sprout in a cellar, grow many

FIGURE 430. — WATERLILIES — HYDROPHYTES.

feet to get into the light. Darkness causes plants like clover and oxalis to close their leaves.

Moisture is a stimulus which affects the roots of a plant, as is shown in Figure 428.

275. **Plant Societies.** — The term *plant society* is applied to any collection of plants which grow under similar conditions. The trees of the forests, and the grass and weeds of our lawns, are typical examples. In most cases water, or the lack of it, is the basis for classifying or grouping plants in societies. Plants, like some algae, live submerged in the water, while others, like the waterlilies, live

partly in the water, lifting their leaves and flowers into the air.

Plants which live in the water are called ***hydrophytes*** (hȳ′drō-fītes: Greek, *hydor*, water; *phyton*, plant). If such plants have roots, they are little more than holdfasts, for the hydrophytes do not need organs of absorption. Most of the members of this plant society are without

FIGURE 431. — CAT-TAILS AND ARROW-LEAF.

mechanical tissue, for the water holds them firmly on all sides. The algæ lack a conducting system as well, for their source of food is all about them. Waterlilies get their oxygen and much of their carbon dioxide from the air through their leaves, which float on the surface of the water with the stomata on top. Air passages in the long, slender stems convey air to the roots which lie in the mud. Hydrophytes which lie under water have their leaves finely divided to offer as much surface as possible to the water and thus secure a full supply of oxygen.

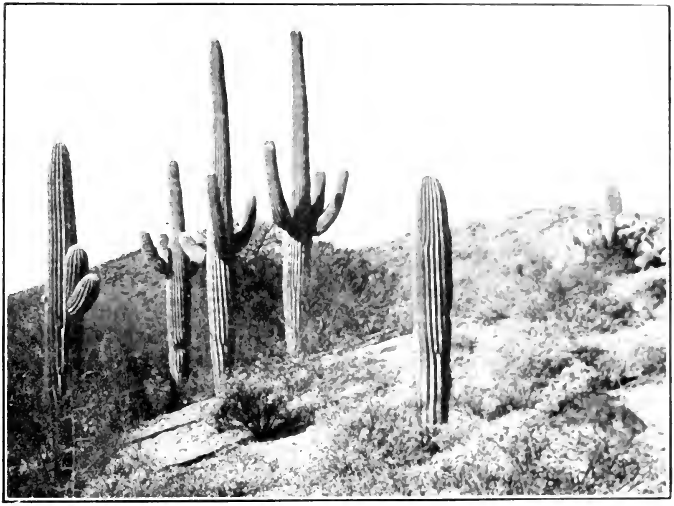

FIGURE 432. — GIANT CACTUS.

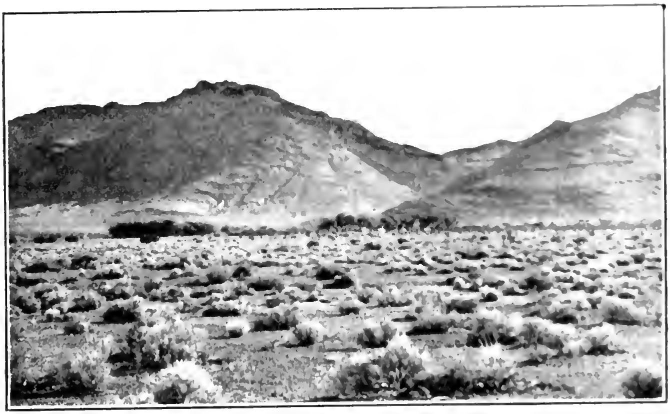

FIGURE 433. SAGE BRUSH.

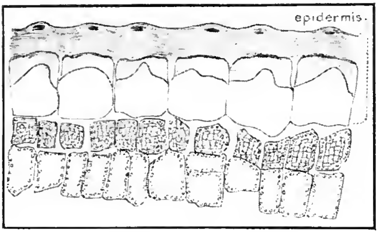

FIGURE 434. — DIAGRAM.

Section of the epidermis of agave, a xerophytic plant. Compare this section with the section of the bean leaf in Figure 265.

Plants which live in desert regions, of necessity, have to live on little water. They are called *xerophytes* (zĕr′ō-fītes: Greek, *xeros*, dry; *phyton*, plant). Xerophytes usually have long roots so that when moisture is present they may gather it rapidly. Many forms have little surface exposed to the air; the branches are few, and there are no leaves. The stem, which is green in color, performs the work of photosynthesis. To conserve their water supply further, the xerophytes have a thick epidermis and few stomata. These plants are an admirable illustration of making the most of what one has.

FIGURE 435. — BULL THISTLE.

A mesophyte weed.

Desert plants live in regions where it is usually both hot and dry, but plants of the Arctic Regions have many of the same modifications, only in a lesser degree. Much of the time severe cold prevents the roots from absorbing water, and the plant must keep what it already possesses. Some of the Arctic plants, therefore, have leaves which roll to reduce the surface and have, in addition, a coating of hairs, both devices for retarding transpiration.


FIGURE 436. — LADY SLIPPER.

Most of the plants which we see and which live where there are no great extremes of heat or cold and where it is neither wet nor dry are called *mesophytes* (mĕz'ō-fītes: Greek, *mesos*, middle; *phyton*, plant). They have few characteristics in common, but all have roots suited to the soil in which they grow, and leaves which in shape and arrangement serve the purposes of each plant better


FIGURE 437. — LONG-SPURRED VIOLET.

than any others would do. Examples of this are the nar row, upright leaves of the grass, which grows thickly

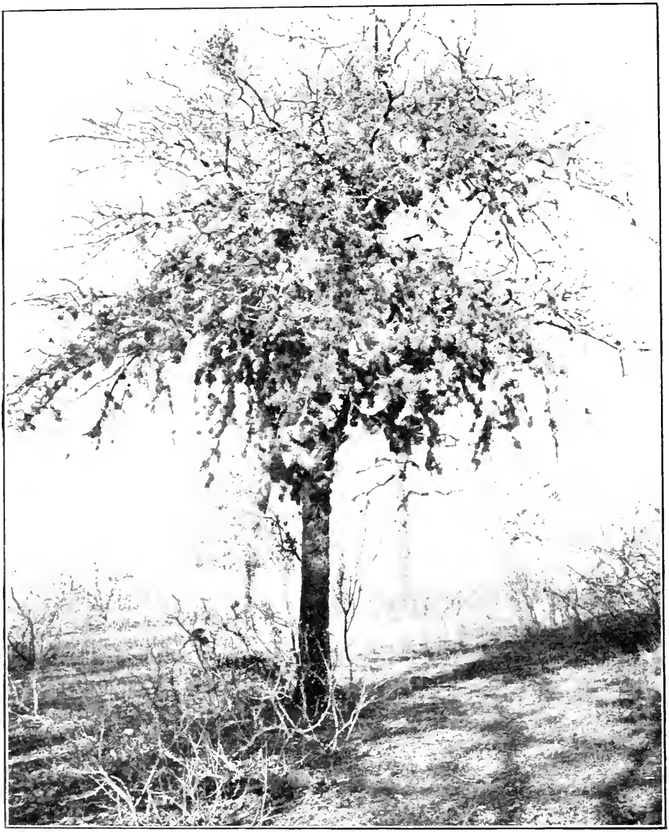

FIGURE 438. — MISTLETOE.

A semi-parasite. This tree has no leaves.

crowded together, the broad leaves of the trees, and the leaves of the ivy, which grows on walls, arranged like a mosaic. Many divisions of the mesophytes might be made, for some prefer sunny locations, others shady places, and so on.

Plants which live in the air make up another group, called *epiphytes* (ĕp′ĭ-fītes: Greek, *epi*, upon: *phyton*, a plant) because they usually attach themselves to the stem of a larger plant. Their modifications consist of one kind of roots for fixing them to their support and another capable of absorbing and storing water. The latter organs are called *velamens* and are composed of spongy tissue. They are situated on the outside of the plant, soak up rain and dew and conduct it to an inner region where it is used as the plant needs it. Velamens can also absorb moisture from the air. The epiphytes are characteristic of the tropics, where the air is full of moisture and where rains fall frequently. In our own part of the world, lichens have somewhat the same habit, and orchids in greenhouses are another example.

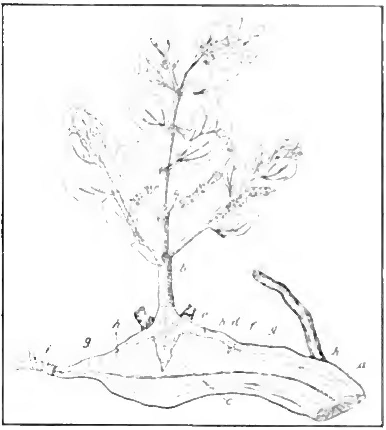

FIGURE 439. DIAGRAM.

Sectional view of a branch infected with mistletoe, showing the relation between the parasite and host; *a*, branch of host tree; *b*, mistletoe; *c*, primary sinker; *d*, sinker from cortical root; *e*, *f*, cortex of soft bark; *g*, cambium or growth ring; *h*, wood of branch. The starving and dwarfing of the branch beyond the mistletoe is shown at *i*.

The study of plants which deals with their distribution and the factors which govern it is called *plant ecology* (ē-kŏl′ō-jȳ: Greek, *oikos*, home; *logos*, talk).

276. Plant Succession. — When a swamp is drained, a forest cleared, or a desert irrigated, plant conditions are changed. Thus it becomes impossible for some plants to thrive in their former habitat, and possible for others to grow where before they could not. The replacing of one plant society by another is termed *plant succession.* When a forest is cleared and the tract burned over, the plant called fireweed appears in large numbers, even if a cultivated crop is planted. After a year or two the fireweed gives way to a growth of blackberry and raspberry bushes, which are later replaced by grasses and weeds of various kinds.

Another example of plant succession is seen in regions covered by fresh lava from a volcano. At first nothing grows. Probably bacteria and fungi appear before other plants are noticed, but lichens are usually the first to be observed. These die and decompose, and their remains, together with bits of lava loosened by frost, wind, or water, accumulate in depressions and form a soil in which mosses can grow. The remains of the mosses add to the organic matter in the slowly increasing soil, and, in the course of time, ferns and larger plants can grow. The last finally replace the mosses as they replaced the lichens.

277. Summary of Our Interest in Plants. — Our first interest in plants is economic, that is, we think of them first in terms of their usefulness or harmfulness to us. As every animal in the world is dependent directly or indirectly upon plants for food, it becomes obvious to what a degree we are benefited by the ability of plants to make food out of the air and the soil.

Man could live comfortably on what three plant families furnish, — the grasses, which include all the cereal foods and sugar; the pulse family, which furnishes most of our vegetable nitrogen; and the rose family, which includes the plants which furnish us our luxuries in the way of fruits. In eating animal products, man is still dependent upon the grass family to furnish food for the cattle from which he obtains meat, milk, cheese, and butter. For clothes, man depends indirectly upon plants for the leather and wool of the domestic animals, and directly for cotton and linen.

FIGURE 440. — TROPICAL VEGETATION.
Note how different the plants are from ours.

Plants are the source of many of the materials out of which houses are made and furnished.

Some plants (bacteria) cause disease, while still others provide remedies with which to cure diseases. Plants please our eyes as we travel about. They keep up the supply of oxygen in the air; they rid the air of the carbon dioxide which we have cast off; they provide employment for millions of men who raise food plants, manufacture them into food, and distribute them throughout the world;

and they employ other millions in the production of cotton plants and cotton cloth for our clothing.

The farmer who raises plants has an interest in knowing what kind of soil and climate, how much water, air, and light each kind of plant needs to yield him the best results. To this end he has to know something about the habits of plants in general, and about their enemies and their diseases. He has learned by experience that some plants grow better when planted in hills; others in drills, and still others sown broadcast. He is still trying to find the best kind of plant food for each plant, and the method of cultivation which best enables plants to get their full supply of food and moisture, and he is still fighting weeds which deprive the useful plants of their share of food, water, and light. Yet he is conscious, if he stops to consider, that he cannot make a plant grow. His part is to create good vital conditions.

We are interested in the work of men who are trying by cross-pollination, grafting, and selection to reduce the undesirable parts of plants and to increase their capacity for food, storage or whatever we find desirable. Luther Burbank has made many experiments along these lines, especially in increasing the number of fruits on trees and in reducing the size of the seeds in berries.

278. **Scientific Interest.** — In addition to practical interests, that is, besides the supreme importance of plants to man and his dependence upon them, there is another interest, — that of the scientist in plants as organisms. The scientist studies how plants are like animals; how they differ from them; how each is dependent upon the other for waste products; how plants depend upon animals for the pollination of their flowers and the scattering of their seeds, and how the plants make use of the wind and water for the same purposes.

He studies, too, the increasing complexity of plants from the simple, one-celled plants dependent upon water for existence up through the plants which are becoming accustomed to living on land, and finally to those which have complex systems and complex flowers. He finds that all are related, and the more he learns about them, the more interesting does he find their relationships. He is interested in seeing how the change from water to land calls forth changes in structure to fit the new environment; how in land plants, each one has adapted itself in form, size, arrangement of leaves, and so on, to make the best possible use of the air and water which it is able to procure.

FIGURE 441. — CALLA.
From an X-ray photograph. One of the new ways of studying plants.

In trying to find the causes of such variations of plants the scientist performs many experiments, often upon the smallest plant, for size and complexity are no indication of the interest which may center in a plant structure. Bacteria, for instance, which are the simplest and smallest of all plants, are being studied more to-day than any of the others.

Every year adds to our knowledge of the nature of plants, their relations to each other and to man. Besides these relations due to their surroundings, plants bear towards each other the relation of dependence and independence, which we have discussed under *parasitism* and *symbiosis*.

Plant life itself remains a mystery. The poet Tennyson has given expression to the thoughts of those who have tried in vain to solve the many problems which have arisen in connection with the study of plant life.

"Flower in the crannied wall.
I pluck you out of your crannies.
I hold you here in my hand,
Little flower, root and all.
But if I could understand
What you are, little flower,
Root and all, and all in all,
I should know what God and man is."

LABORATORY

To show the response of stems to gravity, place seedlings or young plants in unnatural positions and note their effort to right themselves. To show the response to light, examine a potato from a dark cellar, which has sprouted in the spring; a plant that has been allowed to grow towards the light in a window; the bending of seedlings, and the like. For the storage of food, examine all the common garden vegetables and test them for the food which they contain. If possible, find some vegetables which have been kept for two seasons and have produced seed, and note their appearance after all the food has been used.

Sprout slips of balsam, geranium, and ivy to get adventitious roots. Show such roots on the stem of a tomato plant where it has been allowed to lie on the ground.

Examine leaves in the laboratory and in the fields to find illustrations of all the terms used. Examine onions and cabbages for example of leaves modified for storage, and the onion also as an example of a reduced stem. Find examples of all the terms used in the discussion of flowers and buds.

APPENDIX A

BIRD STUDY

One of the most fascinating phases of Biology is the study of birds. This is easiest and most interesting during the *migrations*, when the trees are leafless. The early morning is the best time of day for observing birds.

The following tables have been compiled to help pupils acquire a more intimate knowledge of birds, — their appearance, habitat, food, manner of flight, and so on. Not only is this information valuable in itself, but there are few things that may be learned in such a pleasant way.

· Plate A ·

REPORT FOR IDENTIFICATION OF BIRDS

	Where Observed	Apparent Food	Size as compared with Robin	Color of head	Color of breast	Color of wing	Color of tail	Color of back	Tail forked or rounded	Flight strong or weak	Special Markings
Oriole	tree	larvae	smaller	black	orange	black	orange black	orange	rounded	strong	
Purple Finch	tree	flowers seeds	"	reddish	reddish	brown	brown	reddish	forked	"	
Swift	flying	insects	"	dusky	dusky	dusky	dusky	dusky		weak	
Golden Crowned Kinglet	tree	"	"	orange black	light	fuscous	fuscous	greenish	forked	"	
Bluebird	tree	"	"	blue	reddish white	blue	blue	blue	rounded	strong	
Flicker	ground	"	larger	grey scarlet	brownish	yellow black	yellow black	grey black white	"	"	
Robin	ground	worms	same	black	rufous	white	black white	slate			
?*	trees shrubs	insects	smaller	"	black	salmon black	salmon black	black	rounded	weak	
?	trees	?		scarlet	scarlet	black	scarlet	scarlet	"	strong	

* What birds have the characteristics given in these two rows?

Plate B— — Report for feeding station —

	Food	Drive away birds	Store away food	Line of flight towards food	Method of approaching Food—	Manner of — coming to food— Singly—	In pairs—	In a group—	Sing while feeding	Number of different Notes	Easily approached
Downy Woodpecker	Suet	+	No		Light Above and back down	x	x		Yes	Two	Yes
Hairy Woodpecker	Suet	+	No		"	x			"	"	No
Nuthatch	Crumbs Suet	+	Yes		Alight Above walk down head foremost		x		"	"	Yes
Chickadee	"	–	No		Fly directly to food			x	"	Three	"
Brown Creeper	Suet	–	"		Alight below and walk up	x			No	One	"
Song Sparrow	Seeds Crumbs	+	"		Alight Near and hop to it	x			"	Four	No
House or English Sparrow	Seeds Crumbs Suet	+	"					x	Yes	One	Yes
Robin	Crumbs	+	"		"	x			No	Three	Yes
Grackle	"	+	"		Alight Near walk to it			x	Yes	Two	No

Plate C— — Report for Birds in Nesting Season —

	Nesting Site	Material	Arrangement	Eggs Number—	Color—	Size—	Adults Bold—	Timid—	Young Large—	Small—	Opened Mouths	Shrink down
Robin	hedge	grass and mud —	interlaced				x		x			x
Chipping Sparrow	bush	rootlets grass, hair	"				x			x	x	
Oriole	elm tree	plant fibre, grass, string	woven	x				x				
Grackle	Norway Spruce	grass and wool —	interlaced	5	green brown gray	1¼" long		x				
Meadow Lark	ground	grass —	"	5	brown white	" "		x				
Phoebe	under eaves	hair, mud feathers	plastered, interlaced	4	white	¾" "	x					
Cat Bird	bush	rootlets, grass —	interlaced	3	blue	⅞" "	x					
Mourning Dove	Norway Spruce	grass						x	x			x
House Sparrow	behind eave	hay, grass, feathers	heaped							x	x	

Plate D— — Report on a single pair of Birds feeding their young —

	Time —	Male fed —	Female fed —	Nature of food —	Number of times each Nestling is fed —				Direction from which Adults approach nest				Food supply —	Cleaned Nest	Brooded Young
					Nestling No 1	" No 2	" No 3	" No 4	East —	West —	North —	South —			
9:15	A M	X		worm	X	X			X				lawn	x	
9.20	"		X	"	-	X	X	X	X				"		
9 21	"	X		"		X		X	X				"		
9 28	"		X	"	X		X				X		—	x	x
9:30	"	X		cherry	X	X		X				X	—		
9 40	"		X	worm	X	X	X				X		—		
9·45	"	X		"			X	X	X				lawn		
9 47	"		X	"	X	X			X				"	X	
9·55	"		X	"	X		X	X	X				"		

Plate E- — Report for Seasonal Activities of Birds —

	First Arrival	Does Male Precede?	When Common?	Began Nesting	First seen with Young	Color of Young				Color of Adult				Young Independent
						Head	Breast	Wings	Tail	Head	Breast	Wings	Tail	
Robin														
Bluebird														
Chipping Sparrow														
Gold Finch														
Cedar Bird														
Bobolink														
Song Sparrow														
Sandpiper														
House Sparrow														

APPENDIX B

REGULATIONS OF THE SANITARY CODE

ESTABLISHED BY

THE PUBLIC HEALTH COUNCIL OF THE STATE OF NEW YORK

Condensed from the Bulletin of the New York State Department of Health

Isolation of Persons Affected with Communicable Diseases. — It shall be the duty of every physician, immediately upon discovering a case of communicable disease, to secure such isolation of the patient as is required by the special rules issued by the local health authorities or by the state department of health.

Adults not to be Quarantined in Certain Cases. — When a person affected with a communicable disease is properly isolated on the premises, except in cases of smallpox, adult members of the family or household, unless forbidden by the health officer, may continue their usual vocations, provided such vocations do not bring them in close contact with children.

Removal of Cases of Communicable Disease. — After isolation by the local health officer no person, without permission from him, shall remove, or permit to be removed from any room, building, or vessel, any person affected with diphtheria, scarlet fever, smallpox, or typhus fever.

Without permission from the local health officer no person shall remove, or permit to be removed from any dwelling, any person affected with chickenpox, diphtheria, epidemic cerebrospinal meningitis, epidemic or septic sore throat, measles, mumps, poliomyelitis (infantile paralysis), scarlet fever, smallpox, typhus fever, or whooping cough.

Removal of Articles Contaminated with Infective Material. — Without permission from the local health officer no person shall remove, or permit to be removed from any room, building, or vessel, any article which has been subject to contamination with infective material through Asiatic cholera, diphtheria, scarlet fever, smallpox, typhoid fever, or typhus fever, until such article has been disinfected according to the special rules and regulations of the state department of health.

Exposure of Persons Affected with Communicable Disease. — No persons shall permit any child, minor, or other person under his charge, affected with diphtheria, measles, scarlet fever, smallpox, or typhus fever, to associate with others than his attendants.

No person affected with any of said diseases shall expose himself in such manner as to render liable their spread.

Exclusion from School of Cases of Disease presumably Communicable. — It shall be the duty of the principal or other person in charge of any public, private, or Sunday school to exclude therefrom any child or other person affected with a disease presumably communicable until such child or other person shall have presented a certificate issued or countersigned by the health officer, stating that such child or other person is not liable to convey infective material.

Exclusion from Schools and Gatherings of Children of Households where Certain Communicable Diseases Exist. — Every child who is an inmate of a household in which there is, or has been within fifteen days, a case of chickenpox, diphtheria epidemic cerebrospinal meningitis, German measles, measles, mumps, poliomyelitis (infantile paralysis), scarlet fever, smallpox, or whooping cough, shall be excluded from every public, private, or Sunday school and from every public or private gathering of children for such time and under such conditions as may be prescribed by the local health authorities.

Precautions to be observed in Chickenpox, German Measles, Mumps, and Whooping Cough. — No person affected with chickenpox, German measles, mumps, or whooping cough shall be permitted to come in contact with or to visit any child who has not had such disease or any child in attendance at school.

Isolation or Removal in Smallpox. — It shall be the duty of every health officer, whenever a case of smallpox occurs in his jurisdiction, if a suitable hospital is available, to remove or cause to be removed such case promptly thereto. Every inmate of the household where such case occurs, and every person who has had contact with such case, shall be either vaccinated within three days of his first exposure to the disease or placed under quarantine, and, when vaccinated, the name and address of such inmate or other person shall be taken and such inmate or other person shall be kept under daily observation. Such observation shall continue until successful vaccination results, or for at least twenty days. If such inmate or other person refuses to be vaccinated, he shall be quarantined until discharged by the local health officer.

If there is no hospital available, the patient shall be isolated and every inmate of the household shall be vaccinated or strictly quarantined until discharged by the local health officer.

Whenever a case of smallpox occurs in his jurisdiction, it shall be the duty of the local health officer to use all diligence in securing the names and addresses of all persons who have had contact with such case, and in causing such persons to be either vaccinated or placed under quarantine.

Maximum Period of Incubation. — For the purpose of this code, the maximum period of incubation (that is, between the date of the exposure to disease and the date of its development), of the following communicable diseases is hereby declared to be as follows:

Chickenpox	21 days
Measles	14 days
Mumps	21 days
Scarlet fever	7 days
Smallpox	20 days
Whooping cough	14 days

Minimum Period of Isolation. — The minimum period of isolation, within the meaning of this code, shall be as follows:

Chickenpox, until twelve days after the appearance of the eruption and until the crusts have fallen and the scars are completely healed.

Diphtheria (membranous croup), until two successive negative cultures have been obtained from the nose and throat at intervals of twenty-four hours.

Measles, until ten days after the appearance of the rash and until all discharges from the nose, ears and throat have disappeared and until the cough has ceased.

Mumps, until two weeks after the appearance of the disease and one week after the disappearance of the swelling.

Scarlet fever, until thirty days after the development of the disease and until all discharges from the nose, ears and throat, or suppurating glands have ceased.

Smallpox, until fourteen days after the development of the disease and until scabs have all separated and the scars completely healed.

Whooping cough, until eight weeks after the development of the disease or until one week after the last characteristic cough.

Sale of Food Forbidden in Certain Cases. — When a case of diphtheria, epidemic or septic sore throat, amœbic or bacillary dysentery, epidemic cerebrospinal meningitis, scarlet fever, smallpox, or typhoid fever exists on any farm or dairy producing milk, cream, butter, cheese, or other foods likely to be consumed raw, no such foods shall be sold or delivered from such farm or dairy, except under the following conditions:

(*a*) That such foods are not brought into the house where such case exists;

(*b*) That all persons coming in contact with such foods eat, sleep and work wholly outside such house;

(*c*) That such persons do not come in contact in any way with such house or its inmates or contents;

(*d*) That said inmates are properly isolated and separated from all other parts of said farm or dairy, and efficiently cared for; and

(*e*) That a permit be issued by the health officer.

Destruction of Foods in Certain Cases. — When a case of diphtheria, epidemic or septic sore throat, amœbic or bacillary dysentery, epidemic cerebrospinal meningitis, scarlet fever, smallpox, or typhoid fever exists on any farm or dairy producing milk, cream, butter, cheese, or other foods likely to be consumed raw, the state commissioner of health or the local health officer may destroy or order the destruction of any such foods which in his opinion may have been so contaminated as to be a source of danger, and the local authorities may compensate the owner for foods so destroyed.

Handling of Food Forbidden in Certain Cases. — No person affected with any communicable disease shall handle food or food products intended for sale, which are likely to be consumed raw, or liable to convey infective material.

No person who resides, boards, or lodges in a household where he comes in contact with any person affected with bacillary dysentery, diphtheria, epidemic or septic sore throat, measles, scarlet fever, or typhoid fever, shall handle food or food products intended for sale.

No waiter, waitress, cook or other employee of a boarding house, hotel, restaurant, or other place where food is served, who is affected with any communicable disease, or who visits in a household where he comes in contact with any person so affected, shall prepare, serve, or handle food for others in any manner whatsoever.

Cleansing, Renovation and Disinfection Required. — Adequate *cleansing* of rooms, furniture and belongings, when deemed necessary by the local health officer, shall immediately follow the recovery, death, or removal of a person affected with a communicable disease. Such cleansing shall be performed by or at the expense of the *occupant* of said premises, under the direction of the local health officer.

Adequate ***renovation*** of premises, when deemed necessary by the local health officer, shall immediately follow the recovery, death, or removal of a person affected with a communicable disease. Such renovation shall be performed by and at the expense of the ***owner*** of said premises or his agents under the direction of the local health officer.

Adequate ***disinfection*** of premises, furniture and belongings, when deemed necessary by the local health officer, shall immediately follow the recovery, death, or removal of a person affected with a communicable disease. Such disinfection shall be performed by or under the direction of the local health officer in accordance with the regulations of the sanitary code and at the ***public expense*** unless otherwise pursuant to law.

APPENDIX C

WHAT PEOPLE SHOULD KNOW ABOUT CANCER

Francis Carter Wood, M.D.

Condensed from the Bulletin of the New York State Department of Health.

Cancer not a Germ Disease. — The cause of cancer is still unknown, but this does not prevent our being able to cure it. The disease is quite unlike those due to germs, of which so much has been learned in the last thirty years, and no germ which is capable of causing cancer in human beings or in animals has been found. Cancer is, therefore, not contagious, and there is no danger in treating or in dressing a cancer case. Ordinary cleanliness, however, requires that the soiled dressings shall be burned — not because there is any danger of contagion of cancer, but because the discharges and dressings contain germs such as those which cause boils, erysipelas, and other skin inflammations.

Cancer not Contagious. — As cancer is not contagious there is no reason to believe the stories, so often told, of "cancer houses," or "cancer villages" or "cancer belts." The occurrence of a large number of cases of cancer in a house can usually be shown to be due to the fact that the house has been occupied by old people. Since cancer is a disease of old age there will naturally be more cases of the disease in such a house than in one which has been occupied by a number of young people.

Cancer not Hereditary. — Cancer is not hereditary, although much has been said and written about certain experiments with strains of white mice to show that, by inbreeding, the occurrence of cancer in these animals is much increased. While there is no question that this is a fact, yet the increase can be obtained only in certain strains of white mice, not in all varieties, and has never been observed in white rats, guinea pigs, rabbits, dogs, or other animals in which cancer occurs. Therefore, there is no reason to worry because one member of your family has suffered from cancer. It does not at all follow that any other member of the family will have it. In a family the members of which tend to be very long-lived, more cases of cancer will occur than in one in which the members die young, but this is not because cancer is hereditary.

Cancer Attacks the Healthy. — Unfortunately, cancer attacks not only those who are in feeble health, but also, and with equal frequency, those who are strong and healthy and have never suffered from any other disease. For this reason, it is especially important that such healthy people should consult a physician if any sudden change in their well-being takes place, and particularly if there is any digestive disturbance or disorder of the bowels, for the stomach and intestines are frequent sites of cancer.

We see, therefore, the unfortunate circumstances that while the improvement in conditions of living has prolonged the life of the community on an average of ten years in the last century, the same condition has apparently increased the number of cases of cancer, since there are more people who reach the cancer age than formerly. This gives more cases of cancer in the population as a whole, though the relative proportion per age group may not be increased.

How Cancer Begins. — While, as has been said, we do not know the cause of cancer, we do know a good deal about how it occurs and what is apt to precede it. For instance, cancer frequently begins in moles or warts which are irritated by the clothes or are made to bleed and are kept sore by repeated injury of any sort. Such warts and moles are perfectly harmless at first, and become dangerous only after they have been irritated in this way for a long time, especially if the person is of the cancer age, that is, above forty-five years. It is wise, therefore, to have such moles removed if they are in a situation where they are liable to be rubbed or injured. It has been found, also, that cancer frequently develops in the scar of an old burn, or in places where there is a chronic ulcer, as on the lip or tongue or leg, and care should be taken to see that such ulcers are healed as quickly as possible.

Ulcers on the tongue and cheek frequently follow scratching from a poor filling or from the sharp point of a decayed tooth, and a dentist should be consulted if such an ulcer does not heal within a few days, so that the filling may be properly replaced or the point of the tooth filed off. Smokers should be particularly careful about any sore on the lip or tongue; these are commonly found in those who use a pipe or cigars and smoke so that the tissue is burned by the hot stem of the pipe or at the point where the hot cigar smoke strikes, thus keeping up a chronic irritation. For this reason, cancer of the lip and tongue, while very common in men, is almost never seen in women.

The beginning of an internal cancer is much more difficult to determine, because small tumors just as they start cannot be discovered except by accident; but it has been found that they almost always begin in some injury; for instance, ulcer of the stomach is a common cause of cancer, since the ulcers turn into cancers if they are not cured by proper medical or surgical treatment. So, too, cancers of the lower bowel are frequently preceded by chronic inflammation, and persons suffering from chronic dysentery, ulceration of the bowel, or bleeding piles, should consult a physician to see that these troubles are cured promptly and do not develop into cancer.

Cancer of the breast in women frequently follows chronic inflammation, and is not caused by a blow, as is frequently thought. Any woman who notices a lump in the breast should at once consult a physician. It is very much better to be told that the thing is harmless and need not be removed, than to wait too long, only to find that it has already developed into a cancer.

Nature of Cancer. — Cancer is a very curious disease which is due to the running away of certain parts of the body tissue, that is, a few cells in the breast or in the liver or in any other organ grow beyond the natural limit and invade the surrounding tissues; then we have a cancer. This cancer often does not give any notice of its presence until a long time after the trouble has started, because the cells composing it are the same (or nearly the same) as the cells from which they started, and, therefore, the body does not recognize the fact that a cancer is growing until it becomes of considerable size. It starts very quietly, is very small at first, but gradually grows and destroys the very tissues that feed it, until ultimately it kills its host by injuring some important part of the body. But it is, in such a case, the cells of the body itself which are the parasites; in other words, there is no parasite introduced from the outside to cause the cancer.

Kinds of Cancers. — There are many kinds of cancer, and each kind acts differently and spreads in its own way through the body. Certain forms which arise in glands, such as the breast, are called *carcinoma*, and this sort spreads slowly to places where there are small nodules of tissues, called *lymph nodes*, in which the cancer collects, forming there secondary lumps or *metastases*, as the physician calls them. The true carcinoma does not often get into the blood vessels, and therefore it remains localized for a very considerable time, so that the surgeon has an opportunity to remove it, if the diagnosis, is made.

Another kind of cancer, called by physicians *sarcoma*, spreads to the blood vessels and consequently is much more difficult to cure, because this spreading takes place very early in the course of the disease and the cells are swept all over the body, starting new little tumors where they are deposited. While cancer grows through the very tissues which surround it, it does not have roots, as the quacks say. What are called roots are more frequently blood vessels leading from the cancer, or bits of fibrous tissue; so that when a quack assures a patient that he takes a cancer out "by the roots," he is talking nonsense.

Some cancers grow very slowly; for instance, some of those on the skin may remain for ten or twenty years without spreading any very great distance and without forming little lumps elsewhere in the body. Other cancers grow very rapidly and are fatal within a few months. Most cancers, however, remain local for a considerable period, probably six months to two years, before they really start to spread out in the tissues and if only they can be discovered and cut out during an early stage, the patient can be surely cured.

Symptoms of Cancer. — Unfortunately, the very smallest cancers give no symptoms unless they are on the skin or lip or tongue or elsewhere on the surface of the body; and in these situations the earliest diagnosis can be made. Cancers the size of a pea or but little larger are often diagnosed and removed by a surgeon with an assured result, if the operation has been properly done.

In the stomach and internal organs, however, the cancer does not give rise to symptoms until it is quite large, and it is important, therefore, for anyone who has *any* disturbance of the stomach or intestines, loss of weight, or anemia, to go at once to a surgeon, because by modern chemical methods and by the use of the X-ray a diagnosis can often be made on one of these cancers long before it can be felt or seen.

One of the last symptoms of cancer is pain; this is due to the pressure on the nerves by the growth spreading out through the tissues. When a cancer gives a great deal of pain it is usually beyond operation. Bleeding is a common result of cancer of the intestines, and is one of the most important symptoms. Every one should know, however, that when a lump appears anywhere on the body, a physician should be seen immediately; the lump may prove to be an abscess or something quite harmless, for there are a good many tumors which are quite harmless, or it may prove to be a cancer, and then if it has been seen early enough, it can be cured by operation.

Occurrence of Cancer. — It has been shown by the study of a large number of cases of cancer in various countries, that the disease afflicts chiefly those of middle age, that is, from forty-five to sixty-five years. Younger people and those over eighty years are rarely afflicted with cancer, except that in very old people various mild cancers of the skin are not infrequent: these, however, are easily cured by the X-ray or radium, and do not need operation in all cases.

Women about the age of forty-five to fifty-five should be very careful, if any lump appears in the breast, to have a careful examination made. Men of about this age, also, should be watchful of ulcers on the lip, tongue, or inside of the cheek, especially if the teeth are not good, and should have any such ulcers immediately examined by a physician. The physician may have to cut out a small piece and send it to a laboratory in order to determine whether or not the growth is cancerous, if it is too small to diagnose otherwise. It is very much better to have a diagnosis made early than to wait until the doctor is sure that the thing is a cancer, for it is then often beyond operation.

Treatment of Cancer. — The proper treatment of cancer is the removal of the growth as early as possible, it being remembered always that cancer is a local disease when it begins and as a rule spreads through the tissues only after a considerable time. The removal of small cancers or of beginning cancers is often an easy matter and can be done under cocaine. Internal cancers, of course, can be removed only by an extensive operation; but the methods now are so successful that a very large proportion of the cases can be saved if operation is done early.

There is a popular impression that cancer is incurable. This is not so. Early operation cures some kinds of cancer, for instance those of the lip, in about 95 per cent of the cases operated upon. If cancer of breast also could be operated upon at an early stage, nearly four fifths of the cases would remain well. When operated upon at a late stage, only one fifth of the cases are cured, that is, show no further appearance of the tumor.

Radium and X-rays are very good treatment for the small cancers which appear on the faces of old people, and in some cases may be very useful in helping to complete the surgical cure by healing any small lump which appears after operation. They are also the best treatment for a cancer which has gone so far that it cannot be operated upon, and in such a condition may frequently be of such benefit that the patient may live a couple of years in comfort, but as a rule they do not cure cancer, and they should, therefore, never be used on a cancer of any size; instead, such a tumor should always be operated upon.

Great care should be taken in selecting a physician to give the treatment with X-rays or radium, because only a few persons have enough radium for proper treatment, and only a few doctors know how to administer without burning the patient seriously, the large quantities of X-rays which are necessary to produce good effects. It is better that a patient should go to a hospital and get suitable treatment there, rather than to let his local physician experiment.

The use of salve and other forms of treatment which are widely advertised in the newspapers are worse than useless. They often stimulate the cancers and make them grow more rapidly; or if they do eat off the top of the growth, they leave the bottom spreading in deeply, and what is worse, result in a waste of time, for the tumor should be operated upon promptly.

No form of internal medicine will cure a cancer; that we know absolutely. Nor will any fluid injected under the skin cure a cancer. Cases of cures by such means which are reported in the papers or are talked about are merely instances of mistaken diagnosis, for the quack relies upon the ignorance of people as to what a cancer is and what it is not. Any small lump is called a cancer by the quack; then if it disappears he will say he has cured it. As a matter of fact, a great many tests have been made of the cancer cures which are sold in this country, and none of them have been found to be of the slightest value in the treatment of real cancer, and real cancer is the thing in which people are deeply interested, because through it their lives are in danger.

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