BOTANY

DEVELOPMENTAL AND DESCRIPTIVE

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PREFACE.

THE study of botany has a distinct cultural as well as a scientific and practical value, and therefore, the author of a text-book of botany should aim to interest students in plants. Without such interest a large part of the time spent in the study of botany is wasted.

The two phases of botany which will interest the average student are developmental and descriptive botany. The developmental part can be fully illustrated in the laboratory and the descriptive part in both field and laboratory.

Students who show a special inclination for studying any given group should have their interest stimulated further by the study of additional forms.

In Part I special attention is given to the development and relationship of plants, to the modifications of the reproductive process and organs, and to the development of new tissue or special modifications of old tissue in each succeeding higher group. The summary is a brief discussion of the variation of the plants within a group and is helpful when comparing different plants.

Teachers can readily extend Part I to cover a term by giving the student additional forms for study and comparison with the plants illustrated in the text.

In Part II, attention is given to descriptive botany. This part contains all the facts necessary for a complete understanding of the study of roots, stems, buds, leaves, flowers, fruits and seeds.

The figures are all photographs from Nature, and have, therefore, a greater value than line drawings. Such illustrations serve also to stimulate students to make collections of similar forms from other plants.

A knowledge of descriptive botany enables one to identify the plants in any locality by means of the key to the flora of that region. It is a regretable fact that few students have any knowledge of descriptive botany; therefore, they remain ignorant of our flora and lack an interest in our common plants.

Great care was exercised in the selection of the plants for making sections, in the preparation of drawings and in the arrangement of the material of the figures.

Teachers and students should have little difficulty in collecting similar material for laboratory and home study because the plants used in the figures may be readily identified.

The author wishes to express his appreciation to Mr. Ralph Young for the greater part of the photographic work and for much other valuable assistance. He is also indebted to Dr. N. L. Britton, Dr. J. H. Barnhart, Dr. M. A. Howe and Mr. Percy Wilson for assistance in various ways, and to Dr. E. H. House for photographs used in Figures 109, 110, 111, 112, 113 and 114.

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BOTANY.

PART I.

DEVELOPMENTAL BOTANY.

INTRODUCTION.

NATURE may be divided into three kingdoms, mineral vegetable and animal. The mineral kingdom is made up of inorganic bodies which possess neither life nor sensibility. The vegetable kingdom is made up of plants, which possess life and sensibility. The animal kingdom is made up of animals, which possess life and sensibility together with voluntary motion.

Masses of living matter are extremely variable in size and form. To realize this fact you have only to think of such familiar living things as a tree, a humming bird and a whale. Individual masses of living matter are *organisms*.

Organisms are composed of *organs*. The organs of the tree are *roots, stems* and *leaves*, each of which performs certain *functions*. The root fixes the plant and absorbs water containing inorganic and organic food material. The stem conducts the liquid upward to the leaves. The leaves manufacture living substance and provide food for the plant.

Organs are made up of various parts called *tissues*. The leaf has an outer, lifeless, protective covering or tissue beneath which are the tissues that manufacture food. Other tissues conduct the manufactured food to the stem. Tissues are composed of *cells* having a similar function. In the light of our present knowledge the cell is the ultimate unit of structure of living organisms.

The history of the term cell is a curious one and affords a good illustration of the manner in which our scientific conceptions gradually become modified and improved as our knowledge increases. The term cell was unknown before the invention of the compound microscope. *Robert Hooke* observed for the first time the cellular structure of plants, of which he published his account in 1665. He examined a thin piece of bottle cork and named the little openings separated by firm walls, cells. Robert Hooke's idea that a cell consisted of a small cavity filled with air and surrounded by a wall persisted until 1846, when *von Mohl* gave the name *protoplasm* to the slimy contents discovered by him in the cells of living tissue. In time it became evident that this protoplasm was the vital constituent of the cell and that it was identical with minute organisms without cell walls, such as the amœba. The term cell is therefore applied at the present time to masses of protoplasm with or without a wall.

Protoplasm, the living part of the cell, possesses several functions, chief among which are the following:

1. Irritability.
2. Growth.
3. Reproduction.

1. That living protoplasm is *irritable* is shown by its reaction to varying external conditions, such as changes in temperature and in intensity of light.

2. The power to *grow* or increase in size is possessed by all

living things, but for each organism there seems to be a limit to growth.

3. *Reproduction* is one of the striking functions of living things. It is seen in its simplest form in unicellular plants and animals. They reproduce by dividing into two equal parts, each part being exactly like the original. The higher the organism the more complex is its method of reproduction.

Unicellular organisms perform all the functions that in the higher multicellular organisms are performed by different tissues.

What differentiates a plant from an animal? If we consider the more highly organized members of the animal and vegetable kingdoms we can see many obvious distinctions which may disappear in the lower orders.

Plants.	Animals.
1. Plants have *chlorophyll* or green coloring matter which enables them to obtain energy directly from the sun's rays by photosynthesis.	1. Animals have no *chlorophyll;* therefore they cannot manufacture needed food.
2. The higher plants are *fixed* and *stationary*; they do not need to move about since they obtain their food from the air and soil and therefore they have no muscular or nervous system.	2. Animals have a *muscular and a nervous* system which, by means of special organs of locomotion, enables them to move from place to place in order to secure fresh supplies of food.
3. Plants live largely upon *inorganic material* which they build into protoplasm.	3. Animals are *dependent directly or indirectly upon plants* for their food supply.
4. Plants utilize the *carbon dioxide* (CO_2) of the air as a food and give off oxygen as a by-product of photosynthesis.	4. Animals cannot utilize carbon dioxide (CO_2) as a food.
5. Plants have a cell *wall of cellulose* or modified cellulose.	5. Animals have a *nitrogenous cell wall*.
6. Plant food is absorbed in a *liquid or gaseous* state.	6. Animal food is taken in the *solid form*, and is derived from the bodies of other organisms.

Many of these distinctions disappear as we descend lower in the scale of organisms. Many plants move about actively, while many animals, like the sponge, are stationary in the adult condition. *Fungi*, although plants, have no *chlorophyll.*

Every distinction between the lower plants and animals may disappear except that of the presence or absence of *chlorophyll* and the modes of nutrition. Animals take food in the solid form while plants take food in the liquid and gaseous form. All plants and animals have been derived from a unicellular ancestor. The presence of *chlorophyll* enables plants to manufacture food without moving from place to place; therefore, they do not need a muscular and a nervous system. Animals have no *chlorophyll*; they have developed, therefore, a muscular and a nervous system in order that they may move from place to place to secure food.

When we study plants and animals we are studying biology.

Biology including Zoölogy and Botany is the science of living things.

The word *botany* is derived from a Greek word for "herbage," from "bosco" meaning "to graze." Botany is the science of plants.

At the present time botany has many subdivisions, of which the most important are the following:

Plant Taxonomy or Systematic Botany is the study of plants for the purpose of determining their relationship.

Plant Morphology is the study of the structure and form of plants.

Plant Physiology is the study of the functions of the different organs of the plant.

Plant Geography or *Geographical Botany* is the study of the distribution of plants over the earth's surface.

Plant Ecology is the study of the relation of plants to the conditions under which they grow.

Paleobotany or *Fossil Botany* is the study of the remains of plants that are found in rocks formed during past ages.

Cytology is the study of the minute structure of plant cells.

The Plant Groups.

Plants are classified in several great groups:

1. *Thallophytes* which are divided into *Algæ* and *Fungi.*
2. *Bryophytes* which are divided into *Liverworts* and *Mosses.*
3. *Pteridophytes* which are divided into *Ferns, Horsetails* and *Club Mosses.*
4. *Gymnosperms.*
5. *Angiosperms* which are divided into *Monocotyledons* and *Dicotyledons.*

CHAPTER I.

ALGÆ

PROTOCOCCUS[1]

Habitat and Morphology.—Protococcus is a unicellular green plant found growing on tree trunks and various moist objects. It often occurs in such quantities as to impart a bright green color to the trunks of trees.

Histology.—It is so small that its structure is seen only when examined under the microscope. In its normal condition it is a spherical cell, appearing bright green, except for an outer layer or cell wall, which consists of cellulose. A nucleus is present, but it is not visible unless decolorized and stained. Protococcus usually occurs in the non-motile state but under certain conditions the cells become motile and swim freely about by means of two cilia.

Reproduction.—The only known method of reproduction is asexual, by simple fission or division. Frequently the two daughter cells resulting from a division of a mother cell do not separate at once but the daughter cells divide in another plane while still unseparated. Frequently also, divisions occur in a third plane, so as to build up a cubical mass of cells which finally divides into separate plants. This method of division indicates the way by which the higher plants were formed from unicellular ancestors.

[1] *Protococcus viridis Ug.* = *Pleurococcus Naegelii* chodat = *Pleurococcus vulgaris* of modern writers, not of Meneghini.

Physiology.—The nutrition of protococcus is similar to that of the chlorophyll-bearing cells of all plants. The green coloring matter manufactures various organic substances from carbon dioxide (CO_2) and water, starch being

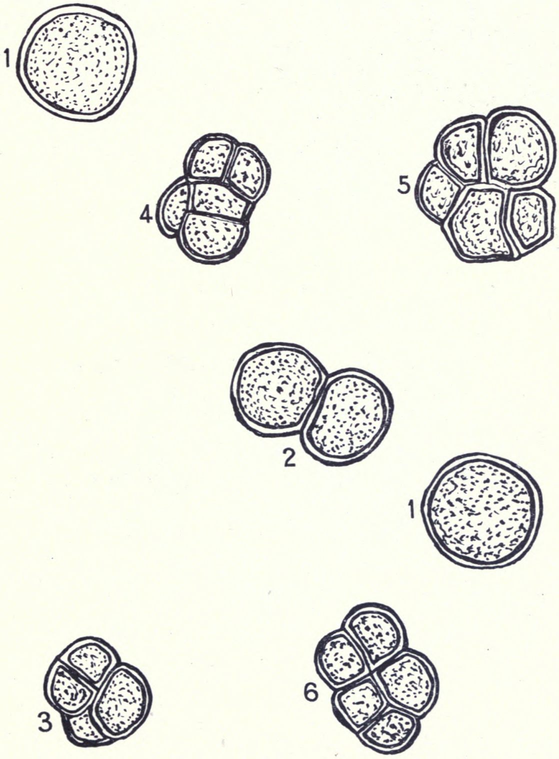

Fig. 1.—*Protococcus.* 1, mature plants; 2, cell divided; 3, 4, 5, 6, cells which after dividing adhere to form colonies of cells.

produced most frequently. The assimilation of starch, its breaking up and recombination with other elements such as nitrogen, sulphur, and phosphorus to form protoplasm, is accomplished by the living protoplasmic substance.

Respiration.—Respiration or oxidation occurs as in all living things. The exchange of gases between the organisms and the surrounding medium is brought about by the difference in gas pressure. Since there is more carbon dioxide within the organisms than without, therefore, the flow of carbon dioxide is outward. In like manner, since there is less oxygen within the cell than without, the flow of oxygen is inward.

FIG. 2.—*Nostoc.* Numerous spherical and oblong masses or colonies composed of thousands of filaments.

Conclusion.—Protococcus is irritable. Its wall consists of cellulose, it has chlorophyll, it requires liquid or gaseous food; therefore, it is a plant.

NOSTOC

Habitat.—Nostoc is found growing in sluggish water and on moist earth that is rich in decaying organic matter.

Morphology.—The filaments or chains of cells composing nostoc frequently form aggregations as large as marbles. These masses, which contain hundreds of plants, are greenish-

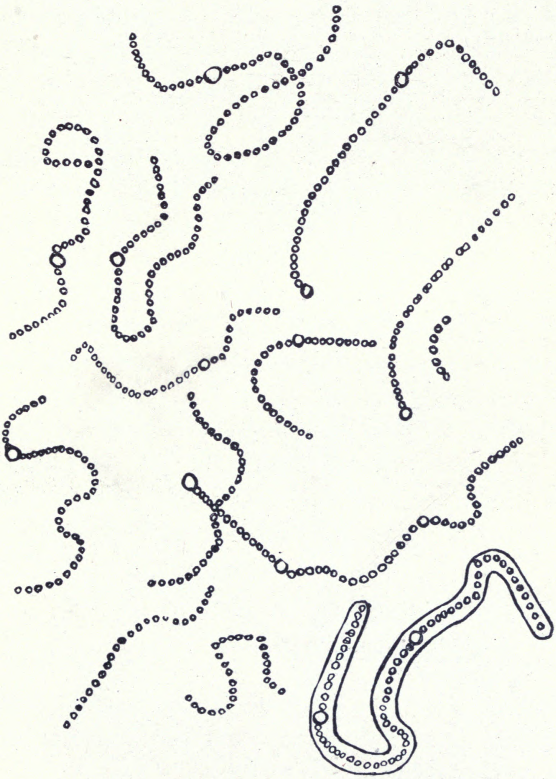

FIG. 3.—*Nostoc.* Numerous filaments. Lower right drawing is a filament surrounded by a gelatinous layer.

blue and, if placed between the thumb and finger are decidedly elastic, particularly when they are left out of water for a few minutes or when they occur on moist soil. If the mass is crushed in the fingers, it is mucilaginous.

Histology.—The individual plants are composed of two types of cells arranged in a filament or chain covered with mucilage. This enables them to withstand drought and to live on land. Most of the cells forming the chain are nearly circular, the wall is colorless and the protoplasm does not appear to be differentiated into plastids and nuclei. The blue-green color is due to *phycocyanin,* a bluish pigment, and to chlorophyll. Among these cells occur at regular intervals *heterocysts,* which are colorless cells without protoplasm.

Reproduction.—Nostoc reproduces asexually, first by simple fission or the equal division of its cells to form two cells; secondly by fragmentation or the breaking up of the filaments into sections, the section in each case being the part of the filament between the heterocysts. The sections finally work their way out of the mass of jelly and by repeated cell division start a new colony.

Conclusion.—Nostoc consists of a colony of one-celled plants, each independent of the other but arranged in the form of a filament or chain. The mucilage secreted by the wall enables the plant to form colonies. Reproduction is asexual by simple fission and fragmentation.

BLADDER WRACK (*Fucus Vesiculosus*)

Habitat.—Fucus is a seaweed found in great quantities along rocky shores, where at low tide thousands of plants may be seen growing on the rocks.

Morphology.—The plant body or *thallus* is firmly attached to a rock by a flat disk-like part called a *holdfast.* Above the holdfast the thallus is cylindric. Next to this cylindric part is the flat leaf-like part of the thallus with a thicker central region. At frequent intervals the thallus is enlarged to form air cavities or vesicles which are filled with mucilage and gases and which function as floats to keep the plant vertical at high tide and horizontal during the rise and fall of the tide.

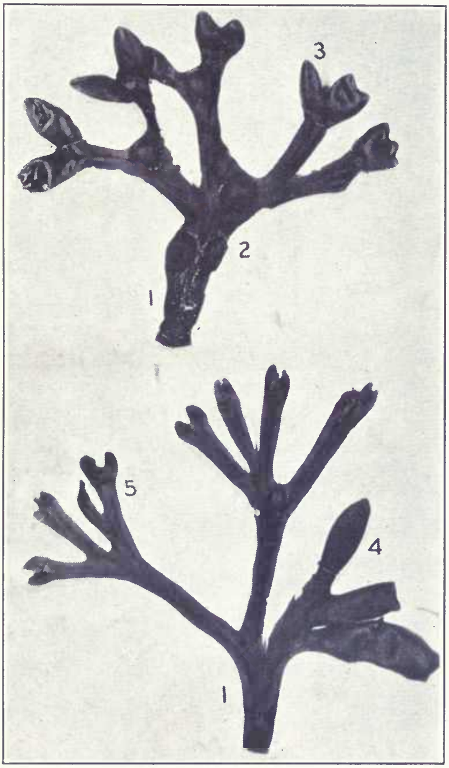

FIG. 4.—Brown alga. Above 1, ribbon like thallus; 2, paired air vesicles; 3, antheridia bearing conceptacles; below 1, thallus; 4, mature oögonia bearing conceptacles; 5, immature female conceptacles.

The ends of the thallus are forked or dichotomously branched owing to the fact that sooner or later the end of each branch develops two growing points. During reproduction the forked tips are swollen and highly mucilaginous because of the presence of the reproductive tissues.

The color of the thallus is greenish-brown because of the presence of a brown pigment and chlorophyll.

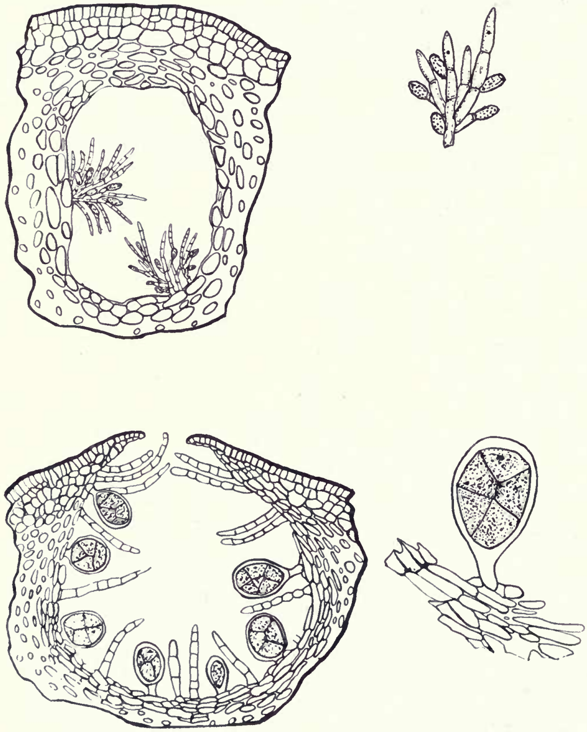

FIG. 5.—*Phæophyceæ. Fucus vesiculosus.* The upper left figure is a cross-section of a male or anteridia-bearing conceptacle, and right, an antheridial hair with five antheridia filled with sperms. Lower left, a female or oögonia-bearing conceptacle with numerous oögonia, each with eight oöspheres, all of which do not show in section.

Histology.—The outer surface of the thallus is composed of a single layer of palisade cells with yellowish-brown contents. Immediately inward from these cells are several layers of cells which are nearly as broad as long and which have brown cell contents. Cells of a third type are branched, have little or no color and are found in the middle of the thallus.

Reproduction.—The reproductive tissues are contained in the swollen ends of certain branches. In these swollen branches numerous somewhat spherical cavities or *conceptacles* extend the epidermis to form blister-like elevations; in the center of each is a small opening extending into the cavity. In *Fucus vesiculosus* the microscopic male and female organs occur on different plants. It is necessary, therefore, to cut sections of the conceptacles in order to study them.

Female Conceptacles.—From the epidermal cells lining the conceptacle grow numerous female reproductive organs or *oögonia.* The contents of each *oögonium* by repeated division divide into eight *oöspheres* or female gametes. These when mature break the wall of the oögonium and are forced through the opening of the conceptacle into the sea water, because the multicellular hairs lining the cavity become converted into mucilage and because the outer cells of the thallus become partially dry and contract during periods of low tide.

Male Conceptacles.—The epidermal cells of the male conceptacle develop into two types of multicellular uniseriate hairs, namely, non-branched mucilage hairs and branched reproductive hairs. The terminal cells of the latter hairs develop into *antheridia.* Each *antheridium* by repeated cell division forms sixty-four biciliate male gametes which are set free in the conceptacle and later forced into the sea water by the conversion of the hairs into mucilage and the partial drying of the plant.

Fertilization.—Fertilization is accomplished when one of the numerous male gametes swims to the female gamete and fuses with it to form the *zygote.* The zygote by repeated division develops at once into a many-celled embryo. This early becomes differentiated into a holdfast and a growing region which develops into a typical thallus.

Summary of Algæ.

GREEN ALGÆ

Plant.—The plant of the simplest green alga consist of a *single cell* as Protococcus, in others of a filament or *chain of cells* as Spirogyra, in others of *masses* of *cells* assuming the thalloid form as Choleochete.

Reproduction.—In Protococcus reproduction is asexual since two plants are formed from one by *cell division.* Sexuality is shown in sphærella; the ciliated or motile zoöspores *unite* or *conjugate* to form a spore which produces a new plant. In Ulothrix the spores are of different sizes and in all cases a small spore unites with a large spore to form the spore which develops the plant. In Spirogyra the contents of a small cell passes into a large cell uniting with it to form a *zygospore* or *resting spore* which after a time develops a new plant. In Volvox the zygospore divides after resting into four spores, each forming a filament. Differentiation of plant structure and division of labor is shown in the Chætophorales by the formation of a hold fast which serves to fix the plant. In Vaucheria there are no cross-walls, the tubular plant being multinucleated (*cœnocyte*), except during the reproductive period; then cross-walls cut off the antheridia or special male organ of reproduction. An antheridium contains numerous sperms, and a hollow receptacle or archegonium contains a solitary female gamete. One male gamete fuses with the *stationary* female gamete in the archegonium to form a zygospore which is parasitic on the parent plant for a time.

BLUE-GREEN ALGÆ

Glœocapsa is a unicellular blue-green alga, which sometimes forms groups of cells; in all cases the cells and groups are surrounded by a gelatinous layer.

Nostoc is a filamentous blue-green alga which often forms large spherical colonies. The filaments are made up of vegetative cells which are separated by slightly larger colorless cells or heterocysts. The breaking up of the filaments occurs at the points of union of the heterocysts and vegetative cells.

BROWN ALGÆ

Plant Body.—The plant body of fucus is a *dichotomously branched* or *forked* thallus, the cells contain *chlorophyll* but the green color does not appear because of the brown of *phycophœin,* a brown color. In fucus the male reproductive organs occur on one thallus and the female on another, so that fucus is diœcious.

Male Thallus.—The point of the thallus in contact with the rock is the *hold-fast,* above the hold-fast is the rounded stem-like part of thallus, this united to the broad leaf-like part which has large *air cavities,* or *vesicles* which act as floats, and during the reproductive period the swollen ends contain numerous *conceptacles* with the antheridial hairs; these have numerous antheridia with sperms which are set free in the conceptacle and later swim out into the water by means of two cilia.

Female Thallus.—The structure of the female thallus is similar to that of the male thallus with the exception that the conceptacles contain numerous oögonia or female reproductive organs which have eight non-ciliated and non-motile oöspheres or female cells. The oöspheres are forced from the conceptacle into the sea water where *fertilization takes place outside of the plant.* The zygotes develop by repeated cell division into a male and a female thallus.

In some species of brown alga the thallus is monœcious bearing conceptacles with antheridia and others with oogonia. The *laminarias* or species of brown algæ grow to a great length. In all forms the vegetative plant is highly developed.

RED ALGÆ

The thallus of the red algæ while large in some species is usually much smaller than the typical brown algæ and is more finely dissected. Some forms have almost hair-like divisions. The thallus contains chlorophyll but its green color is masked by the red pigment or *Phycœrythrin* which is present. Red algæ occur in deep water, the phycœrythrin is supposed to assist the assimilation process. Many of the red algæ are characterized by being soluble in fresh water. Irish moss, a well known drug, is completely soluble in 30 parts of water. It is edible and nutritious as are other forms of red algæ. Reproduction is rather complicated in the forms in which it has been worked out. In a typical case the antheridia are unicellular and are borne at the ends of short branches. Each antheridium develops a single binucleated non-motile sperm. The female sex organ or *procarp* consists of a *carpogonium* and *trichogyne* associated, in some forms, with other cells. The carpogonium contains the egg cell and there is no cell wall separating it from the hair-like *trichogyne.* Fertilization is accomplished when a sperm cell, carried by water currents, becomes attached to the trychogyne. The wall of the sperm and trichogyne dissolve and the two male nuclei pass down the trychogyne

FIG. 6.—*Red algæ.* Irish moss (*Chondrus crispus*) 1, stemlike portion of the thallus; 2, branch of the thallus; 3, bifurcating or forked tips of the thallus.

and one only fuses with the egg cell of the carpogonium. The carpogonium develops, after fertilization, into numerous filaments, each of which bears a *carpospore.* The collection of spores and other structures is the *cystocarp.* The carpophores develop into new plants.

CHAPTER II.

FUNGI

BACTERIA

Habitat.—Bacteria occur in the air, the soil, fresh and salt water, hot springs and the icy waters of the arctic regions; they are found upon lifeless animal and vegetable substances. In fact, bacteria seem to be everywhere.

FIG. 7.—Varieties of spherical forms: *a*, tendency to lancet-shape; *b*, tendency to coffee-bean shape; *c*, in packets; *d*, in tetrads; *e*, in chains; *f*, in irregular masses. × 1000 diameters. (After Flügge.)

Morphology.—Colonies of bacteria are extremely variable in form and color. Each class of bacteria forms characteristic colonies.

Histology.—Bacteria are the simplest, smallest plants known. They are unicellular and vary in size from $\frac{1}{50000}$ to $\frac{1}{10000}$ of an inch. In a few of the forms the outer wall is composed of cellulose. In most of the others the wall is nitrogenous and it is covered by a layer of mucilage which makes it possible for bacteria to form chains and colonies. In both forms the wall encloses a slightly granular, trans-

FIG. 8.—Long slender bacilli. × 1000 diameters. (After Park.)

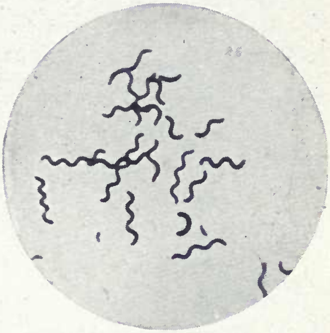

FIG. 9.—Very large spirilla. (After Park.)

parent protoplasm containing one or more non-contractile vacuoles and one or more rounded grains that react to nuclear

FIG. 10

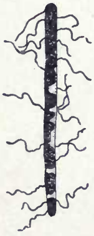

FIG. 11

FIG. 12

FIGS. 10, 11 and 12.—Fig. 10, Spirillum undula; Fig. 11, Bacillus solmsii; Fig. 12, Vibrio choleræ. The flagella are well shown. (After A. Fischer.)

stains. These grains probably represent an elemental nucleus. In some forms hair-like outgrowths from the wall (cilia) occur; they make locomotion possible.

Bacteria in the form of rounded bodies are called *Cocci* (singular, *Coccus*). Those in the form of rods are known as *Bacilli* (singular, *Bacillus*). Those having the form of a curved rod are classed as *Spirilla* (singular, *Spirillum*).

Physiology.—Physiologically bacteria are divided into the following classes:

I. Holophytic.
II. Saprophytic.
III. Parasitic.

I. *Holophytic bacteria* can manufacture organic compounds from carbon dioxide and water in a manner similar to that of chlorophyll-bearing plants. This peculiar function is possessed by many nitrogen bacteria.

II. *Saprophytic bacteria,* derive their food from dead organic matter. The chief classes of saprophytic bacteria are the following:

1. Nitrifying bacteria.
2. Denitrifying bacteria.
3. Fermentative bacteria.
4. Cheese bacteria.
5. Putrefactive bacteria.

1. *Nitrifying Bacteria.*—One group of bacteria occurring in the soil absorbs atmospheric nitrogen and combines it with the chemical elements in solution in the soil water to make nitrates, which is the form of nitrogen suitable for plant food.

2. *Denitrifying Bacteria.*—The reduction of protoplasm to nitrates, of nitrates to nitrites, of nitrites to nitrogen gas is accomplished by several different groups of denitrifying bacteria. These bacteria complete the nitrogen cycle by returning nitrogen to the air from which it was taken by the nitrifying bacteria.

3. *Fermentative Bacteria.*—Among the important fermentative bacteria are:

(*a*) Acetic (vinegar).
(*b*) Lactic (milk).
(*c*) Butyric (butter).

(*a*) *Acetic Bacteria.*—The so-called "mother" of vinegar is composed of thousands of these bacteria. They convert the alcohol (C_2H_5OH) into acetic acid ($CH_3CO.OH$) as follows:

$$C_2H_5OH + O_2 + \text{acetic bacteria} = CH_3CO.OH + H_2O.$$

The reaction is an oxidation process.

(*b*) *Lactic Bacteria* occur in milk. They turn milk sour by changing lactose or milk sugar ($C_{12}H_{22}O_{11}$) into lactic acid $(C_3H_6O)_3$ as follows:

$$C_{12}H_{22}O_{11} + H_2O + \text{lactic bacteria} = 4C_3H_6O_3.$$

This lactated milk forms an important part of the diet of some nations. In the United States it is used as a beverage, the acid or tart taste of the milk being due to the lactic acid.

(*c*) *Butyric Bacteria* occur in butter. Butyric bacteria break up the lactic acid formed in the lactic fermentation as follows:

$$2C_3H_6O_3 + \text{butyric bacteria} = C_3H_7CO.OH + 2CO_2 + 2H_2.$$

4. *Cheese Bacteria.*—Several of the most important saprophytic bacteria are used in the manufacture of cheese. These bacteria live upon the solid constituents of milk, forming colored products of excretion and odorous compounds which give the color, flavor and odor to cheese. There are as many types of cheese bacteria as there are varieties of cheese. The most important of these are American, Swiss, Roquefort, Limburger, Gorgonzola, Brie, Stilton, Camembert, Chedder and Edam cheese.

5. *Putrefactive Bacteria.*—Putrefactive bacteria break up the complex nitrogeneous and other compounds, occurring in lifeless material of both plants and animals, into nauseating gases and simple compounds which are utilized by plants as food. If it were not for these bacteria the earth would be an immense graveyard piled mountains high with dead plants and animals.

Nitrifying, denitrifying and putrefactive bacteria make it possible, therefore, for present generations to live upon the food furnished by past generations. In like manner present generations of plants and animals will furnish food for future generations.

III. *Parasitic Bacteria,* derive their food from living organisms. There are two classes of parasitic bacteria:

1. Plant parasites, or those living on plants.
2. Animal parasites, or those living on animals.

1. *Plant Parasites.*—(*a*) *Useful Parasites.*—The parasitic nitrogen-fixing bacteria (*Pseudomonas radicicola*), appear as swellings or *nodules* on the roots of beans, peas, clovers and other leguminous plants and form nitrates from atmospheric nitrogen and the inorganic salts of cell sap. It is now a common practice for farmers to mix cultures of nitrogen-fixing bacteria with leguminous seeds in order to insure the formation of nodules and large crops. After the soil has been inoculated it is not necessary to mix bacteria with seed before planting. The association of the nitrogen-fixing bacteria with leguminous plants is mutually helpful and is known as *symbiosis.*

(*b*) *Harmful Parasites.*—Disease-producing bacteria derive their food from their host. They are all harmful and frequently fatal to the plants upon which they live. Some of the destructive plant diseases caused by bacteria are black rot of cabbage, wilt of sweet corn, and wilt or blight of the bean.

2. *Animal Parasites.— Useful Parasites.*—Many of the animal parasites like lactic bacillus of the intestinal tract are not only harmless but decidedly beneficial.

Disease Forming (Pathogenic) Bacteria.—The harmful animal parasites are termed *pathogenic bacteria.* These include the bacteria which cause typhus fever, diphtheria, lockjaw, catarrh and cholera. Pathogenic bacteria cause disease and death by the secretion of *toxins*, which are highly poisonous substances manufactured by the protoplasm. The symptoms of the disease result from the action of the toxins when absorbed into the system. When the toxin enters the blood stream, there is formed in the blood an *antitoxin* or substance which counteracts the effect of the toxin. If sufficient antitoxin is produced to counteract the toxin completely, the patient may recover.

A person that has recovered from a bacterial disease is no longer as susceptible to the action of the bacteria causing the disease because the antitoxin becomes a permanent constituent of the blood. This lack of susceptibility is called *immunity.*

Frequently bacteria gain entrance to the system and, unless destroyed, would multiply very rapidly in the tissues and blood stream. Their presence attracts the *phagocytes* or white blood cells, which immediately surround the bacteria and digest them, or, if insoluble the bacteria are conducted to and secreted by the lymphatic tissue. Some bacteria cause the formation of bactericidal substances in the blood. These substances destroy the bacteria, usually by dissolving them.

Reproduction.—Bacteria grow and reproduce very rapidly because food absorption takes place through all parts of their surface, which is very great in proportion to their size. As soon as they reach their maximum size they must either remain inactive or reproduction must occur.

Simple Fission.—The usual method of reproduction is by simple fission. This is so rapid under favorable conditions that the bacteria often form groups or chains. One bacterium can produce eighteen million bacteria in twelve hours by this method.

Spore Formation.—Under favorable conditions the protoplasm draws away from the cell wall and rounds off, developing a *spore* with a thick wall inside the wall of the mother cell. In this state spores can be dried out, blown about, heated to a high temperature, or subjected to the action of chemicals, and still, when placed under favorable conditions, they will develop into bacteria.

Object of Cooking Food.—Food is cooked in order to break the cell walls and to free the cell contents so that they can be acted upon by the digestive ferments. Another reason for cooking food is to destroy the bacteria found in it. No uncooked food should ever be eaten in countries like China and India where the plague is common; in fact, it is always safer to eat cooked food.

Pasteurization of Milk.—Milk contains all the food necessary for the growth of bacteria and it is used as a culture medium for growing bacteria artificially. Milk is contaminated by bacteria from the body of the cow, from the hands and clothing of the milker and from the air. Frequently tubercle bacilli occur in the milk of tubercular cows.

Bacilli of typhoid fever frequently occur in milk because pails and cans have been washed in polluted water. That milk is also a carrier of diphtheria has been proven by the fact that milk bottles returned unsterilized to the milkman have been the cause of spreading this disease.

If milk is boiled for a few minutes all the bacteria are killed; the public, however, will not use boiled milk; therefore, milk is pasteurized by heating at a temperature of 86° to

91° C. At this temperature the "boiled" taste is not developed and the bacteria are killed, although the spores are not. Pasteurized milk, if properly refrigerated, will keep much longer than ordinary milk, because no bacteria are present and the spores cannot develop in iced milk.

Refrigeration.—Refrigeration or cooling does not destroy bacteria or spores but since a low temperature is not favorable to their growth it is possible by this method to keep meat, fruits and vegetables for long periods.

Sterilization.—Food, clothing, medicines, surgical instruments and apparatus are sterilized when all bacteria and their spores have been killed.

Heat Sterilization.—Surgical instruments and dressings, apparatus, all glass containers and stoppers are readily sterilized by heating in a hot air oven at a temperature of 160° to 170° C., or by heating in a steam bath for one-half hour at a temperature of 115° to 120° C., or by boiling in water for fifteen minutes.

YEAST (*Saccharomyces Cerevisiæ*)

Habitat.—The common yeast plant (*Saccharomyces Cerevisiæ*) is found in the wild or natural state growing in the juices of such ripe fruits as apples, pears and grapes. Cultivated yeast plants have been grown and used for years in bakeries, breweries and distilleries. In the last few years yeast has been cultivated and put on the market in a solid form or yeast cake consisting of the yeast plants mixed with starch and other nutritive substances.

Histology.—Yeast is a microscopic, unicellular plant. It varies greatly in size, according to its age. The cellulose cell wall is very thin and encloses the protoplasm and nucleus, and one or more non-contractile vacuoles. When the yeast plant does not obtain sufficient food, the vacuoles are more numerous and the protoplasm undergoes fatty degeneration,

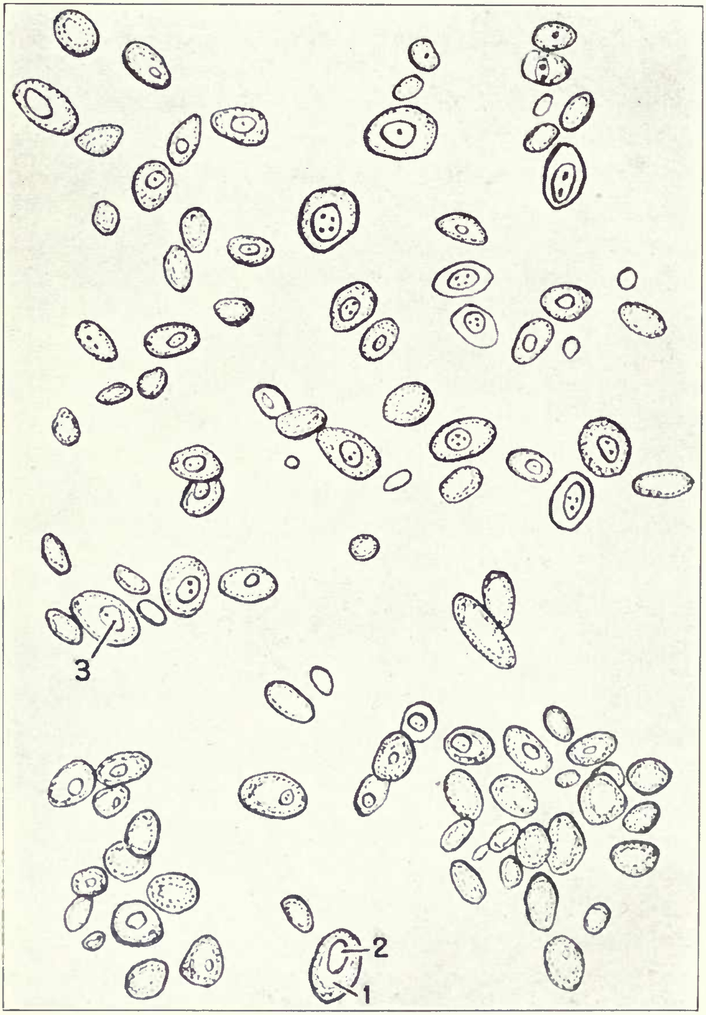

FIG. 13.—*Fungi.* Yeast (*Saccharomyces cerevisiæ*). 1, Granular protoplasm; 2, vacuole; 3, globules of fat.

resulting in the formation of globules of fat, which accumulate in the vacuoles.

Physiology.—The yeast plant contains no chlorophyll; therefore, it cannot manufacture its own food. Its food is the substance found in fruit juices, sprouted seeds, bread dough, etc. It obtains carbon dioxide and oxygen from sugar, nitrogen and phosphorus from the soluble proteids or from the soluble salts present in the solution. It cannot take nitrogen from a compound as simple as a nitrate. It can, however, extract the nitrogen from an ammonium tartrate solution.

Yeast grows best in a solution of malt. When barley is sprouted, it forms malt, which contains *diastase,* a substance converting the starch of the fruits into dextrose or grape sugar. At the same time a ferment is formed that converts the proteids of the grain into peptones. Malt when ground and added to water forms a solution of soluble proteids, carbohydrates and various inorganic salts and is known as *wort.* In wort the yeast plant grows and multiplies very rapidly when a temperature of 20° to 30° C. is maintained. Under these conditions the yeast plant produces a ferment called *zymase,* which converts the dextrose into alcohol and carbon dioxide as follows:

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_5OH + 2CO_2$$

The above process, which is known as *fermentation,* is not confined to the yeast cell. In fact, every living cell contains one or more ferments which make it possible for it to break up and recombine food to form protoplasm and to decompose food, thus liberating heat and energy for carrying on the life process.

The same action takes place in bread making, the escaping CO_2 producing the so-called rising of the bread, and the alcohol being evaporated in the process of baking. In wine making, the alcohol produced may reach 15 per cent, if enough sugar is present. Further production of alcohol is then stopped, as an alcoholic solution above this strength acts as an *antiferment*, and prevents the action of the yeast.

The waste products of the respiration of the yeast plant are nitrogen and carbon dioxide. These are removed from the cell by diffusion. The breaking up of its protoplasm under unfavorable conditions results in the formation of fat. As a result of the physiologic processes of this minute plant, there have been established several gigantic industries, which furnish a large part of the food and drink of man.

Reproduction.—Under favorable conditions, such as sufficient food, moisture and the right temperature, the yeast plant reproduces asexually by "budding." Under these conditions the protoplasm, which is increasing in amount, extends the wall at one point in the form of a minute elevation. The bud increases to a certain size, when the nucleus of the mother cell divides, one-half passing into the bud. A wall then forms across the constricted portion of the bud, separating it from the parent plant.

A second method of reproduction occurs when the yeast plant cannot obtain sufficient food. Under these conditions its extermination is prevented by the division of the protoplasm into from two to four parts, around each of which a thick wall is developed. These are the spores (very simple ascospores), which can resist high temperatures and remain dormant until such time as the conditions are again favorable for their growth. Then each spore may develop into a yeast plant of the normal form.

BLACK MOLD (*Rhizopus Nigricans*)

Habitat.—Black mold is one of the most common fungi. It is found growing on any decaying organic matter that has

FIG. 14. — *Fungi.* Bread mold (*Rhizopus nigricans*). In the upper figure the mycelium completely covers the bread. In the lower figure the sporangia have matured and are filled with black spores as shown in the black portions of the plate.

been exposed to the air. It is readily obtained by exposing moist bread to the atmosphere, and covering it with a dish in order to keep it moist. Under these conditions rhizopus will develop within a few days.

Morphology.—That plant body consists of slender, thread-like, colorless, branching filaments called the *mycelium*.

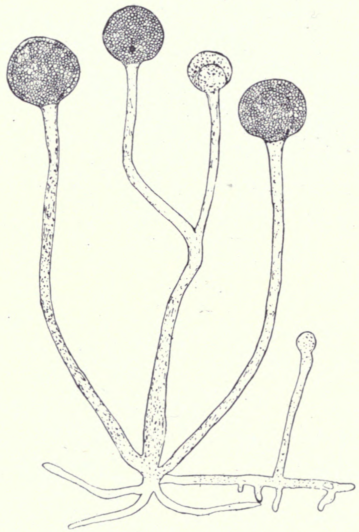

FIG. 15.—*Fungi.* Bread mold (*Rhizopus nigricans*) showing young plant at the left and a stolon with young subterranean hyphæ and an aërial hypha.

Each branch of the mycelium is called a *hypha* (plural *hyphæ*). The hyphæ which grow into the bread or other media are called the *subterranean hyphæ.* They function as holdfast organs and as organs of absorption. Other branches grow up into the air and are called *aërial hyphæ.* At this stage of development the hyphæ are not divided by cross-walls but the entire mycelium is a greatly branched one-celled plant with numerous nuclei. Rhizopus and other multinucleated plants are called *Coenocytes*.

Asexual Reproduction.—At first the aërial hyphæ are similar to the other hyphæ but in a short time the apical portion

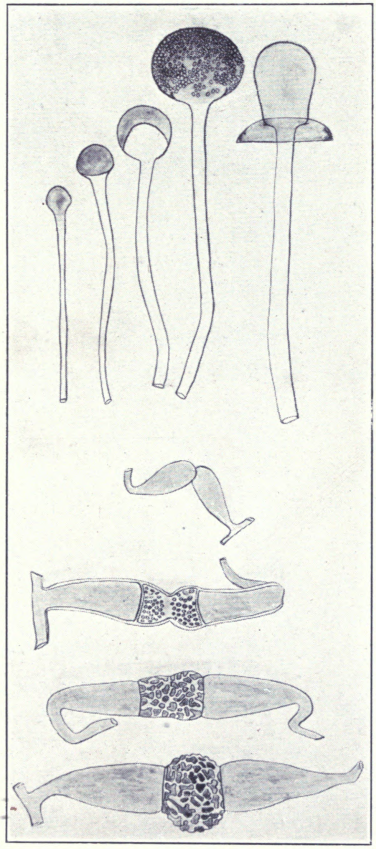

FIG. 16.—*Fungi*. Bread mold (*Rhizopus nigricans*). The four upper figures show the development of the sporangia. The fifth upper figure shows the spores removed from the columella and the sporangial wall curved downward. The lower figures show hyphæ conjugating to form the large rough-walled zygospore.

enlarges to form the globular *sporangium*. As the sporangium continues to enlarge, protoplasm and numerous nuclei flow into and fill it. Finally this enlarged portion becomes

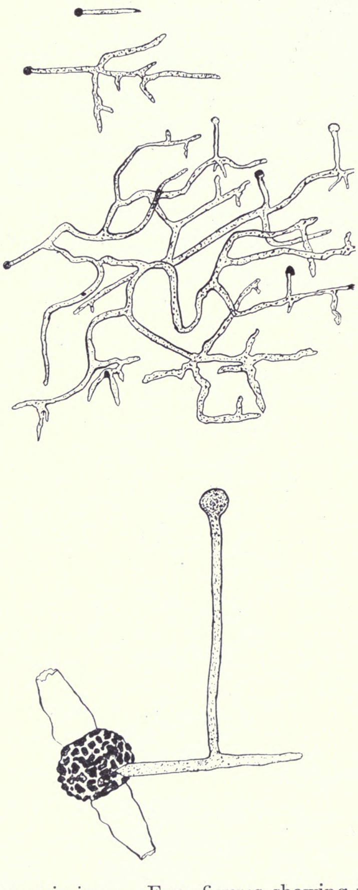

FIG. 17.—*Rhizopus nigricans*. Four figures showing the asexual germinating spore and the mycelium with aërial and subterranean hyphæ developing from the spare. The lower figure shows the sexual spore or zygospore germinating and growing at once into an aërial hypha.

separated by a thin wall or *columella,* which arches upward, thus forcing the nuclei and protoplasm to the outer part of the sporangium. At this time the central part of the sporangium and the hyphæ do not contain any nuclei. The nuclei in the sporangium separate into groups of six or more. Finally each nucleus becomes surrounded with protoplasm and a thin cellulose wall to form a *spore.* When the spores are all formed, the outer wall of the sporangium breaks open and the innumerable spores float away on the air currents. Each spore under favorable conditions develops into a black mold.

Vegetative Reproduction.—Frequently an aërial hypha will grow down into the substrata, branch into numerous subterranean and aërial hyphæ and develop a typical plant, which may reproduce in the same way.

Sexual Reproduction (by Conjugation).—It has only recently been discovered that there are two types of black mold plants; namely, male and female. From each of these plants lateral branches develop which grow toward each other until their tips meet. The tips enlarge and become separated from the hyphæ by a wall. The contents of the two tips fuse to form the *zygospore,* which develops a thick black wall.

Germination of the Zygospore.—The zygospore upon germination develops directly into an aërial hypha which forms a sporangium containing typical spores. Rhizopus does not possess chlorophyll; therefore, it must obtain its food from decaying organic substances. Rhizopus and all similar plants are called *saprophytes.* In canning fruits and vegetables great care must be taken to kill the spores of molds and to keep the cans air-tight; otherwise their contents will become moldy and unfit for use.

LICHENS

Habitat.—Lichens grow on rocks, on tree trunks, and on the ground.

Morphology.—In Cetraria the plant body is thallus-like and greatly branched and it lies flat upon the soil. Other

FIG. 18.—*Lichen.* Iceland moss (*Cetraria icelandica*) showing the thallus with hairs along the margins and the reproductive bodies which are the lighter regions of the terminal branches.

forms are stem-like, branched, and erect, still others are very long, grass-like, and pendulous from trees. It is necessary to section a lichen in order to know its structure and true nature. Sections reveal the fact that a lichen is a composite body made up of a fungus belonging to the ascomycetes and numerous green algæ. This relationship cannot be harmful because these plants occur in great numbers and under conditions which would make it impossible for most plants to grow.

Histology.—Sections show a well defined epidermal cell layer and branched and intertwined hyphæ of the fungus. The cells of the alga are spherical and occur in groups or clusters among the hyphæ.

Sections through an apothecium show the asci. Each ascus has eight ascospores, and is surrounded by several paraphyses or hairs. Each spore may germinate and become associated with alga cells to form a new lichen. Asexual reproduction is brought about by soridia or fragments of the thallus separating and developing into typical plants.

Summary of Fungi.

Fungi as a group are characterized by the absence of chlorophyll, therefore, they are dependent on plants and animals for food. Some forms are *parasitic*, the living plant or *host-plant* furnishing food for their growth and reproduction. Other fungi are *saprophytic*; they live upon dead plants or animals or the products formed by plants and animals. The fungi are further characterized by producing a great number of spores.

The plant body is very variable in structure, size and form. In the *Schizomycetes* or fission-fungi represented by *bacteria* the plant body consists of a single minute cell of variable form.

In the *Phycomycetes* or Algal-fungi represented by *mucor* the plant body consists of multinucleated, branched, intertwined hyphæ, the mass of hyphæ making up the mycelium. Reproduction is *asexual* by means of spores formed in the sporangium and *sexual* by means of conjugating hyphæ, the zygospore differing from the ordinary spore by growing directly into a sporangium-bearing aërial hypha, the ordinary spore developing into a mycelium.

In the *Ascomycetes* the simplest form is yeast, which is unicellular; the nucleus is diffuse and the cells are solitary or they occur in temporary filaments, which result from rapid cell division. Reproduction is largely by budding. Some forms produce a sac or ascus which contains two or more

FIG. 19.—A bracket fungus growing from a dead stump.

spores or ascospores, a fact which has resulted in giving the name *ascomycetes* to the group. In other forms there is a *subterranean mycelium* which absorbs food material. The mycelium gives rise to branched, intertwined, firm, masses of hyphæ which grow into the air, thus elevating the asci which bear the spores.

Basidomycetes, represented by toadstools and mushrooms, have mycelia from which grow an aërial structure differentiated into a stipe or stem, an annulus, and a pileus or cap, from the under side of which are the radiating lamellæ; these extend from the apex of the stipe to the circumference of

Fig. 20.—*Amanita phalloides*: 1, Volva; 2, stipe; 3, veil; 4, gills; 5, pileus.

the pileus, bearing the *basidia* or *club-shaped* bodies which end in points, sterigmata, which bear the basidiospores. The basidiomycetes include the *smuts* represented by corn smut,

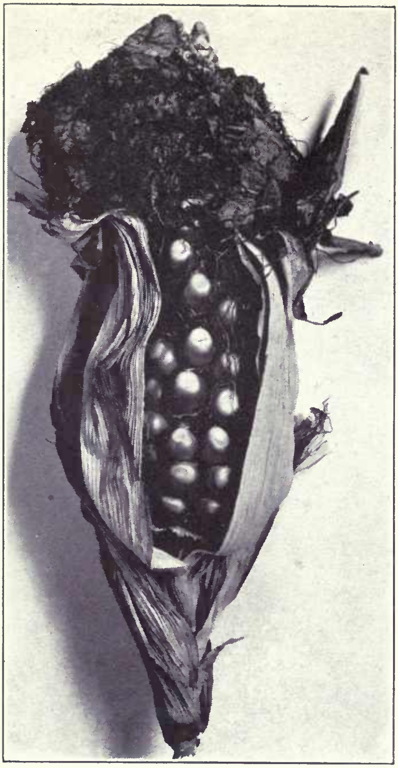

FIG. 21.—*Fungi.* Corn smut (*Ustilago zeæ*) which destroys the grains of corn.

FIG. 22.—*Fungi.* Puffballs (*Lycoperdon gemmatum*) showing the pores through which the spores escape

which destroy corn, and the *rusts*, which have several distinct stages in their life history: (1) the æcial or clustercup stage occurs in early summer on leaves, producing æciospores, which give rise to mycelium bearing urediniospores; the uredinial stage grows often upon a different host-plant and bears the teleospores or resting winter-spores, which have thick walls; the teleosporic stage develops in the following

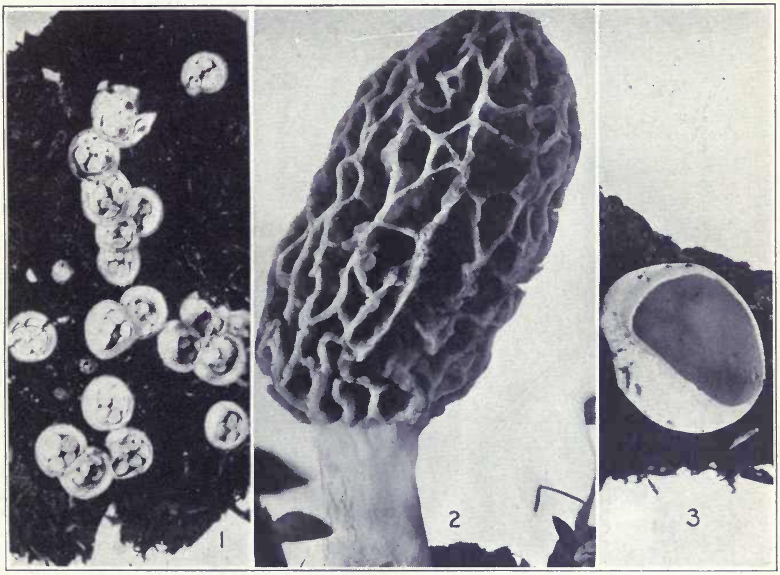

FIG. 23.—*Fungi.* 1, Bird's nest fungus (Cyanthus vomicosus); 2, Morel (Morschella esculenta); 3, cup fungus (Peziza Sp.)

spring, giving rise directly or indirectly to the æcial or clustercup stage previously mentioned. The *puffballs* also belong to the basidiomycetes; the mycelium develops the aërial puffball composed of numerous internal, intertwined, branching hyphæ bearing basidia and basidiospores; the hyphæ form a compact outer layer or peridium which is parchment-like in texture.

CHAPTER III.

LIVERWORTS (HEPATICÆ)

Habitat.—Liverworts, which rank as the next higher group above the Algæ and Fungi, grow in streams and swamps and on dry soil and trees.

Morphology.—The permanent plant body is always of some shade of green because of the presence of chlorophyll. In some, the plant body is a thallus, showing no conspicuous differentiation into stem and leaves, but about nine-tenths of the American species of liverworts have stem and leaves; and some have a plant body that is transitional between a thallus and a leafy stem. In Marchantia, a common thalloid form of greenhouses and of burned places in the woods, the upper surface is divided into diamond-shaped areas, in the center of each of which is a pore communicating with an air-chamber beneath. From the under surface of the thallus grow tubular structures or *rhizoids* and plate-like masses of tissue or *lamellæ*. The rhizoids hold the plant in the soil and act as organs of absorption. The lamellæ are rudimentary leaves.

Reproduction.—In Marchantia and in some of the other hepatics there are two forms of reproduction, (1) asexual and (2) sexual.

1. *Asexual Reproduction* is brought about by Gemmæ or Buds which in Marchantia grow on the upper surface of the thallus in cup-shaped structures called *gemmæ cups.* Each gemma is a slightly constricted oval body attached to a stalk.

When the gemmæ become detached they develop into typical liverworts. If a thallus is broken into several parts, each part will develop into an independent plant.

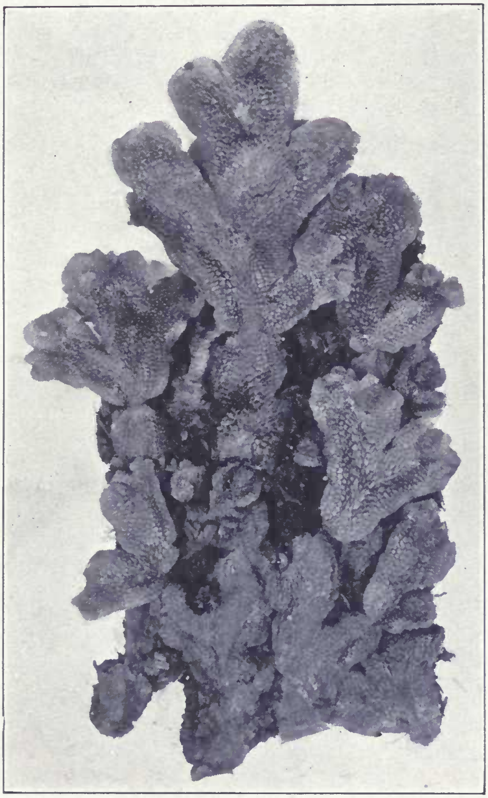

FIG. 24.—*Marchantia thallus*, showing bifurcating tips and diamond-shaped areas of the upper surface.

2. *Sexual Reproduction.*—There are two types of sexual organs, (*a*) *Antheridia* and (*b*) *Archegonia*, which in Marchantia occur on separate individuals.

(*a*) *Antheridia* in Marchantia are borne by special upright branches which develop from the ends of horizontal branches

FIG. 25.—*Marchantia polymorpha.* Male gametophyte. The last figure shows numerous antheridia sunken in the upper surface.

of the thallus. The special branch is umbrella-shaped and in its upper surface grow many *antheridia.* An *antheridium*

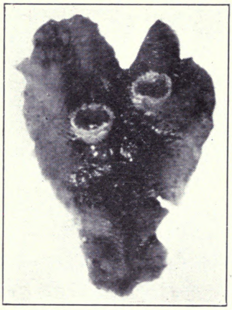

FIG. 26.—*Marchantia thallus* with two gemmæ cups.

is a rounded or oval body attached to a slender stalk. The whole structure is imbedded in the upper surface of the thallus.

The inner cells of the antheridium form *Antherozoids* or male reproductive cells. An antherozoid is a biciliate oblong cell.

(*b*) *Archegonia* in Marchantia develop on differently formed special upright branches which grow out from the ends of horizontal branches of the thallus. The upper part

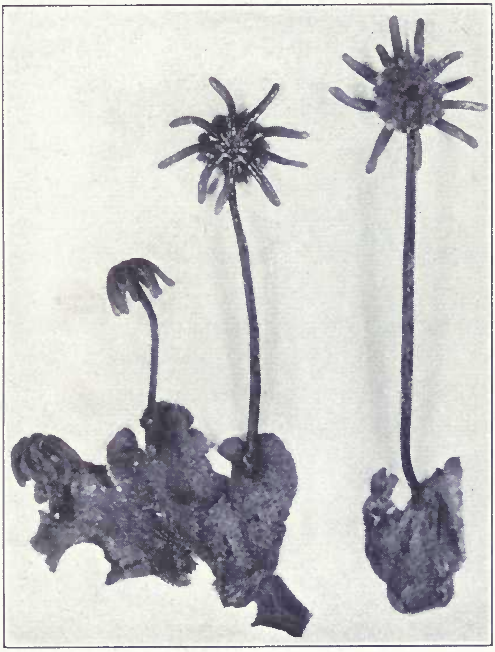

FIG. 27.—*Marchantia polymorpha.* Thalli showing archegonia-bearing branches. The fourth figure shows the under surface of the archegonial branch.

of the special branch has a number of radiating finger-like outgrowths from between which, on the under surface, grow groups of archegonia. An *archegonium* is flask-shaped. It consists essentially of an outer layer of cells enclosing an axial row of cells. The outer layer forms the wall. The egg or female cell is the lowest of the axial row and is in the enlarged part or *venter* of the flask. It is a rounded or oval body. Above the egg cell in the axial row are the *neck cells* which become converted into mucilage when the egg cell is mature.

Fertilization.—An antherozoid enters the neck of the archegonium and swims to and unites with the egg cell. This fused cell is the beginning of the sporophyte or new asexual generation. By repeated division a great number of cells are produced, thus forming the sporophyte. Some of these cells, the spore-mother-cells, form the spores, each producing four. Each spore upon germination may develop into a *gametophyte* or sexual plant.

The liverworts or hepaticæ have two distinct stages in their life history. (1) The gametophyte or sexual generation, which develops the sexual organs, is the more conspicuous or permanent plant. (2) The sporophyte or asexual generation, which produces the spores, is the temporary plant. In all forms the sporophyte is dependent upon the gametophyte for its food and in all forms the sporophyte dies after producing the spores. This alternating of the sexual and asexual generation is known as the *alternation of generations.*

Summary

Alternation of Generations occurs; the *gametophyte* or sexual generation alternates with the *sporophyte* or asexual generation.

Gametophyte.—The gametophyte is the permanent, conspicuous stage of the hepatics or liverworts. The plant body or thallus has a forked or bifurcating method of branching. Rhizoids or absorbing and fixing organs develop from the under or dorsal side. Air-spaces and air-cells or openings occur on the thallus. The sporophyte of anthoceros has true *stomata.* The air-cells and stomata permit the exchange of gases during photosynthesis and respiration. The gametophyte bears the antheridia or male reproductive organs and

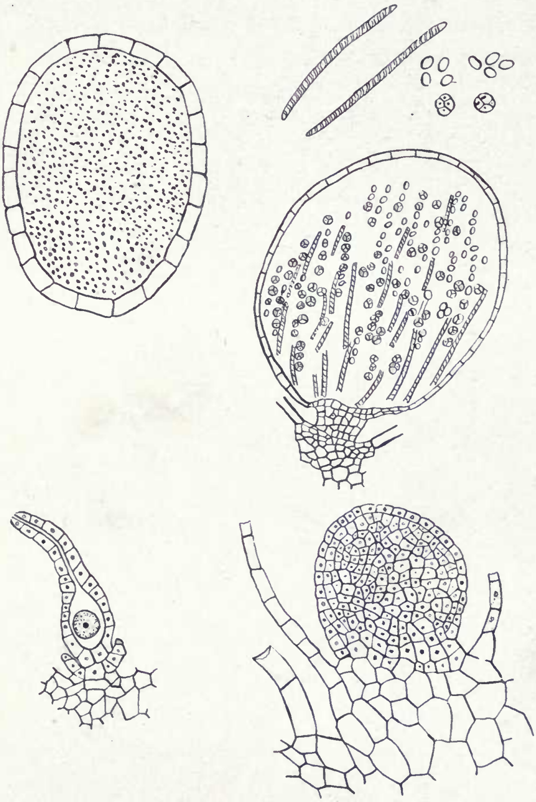

Fig. 28.—*Hepaticæ.* (*Marchantia polymorpha*). The upper left figure is an antheridium filled with sperms. The lower left is an archegonium with a large egg cell. The lower right figure shows a young sporophyte developed as a result of the union of the sperm and the egg cell. The upper right figures show the sporangium with spores in the tetraspore stage and above this separated spores and elaters with spiral bands.

the archegonia or female reproductive tissue. The antheridium is rounded or oval in form, and filled with biciliated sperms which escape when water is present and enter the archegonia. The archegonium is flask-shaped and the female cell is contained in the enlarged part or venter.

Sporophyte.—The sporophyte is inconspicuous in most species. In the lowest forms it consists of a mass of spores and with no sterile tissue, but in the higher forms, as

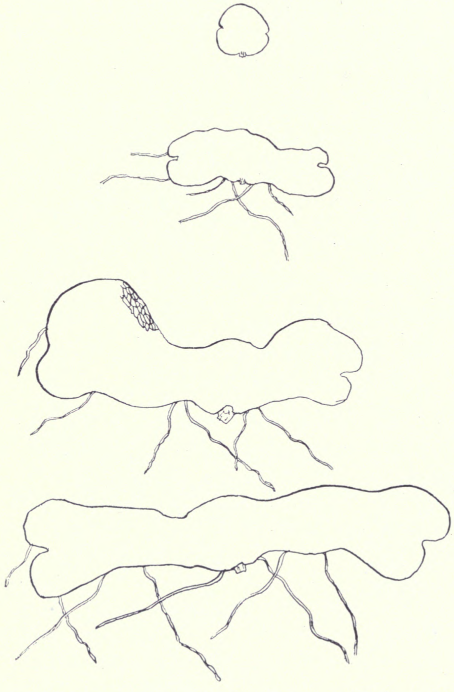

FIG. 29.—*Hepaticæ.* Gemma developing into a thallus by lateral growth in two directions.

Marchantia, the sporophyte has sterile tissue or elators and spores. In Anthoceros the sporophyte is highly differentiated having a foot which absorbs food from the gametophyte, the spore-formation being restricted to a special region; and the sporophyte contains assimilative tissue and stomata which enable it to manufacture part of its food.

CHAPTER IV.

MOSSES (MUSCI)

Habitat.—Mosses, which are a higher form of plant life than the hepatics, are found growing in streams, moist soil, on tree trunks and on rocks.

Morphology of the Gametophyte or Sexual Plant.—The *gametophyte* or permanent plant of the mosses, resembles externally the higher plants. The plant consists of a stem or central axis from which grow three sets or rows of leaves. From the underground part develop numerous brown rhizoids, which hold the plant in position and absorb nourishment from the soil.

Reproduction.—The two forms of reproduction common to the mosses are (1) sexual reproduction and (2) asexual reproduction.

1. *Sexual Reproduction.*—The two types of sex organs are: (*a*) Antheridia and (*b*) Archegonia.

(*a*) *Antheridia* grow at the tip of the male plant and in the axils of the leaves, arranged in a cluster or rosette. An *antheridium* is club-shaped. It has an outer wall composed of a single layer of cells. The wall encloses a mass of cells which change to sperms or male reproductive cells. When the sperms are mature the wall breaks and the sperms swim out. A *sperm* is a coiled elongated cell with two cilia.

(*b*) *Archegonia* grow from the tip of the female plant and are surrounded by a rosette of leaves. An *archegonium* consists of a *neck*, or narrow portion, a *venter* or enlarged portion containing the egg or female cell, and a *pedicle* or stalk. The wall of the neck is composed of a single layer of cells and the venter of two layers. The wall incloses one layer of neck cells which dissolves to form mucilage when the egg is mature. The egg is a large spherical cell contained within the venter.

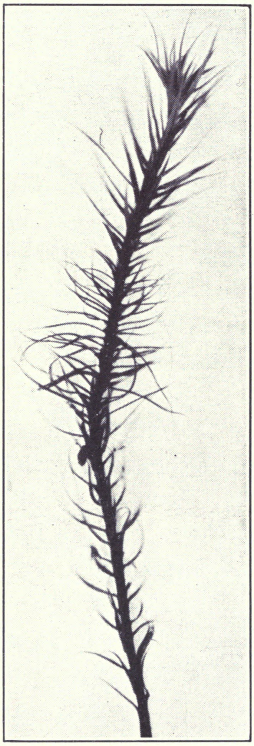

Fig. 30.—Mosses. Gametophyte of polytricum.

Fertilization.—Antherozoids enter the neck of the archegonium but only one unites with the egg cell to form the beginning of the sporophyte plant. This cell remains in the archegonium and is nourished by it. By repeated division a sporophyte or asexual plant is formed.

The young sporophyte grows down at first into the tissues of the gametophyte, but finally it begins to elongate. The lower part becomes stem-like and forms the *seta*, while the upper part becomes enlarged. This enlarged portion becomes differentiated into a calyptra and a capsule.

The *Calyptra* is the loosely attached outer protective covering of the capsule.

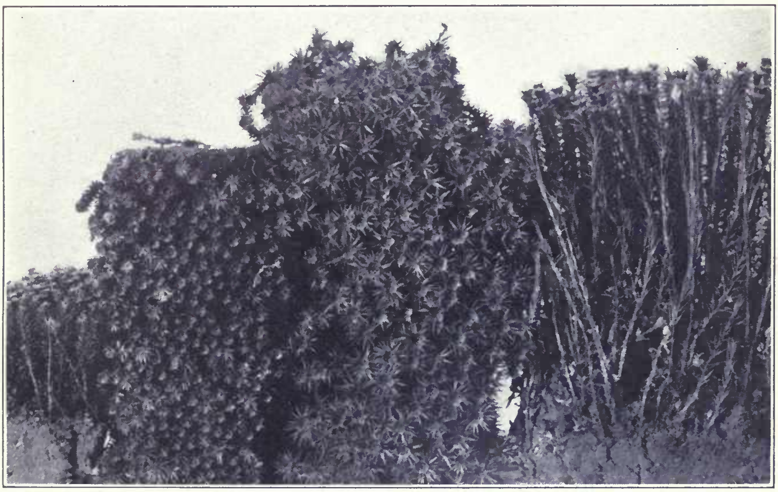

FIG. 31.—*Musci*. Left, colonies of antheridia-bearing plants, right, colonies of archegonia-bearing plants.

The *Capsule* is differentiated into operculum, epiphragm, peristome and spore-bearing tissue.

The *operculum* is the lid which usually covers the upper part of the capsule and separates circumscissilly when the spores mature.

The *epiphragm* is a network of fibrous cells covering the spore-bearing tissue. The whole structure is circular in outline and the cells are far enough apart to permit the passage of the spores.

The *peristome* consists of a number of hygroscopic tooth-like projections called *peristome teeth.* These teeth are so constructed that when the air is moist they absorb water and bend inward to cover the epiphragm; when the air is

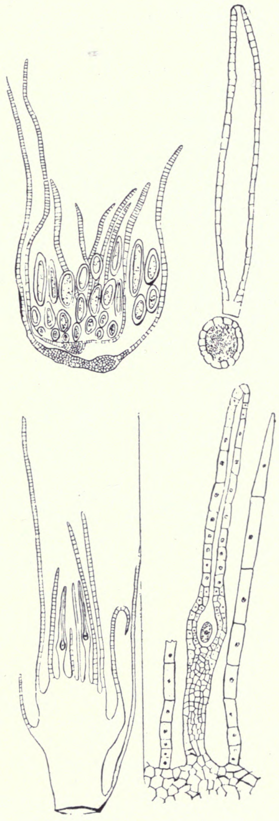

FIG. 32.—*Musci.* Upper left figure is a longitudinal section of an antheridial head. The upper right figure is a longitudinal section of an empty antheridium and immediately below a cross-section of an antheridium filled with sperms. The lower left figure is a longitudinal section of an archegonial plant. The lower right figure is a longitudinal section of an archegonium with egg cell.

dry they lose their moisture and stand erect, thus forcing off the operculum and permitting the spores to be carried away by the currents of the air.

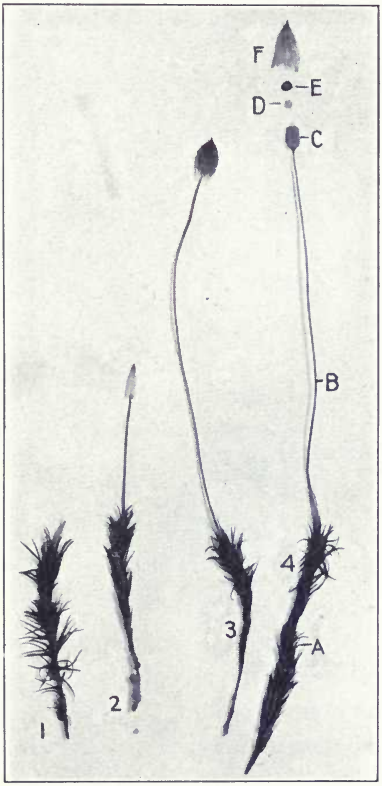

FIG. 33.—*Musci.* Four figures showing the sporophyte developing from the gametophyte. Figure 4–*A* is the gametophyte; 4–*B*–*F*, the sporophyte; *B*, seta; *C*, capsule; *D*, epiphragm; *E*, operculum; *F*, calyptra.

The *spore-bearing tissue* consists of a single layer of spore-bearing cells arranged in a horse-shoe shaped mass.

During its entire existence the sporophyte remains attached to the gametophyte and receives all its nourishment from it because it does not contain chlorophyll. When the spores have matured the sporophyte dies and disappears while the gametophyte or sexual plant, which is the chlorophyll-bearing plant, continues to live from year to year.

FIG. 34.—*Musci*. Colony of sporophyte-bearing gametophytes.

2. *Asexual Reproduction.*—Moss plants reproduce asexually by several different methods:

(*a*) By spore germination.
(*b*) By the formation of gemmæ.
(*c*) By proliferation.
(*d*) By the formation of stolons.

(*a*) *Spore Germination.*—Under favorable conditions the spore germinates and forms a small tubular outgrowth called the *protonema*. The protonema finally grows into a thallus-like structure. From this thallus a typical gametophyte or moss plant develops.

(*b*) *Formation of Gemmæ.*—Gemmæ develop from the tissue at the apex of the gametophyte. Each gemma is rounded or oval in outline and consists of a single layer of cells attached to a stalk composed of one row of cells. Each gemma will, under favorable conditions, develop into a gametophyte plant.

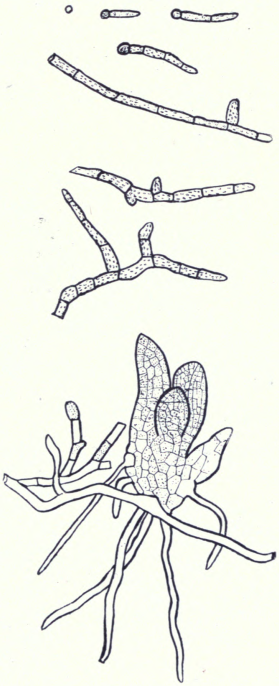

Fig. 35.—*Musci.* Eight figures showing the moss spore, the protonema-bearing buds and a young moss plant.

(*c*) *Proliferation* occurs in male plants after the formation of antheridia. A bud forms at the apex and grows into a male plant. Frequently proliferation occurs three times in the same plant, each new plant in turn producing antheridia or male reproductive organs.

(*d*) *Formation of Stolons.*—A branch reclining or trailing on the ground and forming rhizoids and a bud is called a stolon. Stolons develop into erect plants.

Alternation of Generations is as sharply defined in the mosses as in the liverworts. The *life cycle* is divided into a permanent gametophyte or sexual generation and a temporary sporophyte or asexual generation, both more or less equally conspicuous.

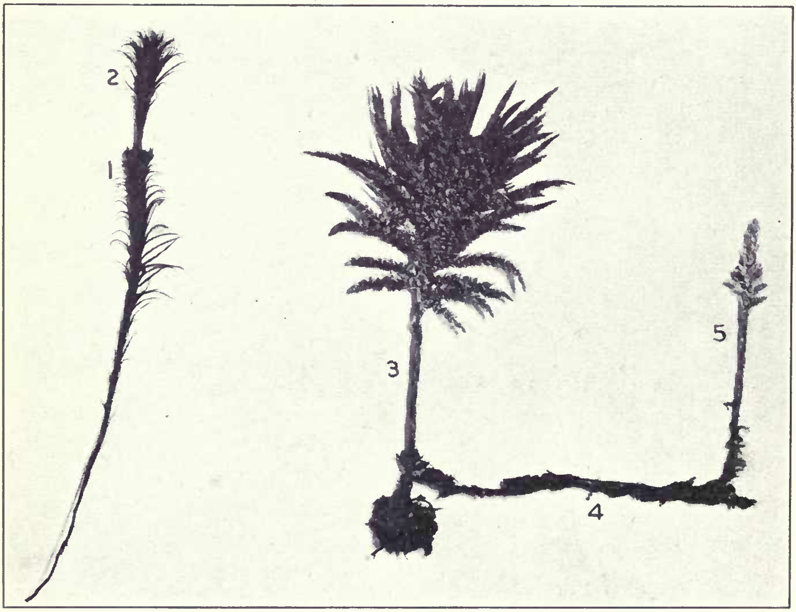

Fig. 35.—*Musci.* 1, Gametophyte moss plant; 2, plant produced by proliferation; 3, gametophyte with (4) stolon and (5) young gametophyte.

Summary

Alternation of generations occurs, as in the hepatics.

Gametophyte.—The gametophyte, which is the permanent generation, is differentiated into *rhizoids*, *central axis* and *leaves*. The rhizoids, which resemble root hairs, increase in length by apical growth, and they function as absorbing and fixing tissue. The antheridium is stalked and clavate; the male gametes are biciliated and can reach the archegonia only in the presence of water. The archegonium is stalked, and its structure is nearly similar to that in the hepatics.

Sporophyte.—The sporophyte is dependent upon the gametophyte and is the temporary generation lasting only until the spores are formed. The base of the sporophyte has a well developed foot which acts as an organ of absorption, a *seta* or stem for elevating the sporangium or spore-bearing part which is structurally differentiated into the calyptra, operculum, epiphragm in some species, and peristome. The tissues of the sporophyte are differentiated into the spore-bearing, assimilating and mechanical tissues.

CHAPTER V.

FERNS (FILICALES)

Habitat.—Ferns, a higher form of plant life than the mosses, are found growing in moist and dry soil, on rocks and tree trunks.

Morphology of the Sporophyte.—The sporophyte is the permanent plant of the fern. It consists of a rhizome or stem which is perennial; that is, it lives from year to year. It may grow upon or under the ground and it may be simple or branched. The rhizome is made up of nodes and internodes. From the nodes grow branches and leaves; the internodes are the spaces between the nodes. Growing from the under surface and sides of the rhizome are numerous *true roots,* which occur for the first time in the ferns. These fix the plant and absorb nourishment from the soil.

Fronds or Leaves.—From the rhizome leaves develop which become larger as the stem grows older. The leaves are the most striking and beautiful part of the fern plant. The leaves are coiled when young but as they grow older they uncoil and finally become flat. They vary from entire to three times compound. There are *two kinds of fern leaves,* (1) foliage leaves and (2) spore-bearing leaves.

1. *Foliage Leaves* are similar in structure and function to the leaves of the higher plants. In the center of each leaf and each division of the leaf there is a strand of vessels or conducting tissue. This type of tissue occurs for the first time in the ferns. Frequently the leaf blade is separated into a

number of divisions called *pinnæ* (singular, *pinna*). If the pinnæ are divided the divisions are called *pinnules*. In the

Fig. 37.—*Filicales*. Evergreen wood-fern (*Dryopteris marginalis*). 1, Roots; 2, stipe bases covering the rhizome; 3, stipe of frond; 4, frond divided into pinnæ and these divided into pinnules as at 4.

Fig. 38.—*Filicales.* Spore-bearing fronds. 1, Clayton's fern (*Osmunda Claytoniana*) with only the central pinnæ spore-bearing; 2, royal fern (*Osmunda regalis*) with the apical pinnæ spore-bearing; 3, cinnamon fern (*Osmunda cinnamomea*) with the entire frond spore-bearing; 4, sensitive fern (*Onoclea sensibilis*), the entire frond spore-bearing.

FIG. 39.—*Filicales.* Spore-bearing fronds. 1, Sori arranged along the margin of the pinnules of evergreen wood-fern (*Dryopteris marginalis*); 2, sori arranged in parallel rows on the back of the frond of Hart's-tongue fern (*Phyllitis scolopendrium*); 3, Christmas fern (*Polystichum acrostichoides*); 4, march shield fern (*Dryopteris Thelypteris*). Sori completely covering the back of the pinnules as in 5, lady fern (*Athyrium Filix-foemina*).

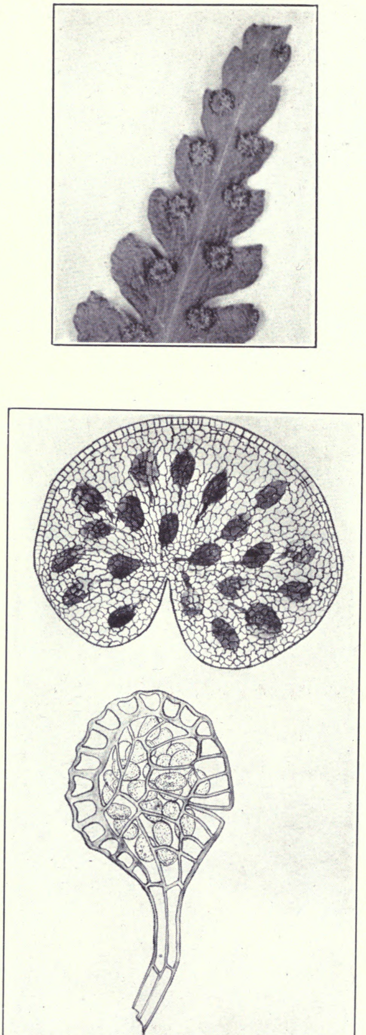

FIG. 40.—*Filicales.* Above, a pinna of evergreen wood-fern with numerous marginal sori. The middle figure is a sorus with its reniform indusium covering numerous sporangia. The lower figure is a sporangium having partially separated lip cells and filled with spores.

first instance the leaf is said to be once pinnate and in the second instance twice pinnate.

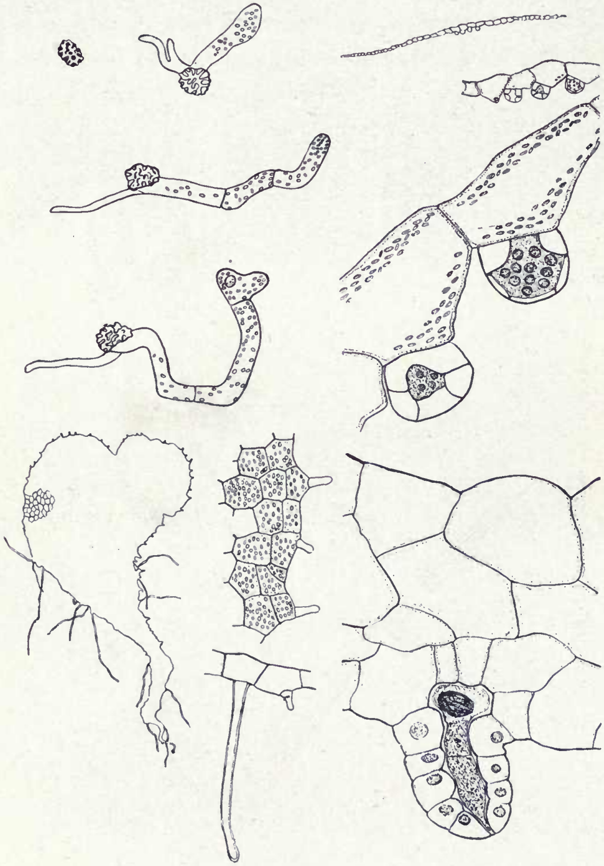

FIG. 41.—*Filicales.* The upper left figure is a spore of evergreen wood-fern. The next three figures show the growth of the protonema. The lower left figure shows the prothallium which bears the antheridia and archegonia. To the right of the prothallium are two figures showing the high power of the cellular structure and a root hair. The three upper right figures show cross-sections of a prothallium with antheridia and male gametes. The lower right figure is a longitudinal section of an archegonium.

2. *Spore-bearing Leaves.*—In the cinnamon fern the entire leaf is spore-bearing; in the interrupted fern only central pinnæ produce spores; in the royal fern only the apical part of the leaf produces spores. In most ferns the spore-bearing tissue is confined to the under side of the leaf. In these cases

Fig. 42-A

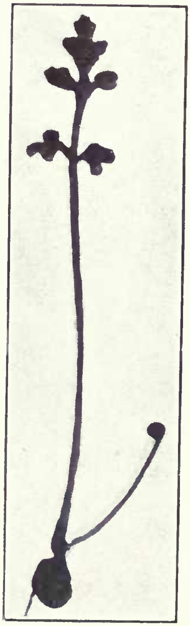

Fig. 42-B

Fig. 42-A.—Bladder fern (*Cystopteris bulbifera*) showing two bulbils.
Fig. 42-B.—Young fern plant developing from the bulbil of *Cystopteris bulbifera.*

the spore-bearing tissue has a characteristic arrangement in different species of ferns. The spore-bearing tissues are grouped in special organs called *sori* (singular, *sorus*). Sometimes the sori are covered with a thin layer of tissue called the *indusium.* The spores are in structures called *sporangia* (singular, *sporangium*). A sporangium consists of a rounded body composed of a wall, one cell in thickness. A single row of the wall cells is modified to form the *annulus*. The cells composing the annulus have thick inner and side walls which are very hygroscopic and open the sporangium at the lip cells to permit the escape of the spores.

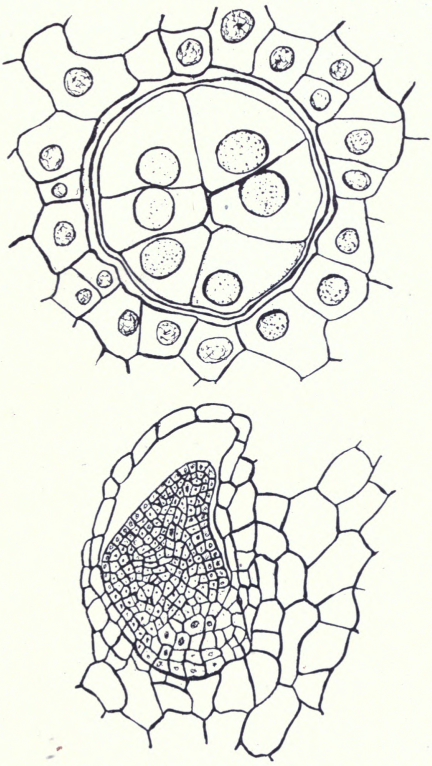

FIG. 43.—*Filicales*. Early stages of the young sporophyte which develops as a result of fertilization.

Spores.—In most ferns the spore-bearing tissue is composed of sixteen large cells, which by dividing twice give rise to sixty-four cells. All of the sixty-four cells develop into spores. When the spores are mature the sporangium loses its moisture, the outer walls of the cells of the annulus bend inward, the sporangium is split open and the spores are carried away by the currents of the air.

Reproduction.—The two types of reproduction common to the ferns are (1) asexual reproduction and (2) sexual reproduction.

1. *Asexual Reproduction* is brought about in one of four ways:

(*a*) By division of the rhizome.
(*b*) By the formation of bulbils.
(*c*) By the formation of stolons.
(*d*) By spore germination.

(*a*) *By Division of the Rhizome.*—When the rhizome is divided into two or more parts, each part may develop into a fern.

(*b*) *By the Formation of Bulbils.*—In certain species of ferns bulbils or buds form on the surface of the leaf and when they fall to the ground they grow into ferns.

(*c*) *By the Formation of Stolons.*—In the so-called walking fern, the tips of the leaves recline on the ground, develop roots and later produce typical fern plants.

(*d*) *By Spore Germination.*—The spores produced in the sporangium will, under favorable conditions, develop a slender tube or *protonema.* This tube produces a branch near the spore, which develops the first rhizoid. The protonema divides and redivides to form a flat green heart-shaped *prothallus,* one cell in thickness. The prothallus bears the sexual reproductive organs.

2. *Sexual Reproduction.*—The two types of sex organs are similar to those of the liverworts and mosses, namely: antheridia and archegonia. Antheridia grow on the under side and near the point of the prothallus. An *antheridium*

is rounded and it has an outer wall composed of one layer of cells. The inner cells develop into *sperms*. The sperms of the ferns are multiciliate coiled cells. The archegonia grow on the under surface of the prothallus just back of the heart-

FIG. 44.—*Filicales*. Eight figures showing the developing sporophyte and the disappearance of the gametophyte after the formation of four fronds.

6

shaped depression. An *archegonium* is flask-shaped. The neck is composed of a single layer of wall cells inclosing one layer of neck cells which later form mucilage. The enlarged basal portion, or *venter* is sunken in the tissues and contains the *egg.*

Fertilization.—In the presence of moisture the multiciliate sperms enter the neck of the archegonium, swim to the egg cell and unite with it to form the beginning of the sporophyte.

Development of the Sporophyte.—The fertilized egg undergoes a series of divisions to form the four-celled *embryo.* One of these cells by repeated division forms a *stem;* one, the embryonic leaf or *cotyledon;* one develops a *root,* while the fourth develops a *foot.* The foot grows down into the tissues of the prothallus and absorbs food to nourish the growing sporophyte. The root of the young sporophyte develops first, then the leaves and finally the stem. The young sporophyte remains a parasite upon the prothallus until about four leaves are formed, then the prothallus or gametophyte generation dies and disappears. The sporophyte because of the presence of roots, a well developed vascular system and chlorophyll continues to live from year to year or is *perennial.*

Alternation of Generations is as sharply defined in the ferns and other pteridophytes as in the liverworts and mosses, but the gametophyte or sexual generation in inconspicuous and temporary, while the sporophyte or asexual generation is conspicuous and permanent.

Summary.

Alternation of Generations occurs.

Gametophyte.—The gametophytes are of temporary duration. The prothallus produces antheridia and archegonia. The antheridium is sessile and mostly spherical; the sperms which are multiciliate reach the archegonia only in the presence of water. The archegonium is sessile or sunken in the tissue.

FIG. 45.—Walking fern (*Camptosorus rhizophyllus*). 1, Roots; 2, leaf; 3, young plant growing from tip of leaf.

Sporophyte.—In the ferns the sporophyte, while dependent on the gametophyte for a time, finally becomes independent of it and becomes the dominant plant. It has true roots, stems and leaves.

Fig. 46.—Cinnamon fern (*Osmunda cinnamomea*) showing the early spring stage with coiled leaves.

Root.—The roots develop apical growth, with branches originating from the cortex of the primary or first root, and with absorbing, conducting, storage and epidermal tissues well developed.

Stem.—The stems, which are the inconspicuous part of the fern, grow as rhizomes under or upon the ground and are simple or branched and of very slow growth; they are smooth or scaly, and in some species are covered with the persistent stipe-bases.

Leaves.—The leaves are the most conspicuous part of the fern and they perform the work of photosynthesis, or food building, and spore formation; when they do not produce spores they are sterile leaves; sometimes an entire leaf is spore-bearing, in other ferns only part of a leaf, while in most ferns only the under side of the leaf bears spores; these are enclosed in sporangia arranged in clusters or sori.

CHAPTER VI.

HORSETAILS AND CLUB MOSSES.

HORSETAILS (EQUISETALES)

Habitat.—Equisetums or horsetails, a higher form of plant life than the ferns, grow in moist or dry soil, depending upon the species.

Morphology of the Sporophyte.—The sporophyte is differentiated into a rhizome and one or two types of stems with or without branches, depending upon the species, reduced scale-like leaves and a strobile or cone-like spore-bearing part.

The rhizome is composed of nodes and internodes. The internodes are furrowed and blackish. The nodes are surrounded by the adnate-toothed sheath of reduced leaves. From the nodes develop branches and numerous whorls of black fibrous roots which fix the plant firmly in the soil and which serve as organs of absorption.

In *Equisetum arvense,* the species illustrated, there are sterile and fertile stems.

The sterile stems and branches which develop after the fertile stems, form the permanent or annual plant which is seen growing in great numbers along railroad tracks and in sandy fields. These sterile stems have furrowed internodes and nodes with a whorl of reduced leaves adnate to form a sheath which is usually dark colored. No branches grow in the axils of several of the sheaths immediately above the ground. In the axils of the upper sheaths grow a whorl of branches. The internodes of the branches are winged and three to four angled. These stems perform the work of photosynthesis because of the presence of chlorophyll and innumerable stomata which occur in the grooves of the inter-

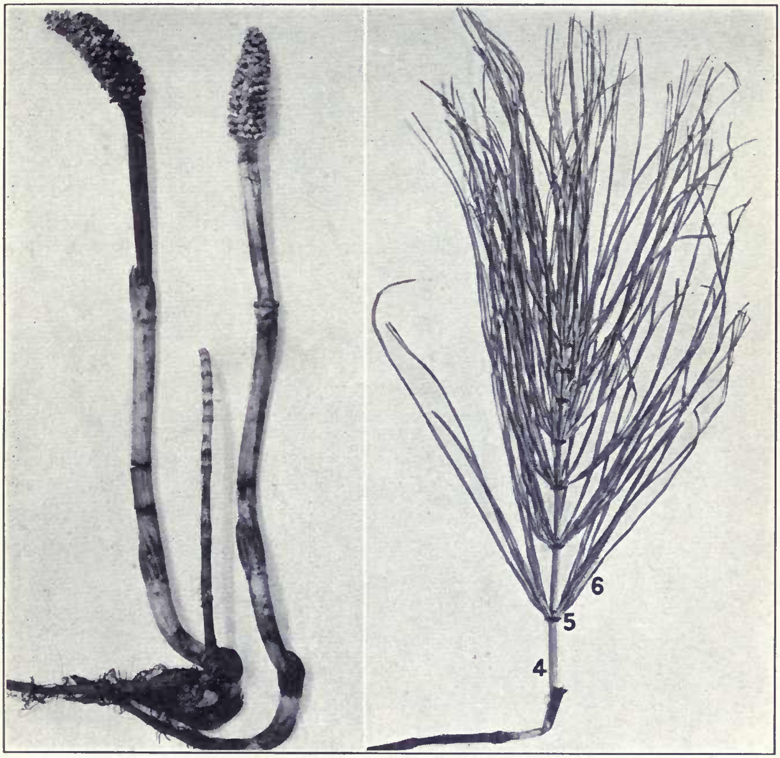

FIG. 47.—*Equistaceæ.* Two fertile strobile-bearing stems of *Equisetum arvense* and between them is a young sterile shoot. To the right, a fully developed sterile shoot showing at the base the rhizome; at 4, internode; 5, node; 6, whorl of branches.

nodes. The growth of the main stem is apical and this growth continues until fall in this latitude. The sheaths surrounding the branches are greatly reduced and have acuminate points.

The fertile stems of *Equisetum arvense* literally cover the ground in May. These fertile stems develop like the sterile stems from the rhizomes. The stems are not branched but

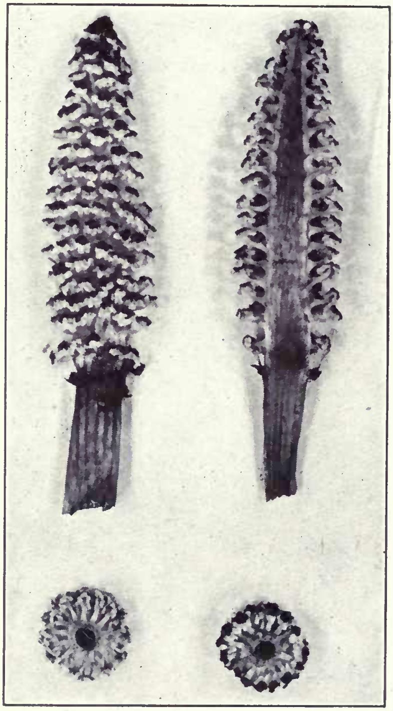

FIG. 48.—*Equisetum arvense.* The upper left figure is the strobilus; the upper right figure is a longitudinal section, the stalked sporophylls with spórangia showing clearly. The lower left figure is a cross-section of the strobilus viewed from the underside; the lower right figure is a cross-section of the strobilus viewed from above.

they are clearly differentiated into nodes and internodes. The internodes are pink, furrowed and free of chlorophyll, the nodes have sheaths with from eight to twelve brown teeth. Each fertile stem is terminated by a cone made up of a great number of spirally arranged sporophylls. Each sporophyll is differentiated into a stalk and a shield-like outer part; from the under surface develop up to ten elongated

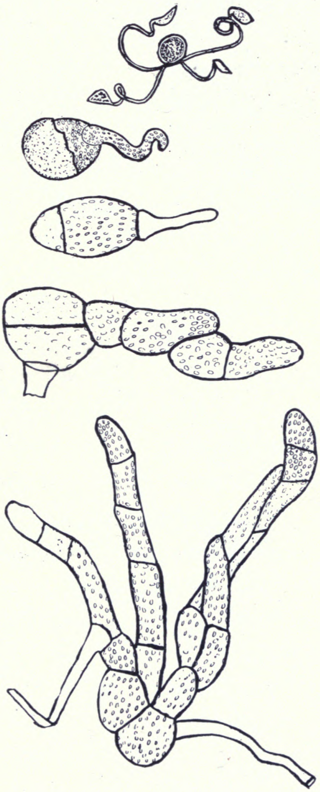

FIG. 49.—*Equisetum arvense.* Five figures showing the development of the gametophyte from the asexual spore.

sporangia. When the spores are mature the sporangia open and the spores, which have four hygroscopic bands terminating in a broad spatulate apex, will when the air is dry be carried by the air currents far from the parent plant.

Reproduction.—There appears to be but one type of spore produced by Equisetum, at least no physical or structural difference can be noted, but there must be a physiological

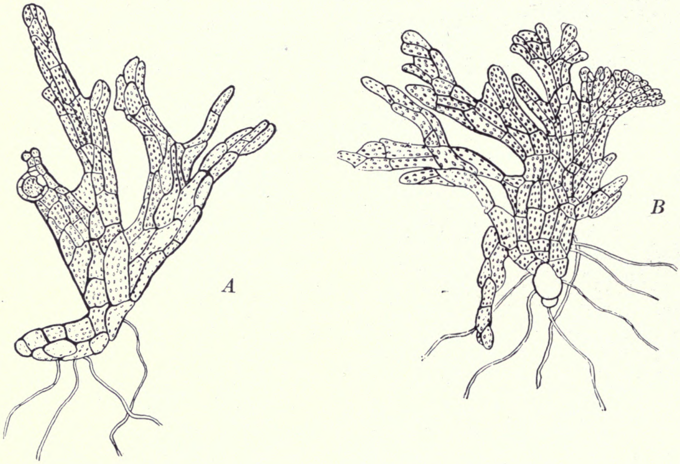

FIG. 50.—*Equisetum arvense.* *A*, Male gametophyte with one antheridium *B*, female gametophyte with archegonia.

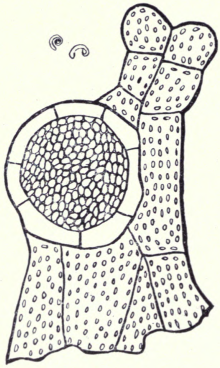

FIG. 51.—*Equisetum arvense.* Enlarged antheridium and above two sperms.

difference because when these spores germinate some develop into male gametophytes, others into female gametophytes. It appears to be a fact that if the spores are sown too thickly only male gametophytes will be formed, but if thinly sown female gametophytes will develop. If this is true then poorly nourished spores develop into male gametophytes while fully nourished spores develop into female gametophytes. The development of the gametophytes of Equisetum and all the other forms studied, can be readily observed by planting in chemical solutions, because from these solutions specimens can be taken daily and the development from the one-celled spore stage to the filamentous stage and finally to the thalloid prothallic stage with its innumerable cells and several branches, can be readily observed.

Male Gametophyte.—The male gametophyte of Equisetum arvense is smaller and less branched than the female gametophyte. Certain of the branches only produce antheridia; some entire gametophytes produce only one antheridium. An *antheridium* is spherical and has a wall composed of one layer of cells. Sperms completely fill the space within the wall. When these are mature the antheridial wall opens and the multiciliated sperms swim out in the presence of moisture.

Female Gametophyte.—The female gametophyte produces several archegonia. Each archegonium consists of neck, composed of one layer of cells and several ventral canal cells, and a venter or enlarged part which is imbedded in the tissues of the female gametophyte. The venter contains the egg cell.

Fertilization.—Fertilization is accomplished when the multiciliated sperm enters the neck of the archegonium and its nucleus fuses with the nucleus of the egg cell to form the beginning of the sporophyte or asexual generation. The young sporophyte is parasitic for a time on the gametophyte, but it finally becomes independent when it has produced a rhizome, roots, stems and leaves to form the sporophyte with which we are familiar.

Summary.

Alternation of Generations occur.

Gametophyte.—The gametophyte is greatly reduced; there are male gametophytes which produce only antheridia, and female gametophytes which produce only archegonia. The male gametophyte is a branched prothallium which bears one or more laterally placed rounded antheridia filled with coiled sperm cells. The female gametophyte, which is larger than the male gametophyte, forms one or more archegonia, similar to the archegonia of the ferns.

Sporophyte.—The sporophyte is the conspicuous stage. Like the fern it has roots, stems and leaves.

Roots.—The roots develop from the endodermal layer of the rhizome; secondary roots arise from the endodermis of the older roots; all are covered with root hairs; they are brown or black and very tough and fibrous.

Stems.—The stems are jointed and the internodes are furrowed. They contain the assimilative tissue and stomata occur in the furrows of the internode. The spore-bearing cones are borne at the end of the stem, and are made up of spirally arranged sporophylls which bear the sporangia containing the spores.

Leaves.—The leaves are reduced to scales, and they are arranged in the form of whorls at the nodes of the stem and branches.

CLUB MOSSES (LYCOPODIALES)

Lycopodium grows in dry or moist soil.

There is a great variation in the sporophyte of the different species, but they all resemble each other by having simple or dichotomously branched stems from which grow numerous small often scale-like leaves completely covering the stem in some species. The tissues of the stem are differentiated and there is a single large central fibrovascular bundle con-

FIG. 52.—*Lycopodium lucidulum* showing 1, bifurcated stem covered with leaves; 2, roots; 3, rhizome.

sisting of several groups of xylem alternating with phloem and surrounded with an endodermis.

The long tough roots grow from the base or sides of the stems.

The leaves of the simplest lycopodiums all bear sporangia in their axils; they are therefore sporophylls. In other species only the upper leaves bear sporangia and in some species the sporophylls form a strobilus at the end of the stem. Sporophylls arranged in strobili do not have chlorophyll,

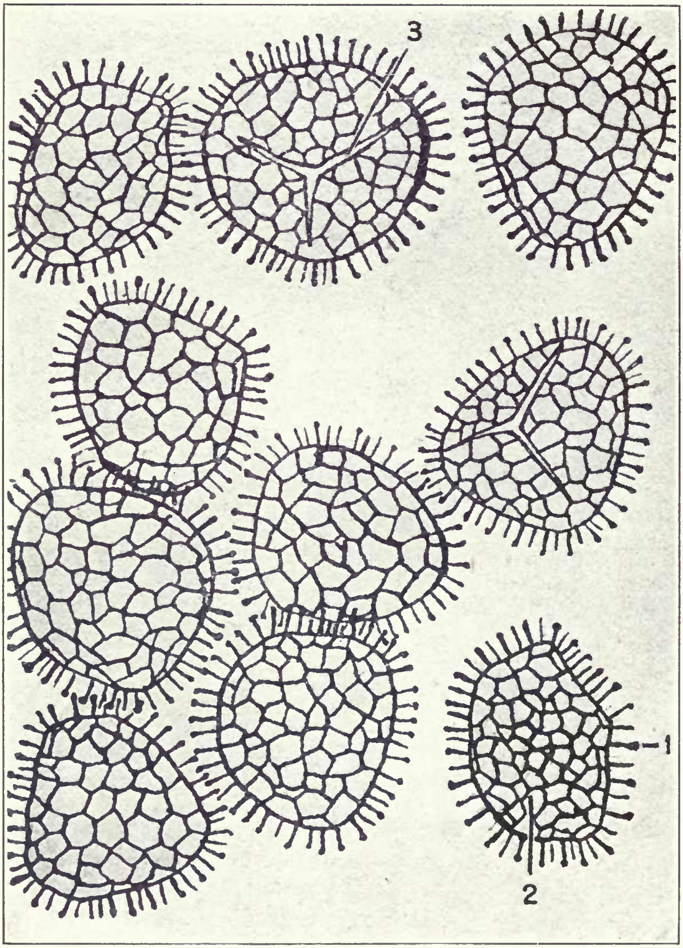

Fig. 53.—*Lycopodium.* 1, Hair-like projection; 2, reticulate surface; 3, characteristic marking of the spore.

but all other sporophylls and sterile leaves have well developed assimilative tissue.

The sporangia are large enough to be visible without magnification and when the spores are mature they open by a slit. The spores which are very light are distributed by

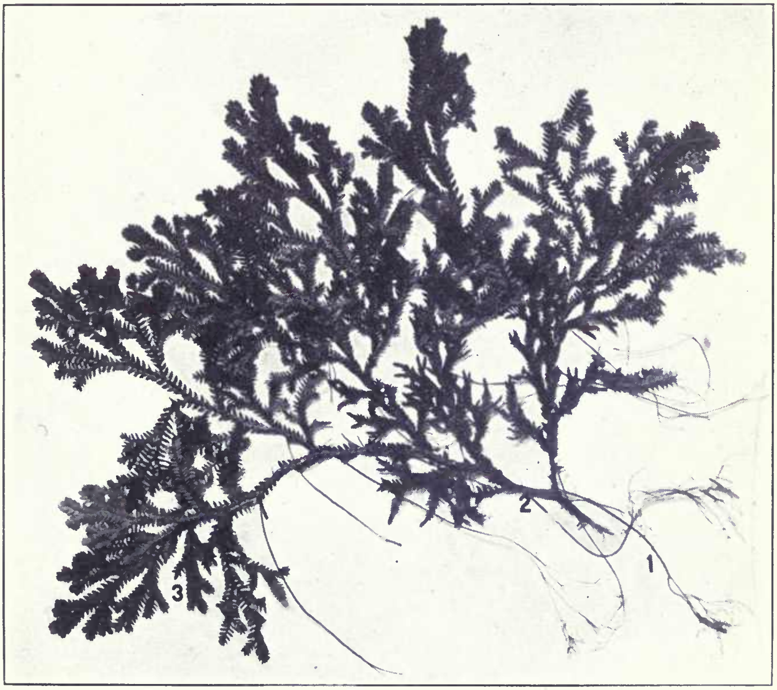

FIG. 54.—Selaginella (*Sp. cultu.*)

air currents, when they fall to the ground under favorable conditions they develop into gametophytes. The gametophyte in a typical lycopodium is a fleshy erect prothallus which bears both antheridia and archegonia.

The sperms are biciliated and when they fertilize the egg cell it divides to form the embryo sporophyte with a suspensor as in the higher plants. The embryo is parasitic on the gametophyte for a long time finally, however, becoming independent.

Selaginella a higher branch of the Lycopodiales is heterosporous. Some sporophylls produce only megasporangia with megaspores, other sporophylls form only microsporangia with microspores. The microspores develop into small simple male gametes which bear a single antheridium with biciliated sperms. The megaspores develop into minute female gametophytes which bear archegonia.

CHAPTER VII.

GYMNOSPERMS (GYMNOSPERMÆ)

WHITE PINE (*Pinus Strobus*)

Habitat.—The gymnosperms are a group of plants higher in the scale of evolution than the pteridophytes, represented by the ferns, horsetails, and club mosses. A common gymnosperm is the *white pine* (*Pinus Strobus*), which grows in dry, rocky or sandy soil.

Morphology of the Sporophyte.—The trunk or stem of the white pine tree is erect and vertical. It frequently grows to a height of over a hundred and fifty feet because of the presence of a terminal bud which adds to its height from year to year. From the trunk grow numerous lateral branches, which in turn branch. From the smallest branches grow the acerose foliage leaves which are long, narrow and pointed. The leaves occur in *fascicles* or groups of five and each group is surrounded by a number of thin scales.

Defoliation or shedding of the leaves occurs gradually; therefore, the tree always bears green leaves and is known as an *evergreen*. The sporophyte bears the reproductive organs.

Reproduction.—There are two forms of reproduction, (1) asexual and (2) sexual, distinguishable morphologically, but physiologically reproduction is essentially a single sexual process.

1. *Asexual Reproduction.*—There are two types of asexual reproductive organs:

(*a*) Carpellate or ovulate cones.

(*b*) Staminate cones.

Fig. 55.—*White pine* (*Pinus strobus*) showing the typical tree, with roots, excurrent stem and leaves.

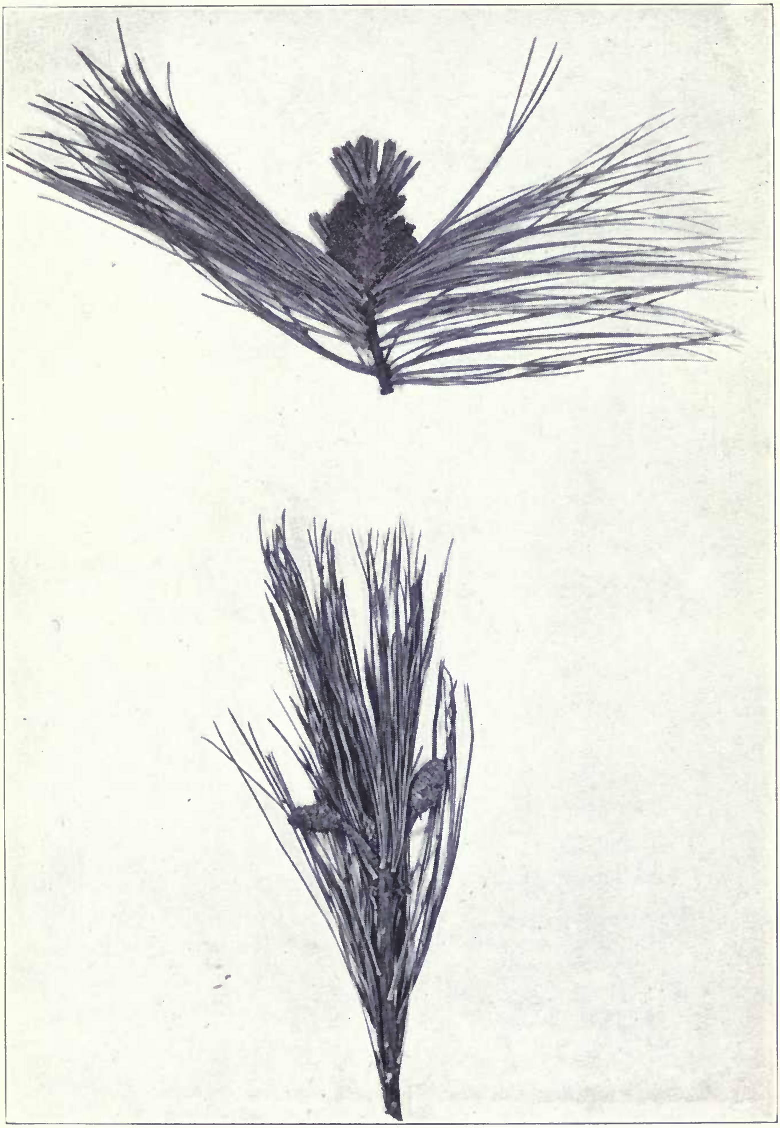

Fig. 56.—*White pine* (*Pinus strobus*). The upper figure is a branch with staminate strobilus. The lower figure is a branch with ovulate strobili.

Each of these organs produces spores which upon germination develop, the former into female, the latter into male gametophytes.

(*a*) *Carpellate Cones.*—The carpellate cones occur on short lateral branches growing near the tip of the young apical branches. Each cone has a central axis which develops numerous thick fleshy outer protective scales and inner macrosporangia or *ovule-bearing* scales.

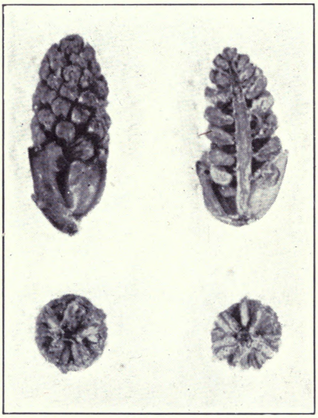

FIG. 57.—*White pine.* The upper left figure is a staminate strobilus. The upper right is a longitudinal section of the microsporophylls. The lower left figure is the top view of the cross-section of the strobilus while the figure at the right is the under view of the strobilus.

A *macrosporangium* or *ovule* consists of an outer covering or *integument*, a *micropyle* or circular opening in the integument which leads into the *pollen chamber*, the *nucellus* or main body of the ovule and a *megaspore* or asexual spore.

Development of the Female Gametophyte.—The megaspore upon germination divides into four cells. The three upper cells dissolve and furnish nourishment for the lower reproductive cells. This cell by repeated division develops into the female gametophyte which consists of an *embryo sac* containing several greatly reduced archegonia. Each archegonium consists of a neck made up of only four cells, a *venter* composed of one layer of cells and containing the *egg cell,* and a *ventral canal cell,* which disintegrates when the egg is mature.

(*b*) *Staminate Cones* occur in the axils of the scale leaves growing on the youngest stems. Each cone is a modified branch and it consists of a central axis bearing numerous spirally arranged scale-like *microsporophylls* or *stamens.* The stamens (microsporophylls) bear two *sporangia* (*spore cases*) containing the *spore mother cells,* each of which divides into four cells. Each of the four cells develops into a *microspore* or *pollen grain* which is an asexual spore. A microspore is yellowish and it consists of a central reproductive body and two air-sacs.

Distribution of Pollen.—When the pollen grains are mature the stamens elongate and separate. The sporangial wall opens, the pollen grains fall out and are carried about by the air currents.

Pollination.—Pollen grains carried by the air currents fall through the micropyle and into the pollen chamber which is filled with a sticky fluid.

Development of the Male Gametophyte.—The central reproductive body develops into the male gametophyte which consists of two *prothallial cells,* which later disappear, a *generative cell* and a *tube cell.* The *gametophyte* is, therefore, greatly reduced and develops within the pollen grain, the whole structure being microscopic.

Development of the Sperms.—In the fluid of the pollen chamber the tube cell of the pollen grain develops a *pollen tube* which secures food for its further growth by dissolving the cells of the *nucellus* or the tissues external to the archegonia. During the elongation of the pollen tube, the tube nucleus passes to the growing tip; the generative cell divides to form a *stalk cell* and an antheridial cell; the antheridial

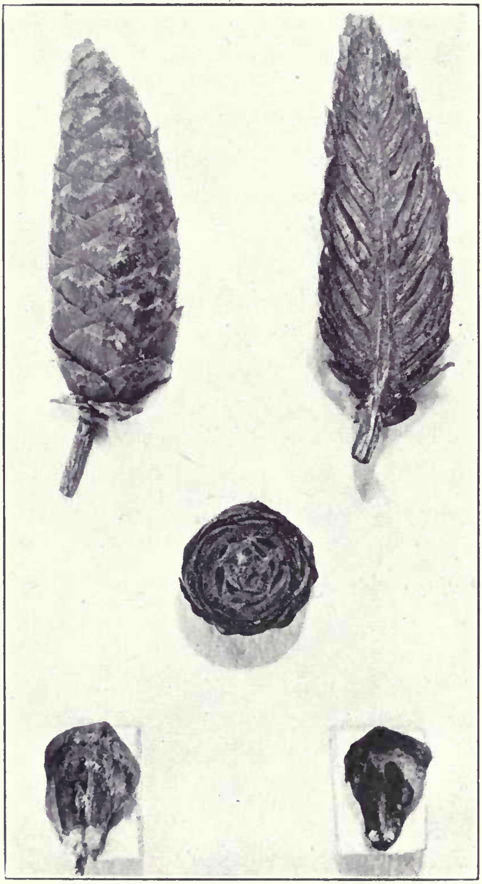

FIG. 58.—*White pine.* Five figures showing the entire strobilus, a longitudinal section and a cross-section of the strobilus and scales with ovules.

cells divides to form two non-ciliated sperms. The pollen tube finally grows through the nucellus and the neck cells of the archegonia and enters the venter.

Fertilization.—The tip of the pollen tube breaks and one of the sperms, which has been carried by the tube to the venter, unites with an egg nucleus to form the *oösperm.*

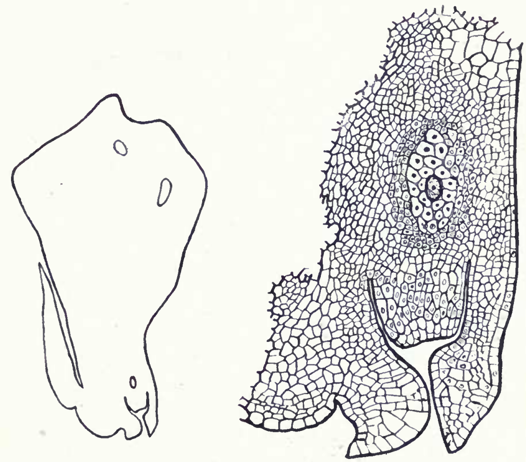

FIG. 59.—*Gymnospermæ.* White pine. The upper left figure is a microsporangium or stamen of white pine showing one cavity filled with pollen grains and one free of pollen grains. The upper right figure is a cross-section of the stamen with numerous pollen grains. The lower left figure is a longitudinal section of an ovuliferous scale with ovule and outer scale. The lower right figure is a longitudinal section of an ovule showing the outer opening or micropyle, the space beneath or pollen chamber, the nucellus and the megasporangium with a large megaspore.

This union of the sperm and egg nucleus is called *fertilization*. Several egg cells may be fertilized but only one usually develops.

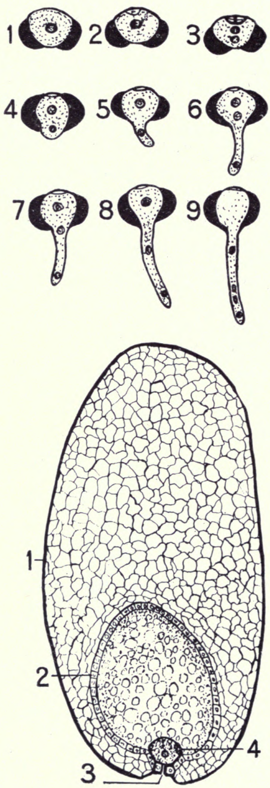

FIG. 60.—*A. White pine*: 1, Pollen grain with nucleus; 2, nucleus divided into two cells; 3, the two cells divided into two upper prothalial cells and a generative and tube cell; 4, one prothalial cell has disappeared and the protoplasm has increased in amount; 5, pollen tube is forming; 6, the generative cell has divided into a stalk cell and an antheridial cell; 7-8, the pollen tube is elongating and the antheridial cell has passed into the tube; 9, the long pollen tube contains the tube nucleus, the two sperms and the stalk cell nucleus.

B. Female Gametophyte. 1. Embryo sac; 2, archegonium; 3, neck cells; 4, egg cell.

Seed Formation.—The oösperm germinates and forms the *embryo sporophyte* which finally becomes differentiated into a rudimentary stem or *hypocotyl,* several seed leaves or

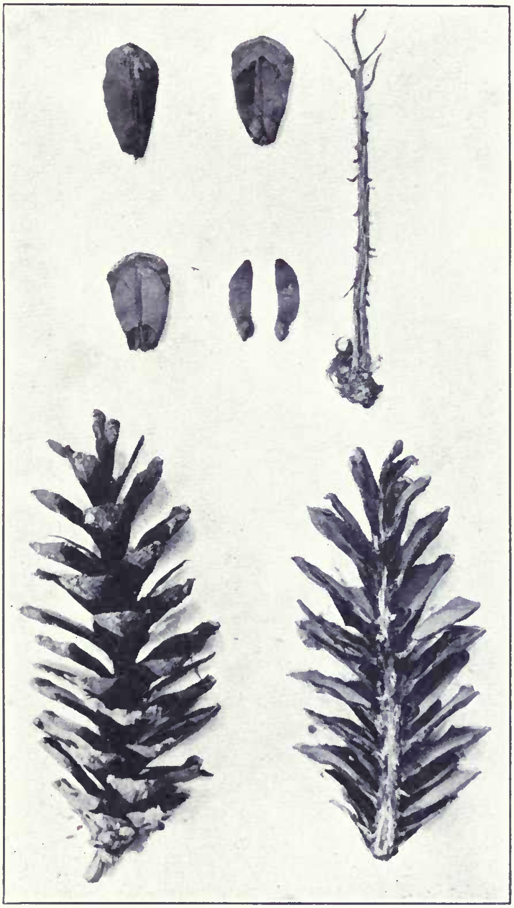

Fig. 61.—*White pine.* Showing the outer surface of a mature scale, inner view of scale with two seeds, scale free of seeds, the stalk which bears the scales, the mature open cone and a longitudinal section of the cone.

cotyledons, and the *plumule* or apical bud or growing point. These structures are surrounded by the *endosperm* or food stored within the embryo sac. The embryo sac is enclosed by the remains of the nucellus and the *integument* becomes modified to form the seed coat or *testa*, a portion of which grows into a wing-like structure, which makes it possible for the seed to be carried by the wind. All the above structures constitute the *seed*.

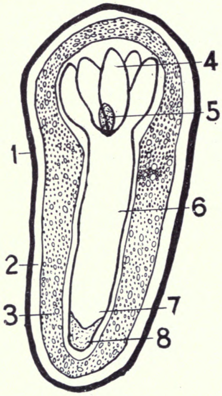

FIG. 62.—*White Pine Seed.* 1, Outer dark layer of the testa; 2, inner light-colored layer of the testa; 3, endosperm of the stored food; 4, cotyledons; 5, plumule; 6, hypocotyl; 7, root; 8, root cap.

Seed Germination.—Under favorable conditions the rudimentary parts of the embryo pine continue to develop, finally producing a typical pine tree or sporophyte plant.

SUMMARY.

Gametophyte.—The male and female gametophytes of the pine are greatly reduced.

Male Gametophyte.—The microsporophylls are arranged in cones, and bear the microspores or pollen grains. The

FIG. 63.—*White pine.* Seed and three seedling pines.

microspores develop into the *male gametophyte* which consists of two prothallial cells, a generative cell and a tube cell. Pollen grains are carried by the winds and *fall directly upon the ovule.*

Female Gametophyte.—The megasporophylls are also arranged in cones. Each ovule is *open* or not enclosed in a chamber, and contains a megaspore which develops into the female gametophyte, consisting of an embryo sac with several archegonia. After fertilization the ovules develop into *seeds* containing the young embryo, sporophyte with several cotyledons or seed leaves making the seeds of this group *polycotyledenous.*

Sporophyte.—The sporophyte is a tree with true roots, stems, and leaves.

Stems.—The stem increases yearly in diameter because of the presence of a formative region between the wood and the bark.

Leaves.—The leaves are needle or scale-like, and are usually angled or several-sided in outline.

CHAPTER VIII.

MONOCOTYLEDENOUS ANGIOSPERMS

WILD YELLOW LILY (*Lilium canadense*)

Habitat.—The wild yellow lily usually grows in low moist ground.

Morphology.—The underground part consists of a scaly bulb, from the under part of which roots develop. During the growing season an aërial stem forms and grows to the height of about two feet. The stem is divided into units of structure termed *nodes* and *internodes*. From a node a whorl of several leaves develops.

These leaves are parallel-veined, like all plants of this group, and the vascular or conducting tissue is well developed. During August the tips of the main stem and branches develop large showy *flowers*, which contain the organs of reproduction.

Structure of the Flower.—The flower of the lily is *complete* and consists of the following parts:

1. A *calyx*, consisting of an outer circle of three *sepals*.

2. A *corolla*, consisting of an inner circle of three *petals*, which closely resemble the sepals.

3. An *andrœcium*, consisting of two sets or circles of three *stamens* each. One set is opposite the three sepals, the other set opposite the three petals.

4. A *gynœcium*, consisting of one central *pistil* made up of three *carpels*.

The calyx and corolla are vegetative organs which, because

Fig. 64.—*Wild Yellow Lily.* Showing buds, flowers, whorls of leaves, cluster of stem roots, fleshy scales surrounding the base of the stem, a short rhizome forming fleshy scales and rhizome roots. The small figure at the right shows the six stamens and the pistil of the flower.

of their color and form and the presence of nectar glands, attract insects for the purpose of bringing about pollination. The pistil and stamens are reproductive organs.

Structure of the Pistil.—Each pistil consists of a *stigma* or expanded part, a *style* or slender neck-like portion, an *ovary*

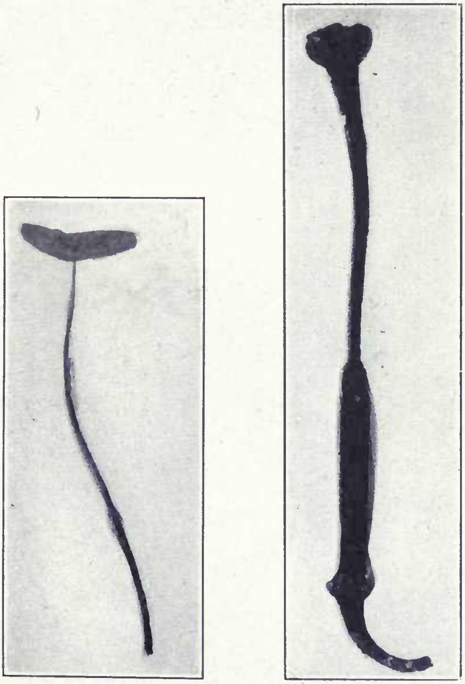

FIG. 65.—*Wild Yellow Lily.* Left-hand figure is a stamen, the right is a pistil.

or enlarged hollow part containing the *ovules* and a slender *stipe* or stem. The *stigma* is usually expanded and in the lily it is three-lobed. Its epidermis develops numerous papillæ which secrete a sticky fluid for fixing the pollen grain and nourishing the male gametophyte developing from it. The *style* contains a great number of loosely arranged inner cells which secrete food to nourish the developing pollen tube.

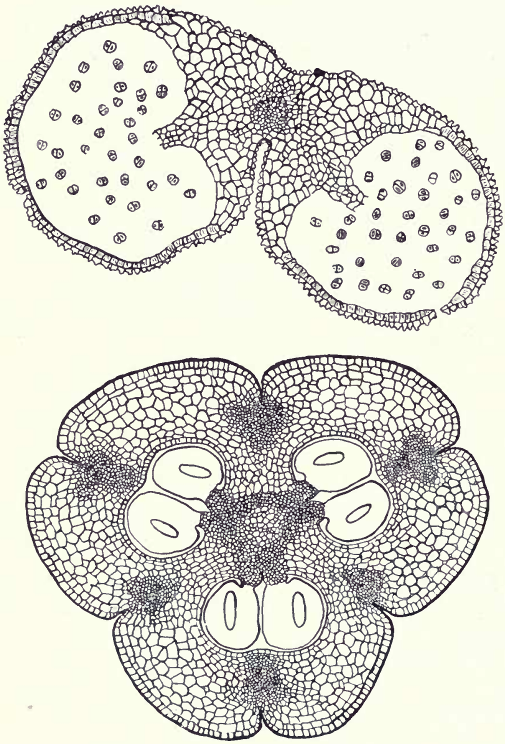

FIG. 66.—Wild yellow lily (*Lilium canadense*). The upper figure is a cross-section of the anther showing chiefly the first division of the spore-mother cells. The lower figure is a cross-section of the ovary, showing the three cavities and six rows of ovules.

The *ovary* or enlarged part of the pistil has three cavities separated by *septa* or walls. Part of the wall is modified, becoming the *placenta* which forms a ridge and from which the ovules develop.

The *ovule* has a short stalk or *funiculus* attached to the placenta. From the apex of the funiculus, the *chalaza*, two *integuments* arise. These completely surround the ovary

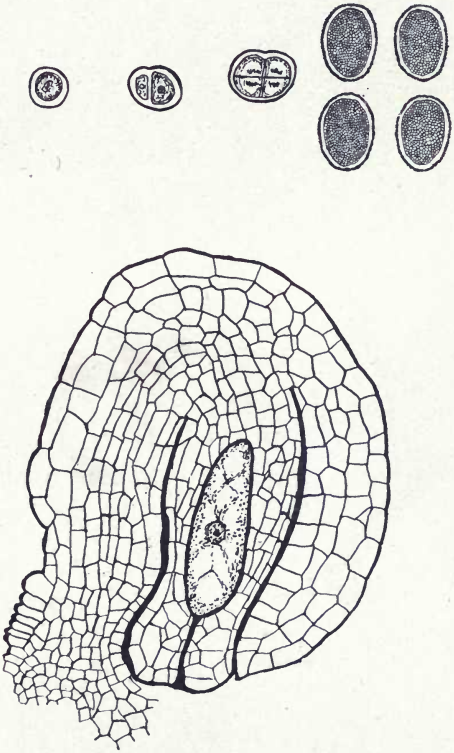

Fig. 67.—*Lilium canadense.* The upper figures show a pollen mother cell, its division into two, then into four cells each of which develops into a pollen grain. The lower figure is a longitudinal section of an anatropous ovule showing the large central megaspore.

except at the apex where a small opening or *micropyle* remains. The integuments inclose the *nucellus* in which is imbedded the *macrospore.*

Development of the Female Gametophyte from the Macrospore.—The macrospore divides into two cells, the two cells into four, and the four cells into eight, all of which are con-

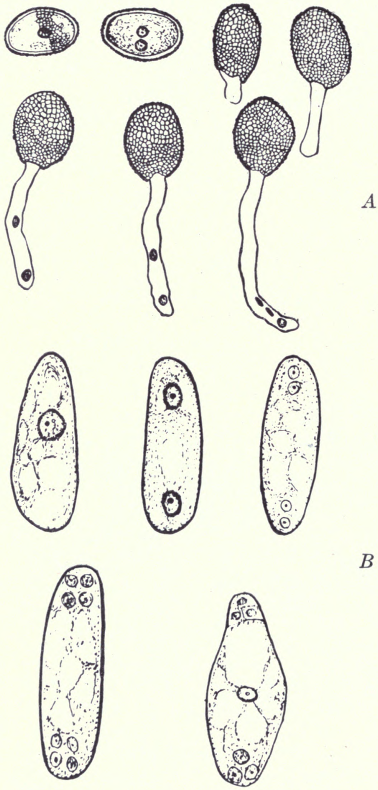

FIG. 68.—*Lilium canadense.* *A*, Development of male gametophyte and sperms; showing the pollen grain with nucleus, the nucleus divided to form the antheridial and tube cell. The next four figures show the formation of the pollen tube, in the last figure the antheridial cell has divided to form two sperms, the tube nucleus is at the end of the tube. *B*, Development of the female gametophyte and egg cell. Megaspore with nucleus, formation of two nuclei, four nuclei formed, eight nuclei formed, two nuclei fused to form the endosperm nucleus at the center, three antipodal cells above, the two lower synergids or helpers and the egg cell.

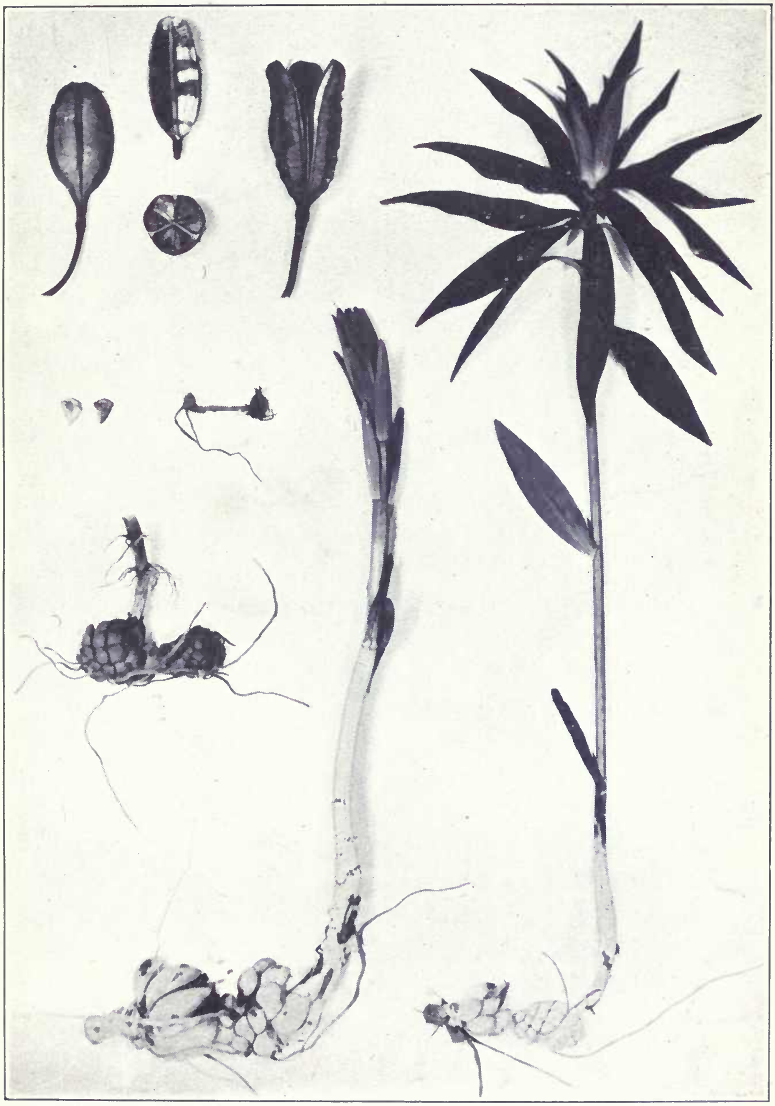

FIG. 69.—*Monocotyledoneæ. Lilium canadense.* The four upper figures show the capsule, closed, cut longitudinally, cut transversely and an old capsule showing the method of dehiscence. Below the capsules are shown two seeds and a very young rhizome and under these an older rhizome. The two right hand figures show the developing stem with leaves.

tained within the embryo sac. Three of these cells pass to the end of the embryo sac nearest the micropyle. The two outer cells are the *synergids*. They help to nourish the pollen tube and direct it toward the inner or *egg cell*. Two cells pass to the center of the embryo sac and fuse to form the *endosperm nucleus*. The three remaining cells pass to the opposite end of the embryo sac and are called the *antipodal cells*.

The embryo sac with the seven cells described above is the *female gametophyte*. In all the monocotyledons and the dicotyledons, the next higher group, no archegonia are found.

Structure of the Stamen.—Each stamen consists of a *filament* or stem, and an *anther*. The anther consists of two double *pollen sacs* separated by a continuation of the filament. The pollen sacs contain the *spore mother cells* each of which divides to form four pollen grains.

Structure of the Pollen Grains.—Each pollen grain consists of an outer wall or *exine*, which is reticulate or netlike in structure, and a thin inner wall or *intine* which surrounds the protoplasm and nucleus.

Pollination.—Bees and other insects visit the flowers to secure the nectar or sugary solution secreted by the nectar glands. While the insect is securing the nectar, it moves the stamens and pollen is dusted on its body. The stigma of another flower, which the insects afterwards visits, rubs against its body and receives some of the pollen grains. In this way cross-pollination is effected.

Development of the Male Gametophyte.—The pollen grain divides to form the male gametophyte which consists of a *tube cell* and an *antheridial ceil*. The tube cell develops the *pollen tube* which breaks through the exine and grows down through the tissues of the style and nucellus to the embryo sac. During the growth of the pollen tube the antheridial cell divides into two *sperm cells.*

Fertilization.—When the pollen tube has grown down through the style and the tissues of the nucellus and past the synergids the pollen tube breaks and the sperm cells are discharged into the embryo sac. One of the sperm cells fuses with the egg cell to form the young embryo. The other sperm cell fuses with the endosperm nucleus and forms the endosperm. The integuments form the *testa,* the nucellus the inner *seed coat,* and the endosperm nucleus the *endosperm.* The fertilized egg cell becomes the young embryo and consists of a *radicle, caulicle* and one *cotyledon.*

Summary of Monocotyledons

Gametophyte.—The male and female gametophytes are still further reduced in the monocotyledons.

Male Gametophyte.—The microsporophylls or stamens constitute the third circle of the flower. The anthers bear the pollen grains. The pollen grains develop into male gametophytes consisting of but two cells, the generative and the tube cell. The tube cell develops the pollen tube which grows through the tissues of the style and conducts the sperm cells to the ovary.

Female Gametophyte.—The megasporophylls or pistils form the fourth and innermost circle of the flower. The ovary or enlarged hollow part of the pistil encloses the ovules; *enclosed ovules* are characteristic of the monocotyledenous and dicotyledenous plants. The megaspore of each ovule develops the female gametophyte or embryo-sac containing a female cell or egg and six other cells, seven in all. *Double fertilization* occurs, one sperm unites with the egg cell to form the embryo-sporophyte characterized by having one cotyledon, a fact which gives the name monocotyledenous to the whole group.

Sporophyte.—The sporophyte is differentiated into roots, stems, leaves and flowers.

Roots.—The roots are all simple and originate from the stem; increase in length is brought about by apical growth. Root-hairs are numerous and persistent.

Stems.—Growth of the stem in diameter is interstitial, the vascular bundles being of a closed type and scattered throughout the other tissues.

Leaves.—The leaves, which are large and showy in many members of the group, have well developed conducting tissue or veins which form a *closed system,* because the branches of the midvein end in a simple vein which runs parallel to the margin of the leaf; furthermore the veins are *parallel,* resulting in a *parallel-veined* leaf, and the margin of the leaves is mostly entire.

Flowers.—The flowers of the monocotyledons are usually *trimerous,* each having three sepals, frequently resembling petals, three petals, six stamens, and a three-carpeled and three-celled pistil. The sepals, petals, stamens and pistils have a cyclic arrangement.

CHAPTER IX.

DICOTYLEDENOUS ANGIOSPERMS

INDIAN TOBACCO (*Lobelia inflata*)

Habitat.—Indian tobacco is abundant in fields and meadows where the growth is not over rank.

Morphology.—The plant, which is annual, is clearly differentiated into roots, stems, branches, leaves, flowers, fruits and seeds. The roots, which are all branches of a primary root, have the tissues differentiated into a cortical region separated from a wood region by the cambium zone which, in the perennial woody dicotyledons, forms cortex on its outer face and wood upon its inner face, thus adding to the diameter of the root from year to year. On the younger portion of the young roots there is a root hair region which develops as the rootlets increase in length and disappears when the epidermis is replaced by the periderm or corky outer layer.

The stems are usually much branched and are covered with hairs. The stem, like the root has a cortical, cambium, wood and pith region. Because of these facts the whole group is known as exogenous plants because the fibrovascular tissue is open and is arranged in a circle and surrounded by a cambium as in the roots, which in perennial dicotyledons adds new cells to the wood and cortex, thus making it possible for the plants to yearly increase their diameter. The vessels in the wood are tubes, frequently of great length, and through which water and cell sap readily pass. Trees and shrubs in our northern climate show in cross-section circles of large vessels formed in the spring when rapid conduction of water

FIG. 70.—*Indian Tobacco* (*Lobelia inflata*). 1, Roots; 2, stem; 3, leaves alternately arranged; 4, lateral flowering branch; 5, terminal flowering branch; 6, inflated persistent calyx in which the fruit develops.

is necessary. These circles are known as annual rings, since only one circle or region of these large-diametered vessels is formed yearly. By counting the rings one can readily determine the age of the tree.

The leaves of the Indian tobacco are alternate, petioled or sessile; the base is rounded; the margin is crenate; the apex is obtuse or acute; the outline is ovate, oval or oblong-oval. The upper surface varies in color from green to purple; the veins branch and the larger branches are joined by smaller veins to form a network of veins and making the *net-veined* leaves so characteristic of dicotyledons. The ends of the veins at the margin of the leaves are free, giving the *open venation* characteristic of the group.

The Flowers.—The flowers are arranged in terminal or axillary racemes. Each flower is subtended by an ovate or an ovate-lanceolate bract. The pedicle or stem of the individual flowers is very short and slender. The calyx is united and tubular below; the free portion terminates in five subulate teeth. The corolla is united below; the free portion terminates in five acute lobes. The andrœcium consists of five stamens; their anthers are united and enclose the style. The gynœcium consists of one pistil with a two-celled ovary and a two-parted stigma. The fruit is a two-celled capsule with numerous reticulate seeds.

Like most dicotyledons the floral organs have a cyclic arrangement and there are five parts to each circle, giving a pentamerous structure; a few of the dicotyledons have tetramerous, trimerous, and dimerous flowers.

The seed of lobelia, like all dicotyledons, has two opposite seed-leaves or cotyledons, and a central apical stem-bud or plumule. The seed will be more fully discussed in the final chapter of Part II.

That dicotyledons are extremely variable will be better understood by a study of Part II which deals largely with dicotyledenous plants.

Summary of Dicotyledons

Gametophyte.—The male and female gametophytes have structures which are essentially like those of the monocotyledons.

Male Gametophyte.—The male gametophyte is formed by the growth of the pollen grain. It consists of two cells only, the generative cell and the tube cell. The tube cell grows down through the tissues of the style to the ovule and to the embryo sac where it empties the two sperm cells resulting from the divisions of generative cells.

Female Gametophyte.—The megaspore, contained in the ovule and enclosed by the ovary, divides to form the female gametophyte or embryo sac which develops the egg cell.

Double fertilization occurs, as in the monocotyledons; one sperm cell unites with an endosperm cell. The fused cell divides to form the endosperm. The other sperm cell unites with the female or egg cell to form the embryo sporophyte which is characterized by having two *opposite cotyledons* and a *terminal stem bud* or *plumule,* a fact which gives the name dicotyledons to the group.

Sporophyte.—The sporophytes of the dicotyledons vary from minute plants to giant trees. All have roots, stems, leaves and flowers.

Roots.—The roots which are *branches of the primary root* arise endogenously from the procambium. The tip of the root ends in a root-cap which protects the formative cells; these divide to increase the length of the roots. The piliferous or root-hair layer, which functions as absorbing tissue, occurs as epidermal outgrowths a short distance back of the formative layer. The root-hair layer is progressive; as the root increases in length new root-hairs are formed.

Stems.—The stems of dicotyledons may increase yearly in diameter because they have *open vascular bundles* arranged as a continuous ring of tissue surrounded by the *cambium cells*; these divide to form new vascular tissue on the inside and new cortical tissue on the outside. The cortex is of variable thickness and when breaks occur or tissue is thrown off because of the increase in diameter of the stem, the *phellogen cells* divide to form parenchyma cells on the inside and cork cells on the outside.

Leaves.—The leaves of dicotyledons usually have an intricate system of venation, the larger veins connected by smaller ones to form a network, resulting in a *net-veined leaf.* The ends of the veins are usually free near the margins, forming the *open venation* characteristic of dicotyledons. A great variety of margins is possible in open-veined leaves. The variations in margins are shown by Fig. 93, Part II.

Flowers.—The flowers have a cyclic arrangement, and they are usually *pentamerous* or in fives, having five sepals, five petals, ten stamens in two sets, and a five-carpeled pistil. The greatest possible variation occurs, however, not only in color, form and position of the floral circles but in the number of units in each. Many of these variations being special adaptations for bringing about *pollination by insects.* Refer to Part II.

PART II.

DESCRIPTIVE BOTANY.

CHAPTER X.

ROOTS

General Characters.—Roots are not divided into nodes and internodes and there is no apparent order in the development of branches, as is the case with stems. Root development seems to obey the law of necessity; when a root is needed by a plant it develops and such development may occur on the older as well as on the younger roots.

Functions.—1. Roots effectively anchor plants because they consist largely of mechanical tissue, the wood fibers predominating. The horizontal spread of the roots of a plant is usually equal to that of the branches. From the horizontal roots grow numerous vertical roots. The soil surrounding and covering this network of roots adds greatly to their anchoring power.

2. Roots absorb water. The water-absorbing power of roots is confined to the root-hair zone of the young roots, located just back of the root-cap. Root-hairs are modified epidermal cells. They are small unicellular tubes with a wall of cellulose covered with a thin coat of mucilage. The tube is lined with protoplasm which secretes carbonic acid, a

substance attracting moisture and assisting in food absorption by rendering soluble the inorganic constituents of the soil. The solution of salts within the root hair is denser than the solution of the soil water; therefore, the soil water passes into the root-hairs, obeying the law of osmosis, which is the equalization of the density of solutions by passing through an intervening permeable membrane, as the wall of a root-

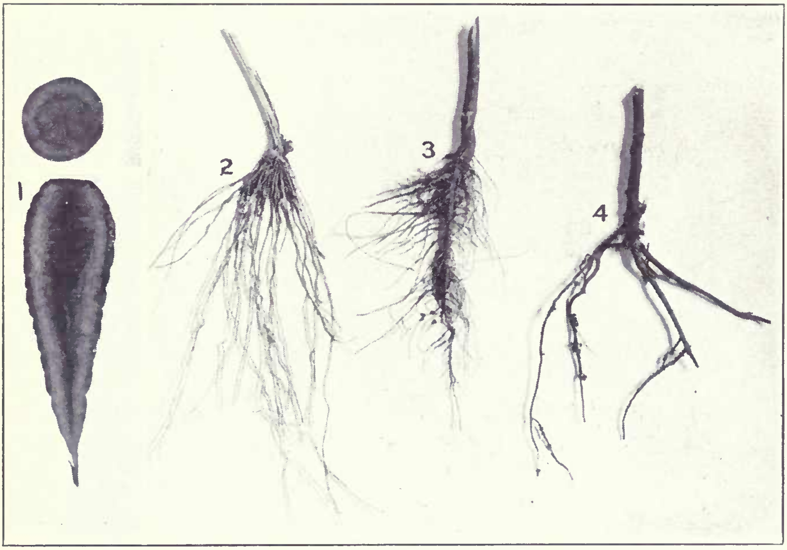

FIG. 71.—*Roots.* 1, Fleshy; 2, fibrous; 3, tap root; 4, woody root.

hair. In like manner the water and salts pass into the parenchymatic cells and finally into the vessels. As roots grow older, the root-hairs disappear and the epidermis is replaced by a periderm.

3. Roots transport food and water through the parenchymatic cells and finally by the vessels or the upward-conducting cells of the root.

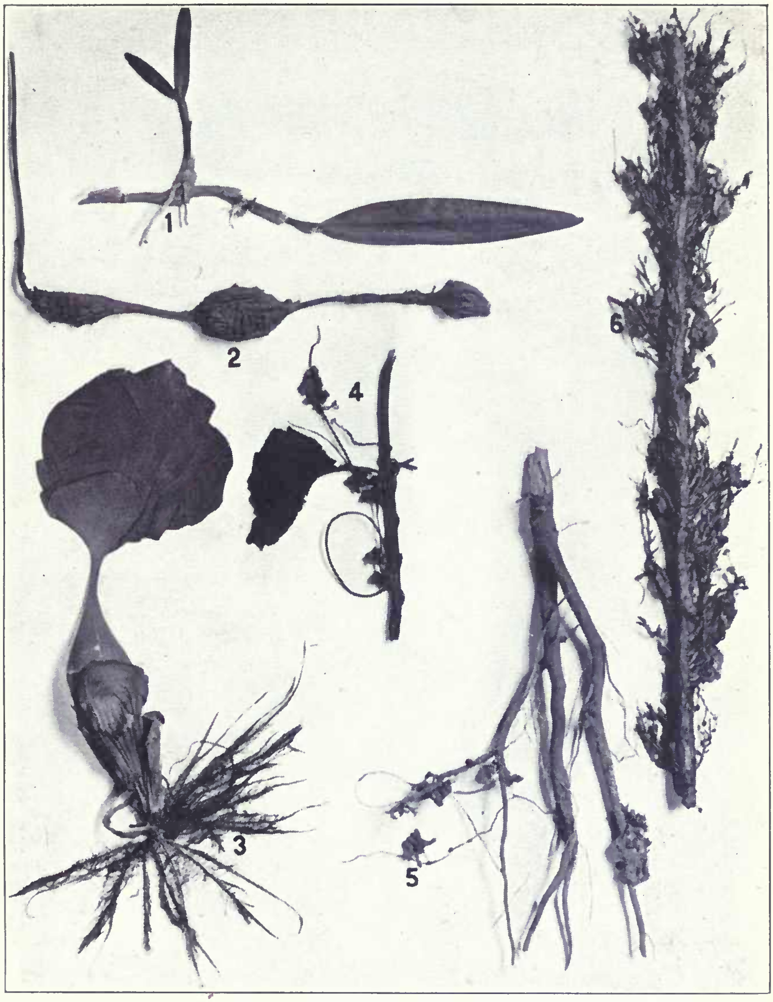

FIG. 72.—Modified roots. 1, Aërial roots of tropical orchid; 2, enlarged storage part of the roots of ground-nut (*Glycine apios*); 3, water roots of water hyacinth (*Piaropus crassipes*); 4, parasitic roots of dodder (*Cuscuta gronovii*); 5, nitrogen bacteria nodules on the roots of New Jersey tea (*Ceanothus americanus*); 6, Virginia creeper (*Parthenocissus quinquefolia*).

4. Roots store food. The parenchymatic cells of most roots function as storage cells for the excess food manufac-

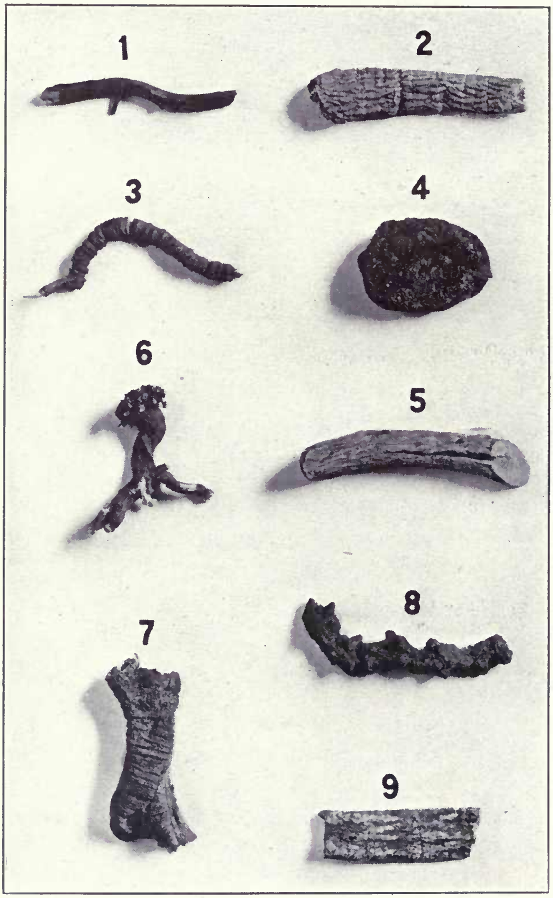

Fig. 73.—*Surface of Roots and Rhizomes.* 1, Furrowed Mexican sarsaparilla (*Smilax medica*); 2, wrinkled butterfly weed (*Asclepias tuberosa*); 3, fissured Cartagena ipecac (*Cephælis acuminata*); 4, sunken Jalap (*Exogonium purga*); 5, split berberis (*Species of odostemon*); 6, keeled senega (*Polygala senega*); 7, Annulate gentian (*Gentiana lutea*); 8, nodulated geranium (*Geranium maculatum*); 9, abraded belladonna root (*Atropa Belladonna*).

tured during the growing season. In such biennial roots as the beet, carrot, parsnip and turnip, the food is stored to provide nourishment for forming flowers, fruits and seed the

FIG. 74.—The lifting power of roots is shown in the above photograph.

following year. The parenchyma of roots will be found to contain stored or reserved food at almost any time of the year.

Origin.—Growing roots, unlike stems, are affected by the force of gravity, which acts as a stimulus and causes the root to grow into the soil.

The *radical* or seed root develops into the *primary* or first root. If the primary root continues its growth and becomes the largest or predominating root, it is known as the *taproot* and is the main axis of the root. Secondary roots develop from the primary root in no regular order and the branches of secondary roots arise in a similar manner.

Nature.—*Simple roots* are unbranched. Many plants have only one simple root, which in this case is said to be *solitary.* In the onion the roots are not branched but there are a great number of simple roots which are *fascicled* or grouped in a cluster. *Branched roots,* which are by far the most common, show numerous branches and are usually very irregular. Simple roots or branches may be straight, curved, twisted or crooked.

Types.—Roots are *vertical* when they grow directly downward into the soil, *horizontal* when they grow parallel to the surface of the soil and *oblique* when they grow in an oblique direction to the vertical root.

Duration.—Roots that live for one year are *annual,* those that live for two years are *biennial* and those that live for several years are *perennial.*

Modification.—Roots are occasionally modified as follows: (*a*) as *haustoria* or absorbing roots of saprophytic or parasitic plants. (*b*) as *aërial roots.* The aërial roots of orchids function as water-condensing organs while the aërial roots of Virginia creeper, which develop after the stem has become quite large and mature, function as hold-fast organs. (*c*) as *root tubercles,* which occur on the roots of all leguminous plants, as the bean, pea and clover.

Texture.—Roots vary greatly in texture. Texture depends both upon cellular structure and upon cell contents.

Root texture based upon cellular structure includes the following: *fleshy roots* which are composed largely of parenchymatic cells; *fibrous roots* which are composed of both parenchymatic and fibrous cells; and *woody roots* which are composed almost entirely of wood fibers.

Root texture based upon cell contents includes starchy or starch-containing roots, resinous roots and waxy roots.

Size.—The size of roots varies greatly but for each root there is a fairly uniform maximum size.

Color.—The colors of roots in the order of their frequency are gray, yellow, brown, and red. For each kind of root there is a characteristic color.

Surface Markings.—The surface of dried roots may be furrowed, wrinkled, fissured, sunken, cleft, split, keeled, annulated, nodulated, abraded or smooth. The various types of surface result from the internal and external structure and the decrease, in drying, in diameter or length or both.

The surface is *furrowed* when it has sharply defined longitudinal parallel elevations and depressions. Furrows may form straight parallel lines, as in Mexican sarsaparilla, or they may be spirally arranged, as in scammony root. The surface is *wrinkled* when it is irregularly contracted into furrows, as in bryony and in pyrethrum. The surface is *fissured* when it has narrow openings caused by the separation of the tissues. The fissures may be shallow, as in stillingia, or deep, as in Savanilla krameria and in Cartagena ipecac. The surface is *sunken* when it is depressed because of the shrinking of the inner tissue, as in jalap; *cleft* when it has irregular openings caused by the separation of the tissues, as in Russian licorice; *split* when it has longitudinal breaks in the tissue caused by cutting it into pieces, as in berberis and in gelsemium; *keeled* when it has a longitudinal ridge or elevation of the cortex, beginning at the crown and extending toward the tip of the root, as in senega; *annulated* when it has transverse parallel elevations or outgrowths of tissue. It may be incompletely annulate, as in phytolacca; or completely annulate, as in parsley root. The surface is *nodulated* when it is extended as a rounded, knotlike mass of tissue, as in wild geranium; *abraded* when the outer layers have been removed by the friction resulting from handling and transporting the drug, as in belladonna root; *smooth* when it has no perceptible projections or depressions, as in cut sections of belladonna root.

Fractures.—Some roots cannot be broken and therefore, have no fracture. The fracture of roots that can be broken is extremely variable and may be divided into the very weak brittle, weak brittle, tough, strong tough, and very strong tough fractures.

Outline of Sections.—Sections vary in outline from circular, oval or rectangular to irregular, as in most roots.

Odor.—Many roots have an aromatic odor which is very characteristic and which is frequently a great aid in identification.

Taste.—The taste of a root may be simple or complex. It is simple if it has only one taste, and complex if it has a combination of tastes. The most common simple tastes are mucilaginous, starchy, sweet, bitter, astringent, pungent, acrid, tingling and aromatic.

CHAPTER XI.

STEMS

General Characters.—Stems normally grow into the light away from the soil and assume an erect position; they are divided into nodes and internodes. From the nodes grow leaves and in the axil of the leaves stems or modified stems.

Functions.—The stem by its growth elevates the plant above the ground; it produces leaves which, because of the presence of chlorophyll, manufacture food from carbon dioxide and water; it conducts water upward to the leaves; it bears flowers which after fertilization develop into fruit and seed. The seed under normal conditions produces a new plant.

Origin.—Stems are formed by the growth of the plumule of the seed. The continued growth of stems is brought about by cell divisions of apical or lateral buds.

Units of Structure.—All stems are divisible into nodes and internodes. From the nodes leaves, stems and flowers develop. Under certain conditions the internodes will give rise to leaves and branches.

Nature.—Stems are simple or branched. By far the greater number of plants, however, have branched stems. If the stem is branched, the branches may be *alternate*, one at a node, *opposite*, two at a node, or *whorled*, more than two at a node.

Method of Growth.—When the apical bud grows so rapidly that the central axis is the largest and highest part of the plant the stem is *excurrent*, but when the main stem divides into a number of stems of about equal size, because apical and lateral buds grow equally fast, the stem is *deliquescent*.

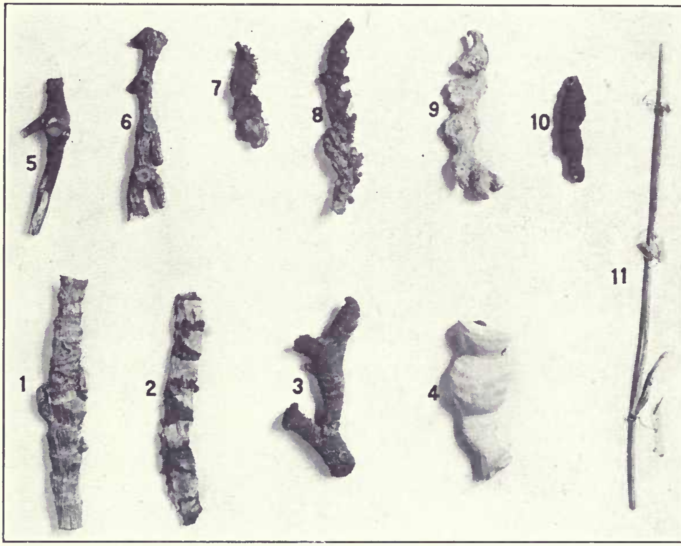

FIG. 75.—*Types of Rhizomes.* 1, Sweet flag (*Acorus calamus*) with leaf scars and lateral buds; 2, blue flag (*Iris versicolor*) with V-shaped leaf scars; 3, galangal (*Alpinia officinarum*) with concentric leaf scars; 4, orris root (*Iris Florentina*) with indistinct circular leaf scars; 5, mandrake (*Podophyllum peltatum*) with circular depressed stem scars; 6, false Solomon's seal (*Vagnera racemosa*) with circular stem scars and concentric scars; 7 twin-leaf (*Jeffersonia diphylla*) with contiguous stem scars; 8, geranium (*Geranium maculatum*) with nodulated surface; 9, Jamaica ginger (*Zingiber zingiber*) with laterally compressed stem bases and rhizome; 10, bloodroot (*Sanguinaria canadensis*) with indistinct stem scars; 11, quack grass (*Agropyron repens*) with finely furrowed rhizome and long internodes from which grow buds and roots.

Modifications.—The most important modified stems are (1) *rhizomes*, (2) *bulbs* and (3) *tubers*. (1) *Rhizomes* are

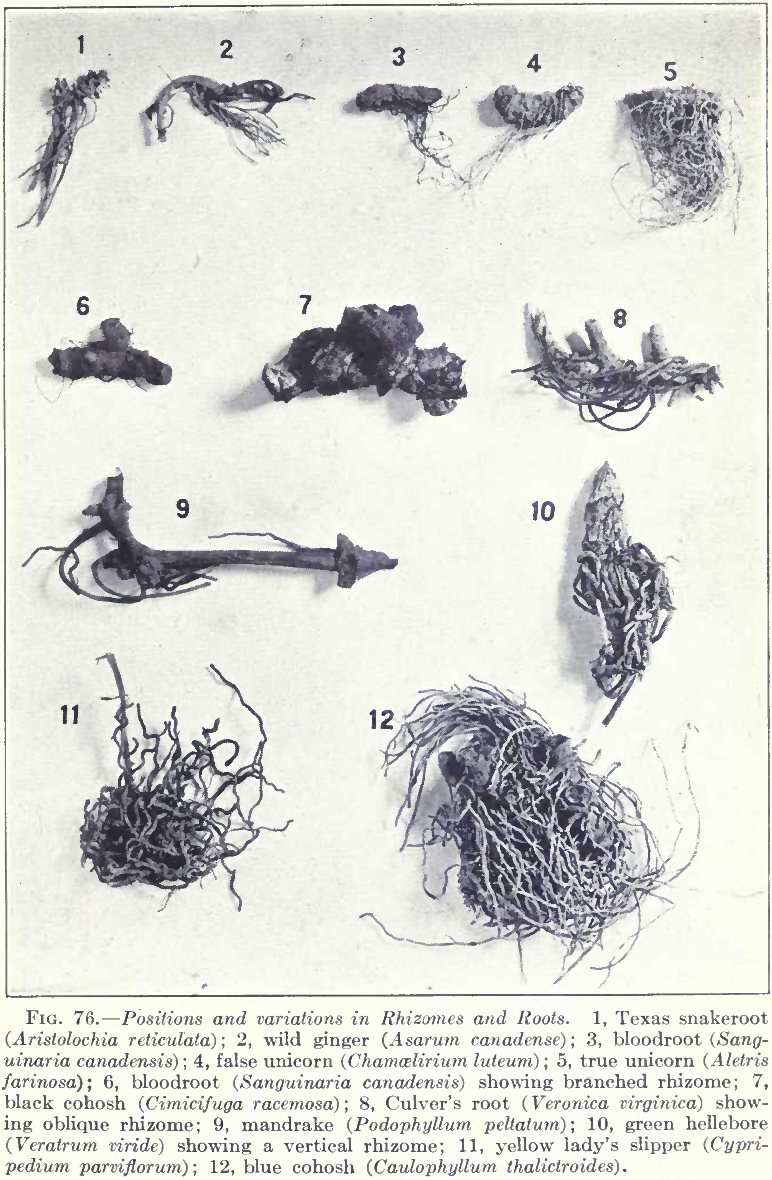

FIG. 76.—*Positions and variations in Rhizomes and Roots.* 1, Texas snakeroot (*Aristolochia reticulata*); 2, wild ginger (*Asarum canadense*); 3, bloodroot (*Sanguinaria canadensis*); 4, false unicorn (*Chamælirium luteum*); 5, true unicorn (*Aletris farinosa*); 6, bloodroot (*Sanguinaria canadensis*) showing branched rhizome; 7, black cohosh (*Cimicifuga racemosa*); 8, Culver's root (*Veronica virginica*) showing oblique rhizome; 9, mandrake (*Podophyllum peltatum*); 10, green hellebore (*Veratrum viride*) showing a vertical rhizome; 11, yellow lady's slipper (*Cypripedium parviflorum*); 12, blue cohosh (*Caulophyllum thalictroides*).

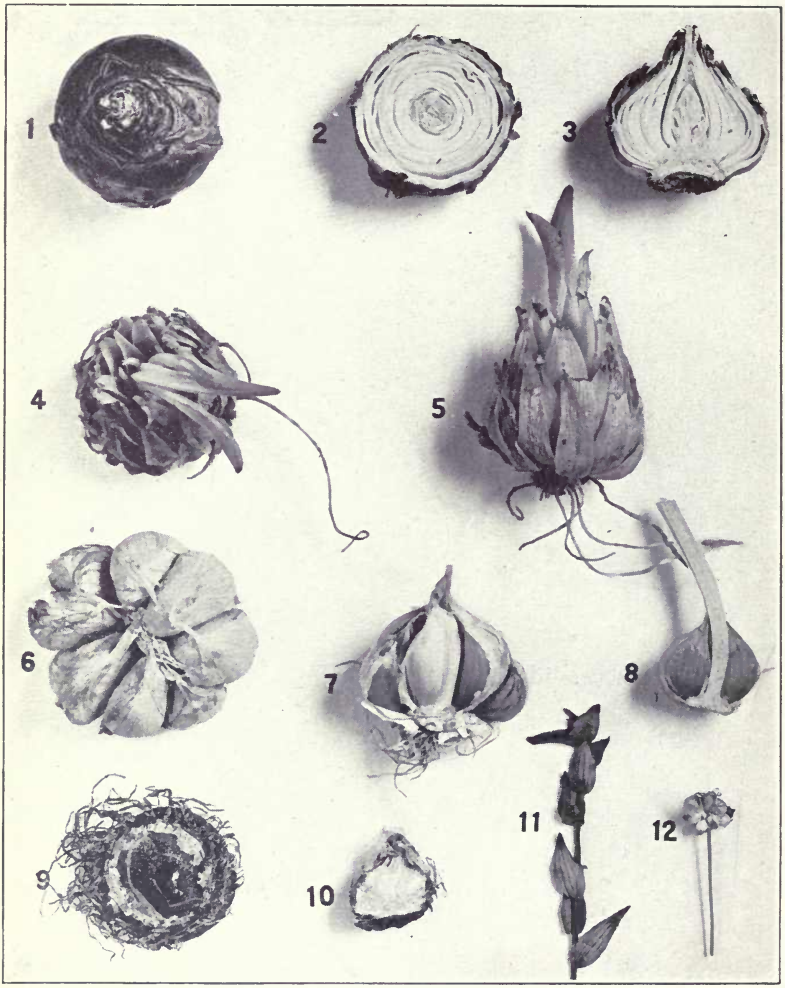

FIG. 77.—*Bulbs.* 1, 2, 3, tunicated bulbs of hyacinth (*Hyacinthus orientalis*); 4, 5, scaly bulb of lily (*Lilium sp.*); 6, 7, 8, compound bulb of garlic (*Allium sativum*); 9, 10, corm of Indian turnip (*Arisæma triphyllum*); 11, axillary bulb of tiger lily (*Lilium tigrinum*); 12, Apical bulbs of wild garlic (*Allium canadense*).

stems which grow upon or under the soil. They are divided into nodes and internodes: From the nodes grow leaves, stems and roots; *types of rhizomes*, rhizomes that grow erect are *vertical*, those that grow parallel to the soil are *horizontal*, those that grow at an oblique angle are *oblique*; *nature of rhizome*, rhizomes are *simple* when they do not branch, but *branched* when lateral buds develop into branches.

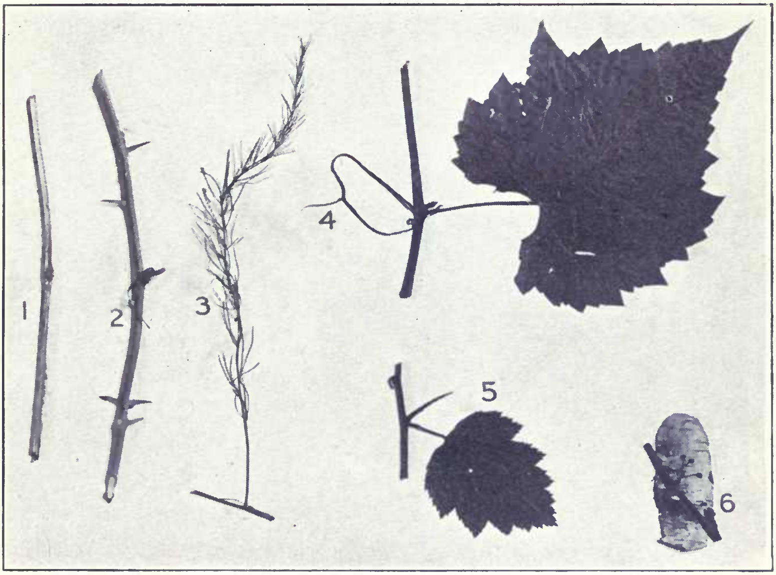

FIG. 78.—*Modified Stems.* 1, Tear-thumb (*Polygonum arifolium*) with small hook-shaped prickles; 2, wild smilax (*Smilax rotundifolia*) with large prickles; 3, asparagus (*Asparagus officinalis*) with leaf-like divisions of the stem; 4, wild grape (*Vitis æstivalis*) with stem modified as tendril; 5, hawthorn (*Cratægus coccinea*) with a stem modified as a thorn; 6, Virginia creeper (*Parthenocissus quinquefolia*) with a stem modified as a tendril with enlarged discs.

2. *Bulbs.*—*Bulbs* are fleshy storage stems and are classified as *scaly*, *tunicated*, *solid* and *compound*. The *scaly bulb*, as that of the lily, is made up of numerous separate fleshy

imbricated scales surrounding a central bud or growing point. The *tunicated bulb*, as that of the onion, is composed of a great number of concentric fleshy scales. The *solid bulb* or corm is a bulb in which the scales have coalesced to form a solid structure, as in colchicum and gladiolus. The *com-*

FIG. 79.—*Direction of Growth.* 1, Erect (*Lobelia inflata*); 2, ascending branches of *Viburnum acerifolium*; 3, decumbent (*Veronica officinalis*); 4, procumbent, partridge berry (*Mitchella repens*); 5, repent, cinquefoil (*Potentilla pumila*).

pound bulb, as that of the garlic, is made up of a number of small bulbs arranged upon a flat disc-like rhizome.

Aërial Bulbs or Bulblets.—Aërial bulbs occur as *axillary bulbs* in the axils of the leaves of tiger lily. In onion the flowers are often replaced by *apical bulbs.*

3. *Tubers.*—Tubers are thick, fleshy underground stems like the potato. Like the bulbs they serve chiefly as storage organs to provide food for the year's growth.

Other Modified Stems.—Although in the cactus the stem is leafless it manufactures food because of the presence of chlorophyll. In asparagus the leaves are reduced to scales but the stem divides into small sections which are green and leaflike and which function as leaves. In hawthorn the stem is modified to *thorns* which in some species become branched like true stems. In the grape many of the lateral stems become modified to *tendrils* which enable the plant to climb frequently to great heights. In Virginia creeper the ends of the tendril-like stems form into disks which adhere to the bark of trees and enable the plant to climb; as the woodbine grows older, however, aërial roots develop and penetrate the bark, and the disc-like stems disappear.

Direction of Growth.—Plants, like lobelia, that assume a vertical position are *erect*; when, like the branches of viburnum, they grow obliquely upward they are *ascending*; when, like veronica, the plant grows along the ground but with the growing tip directed obliquely upward, it is *decumbent*; when, like partridge vine, the entire stem lies flat upon the ground it is *procumbent.* When, like wild strawberry, the stem grows along the ground and develops roots at the joints, it is *repent*; when, like mandrake, the stem grows under the ground it is *subterranean.*

Duration.—Stems, such as herbs, that live for one year are *annual,* those that live for two years are *biennial* while those that live for several years, like the stems of woody plants, are *perennial.*

Texture.—Stems are *fleshy* when the parenchymatic tissue exceeds in amount the other tissues, *fibrous* when they have considerable mechanical tissue such as bast and woody fibers and *woody* when they contain more wood fibers than other cells.

FIG. 80.—*Twining Stems.* 1, Great bindweed (*Convolvulus sepium*); 2, hog peanut (*Falcata comosa*).

Color.—Stems are green, yellow, purple, red and brown, and in addition there are dozens of shades and tints. The color of the stems of herbs will vary somewhat with the season. In the fall particularly, the stems are frequently highly colored.

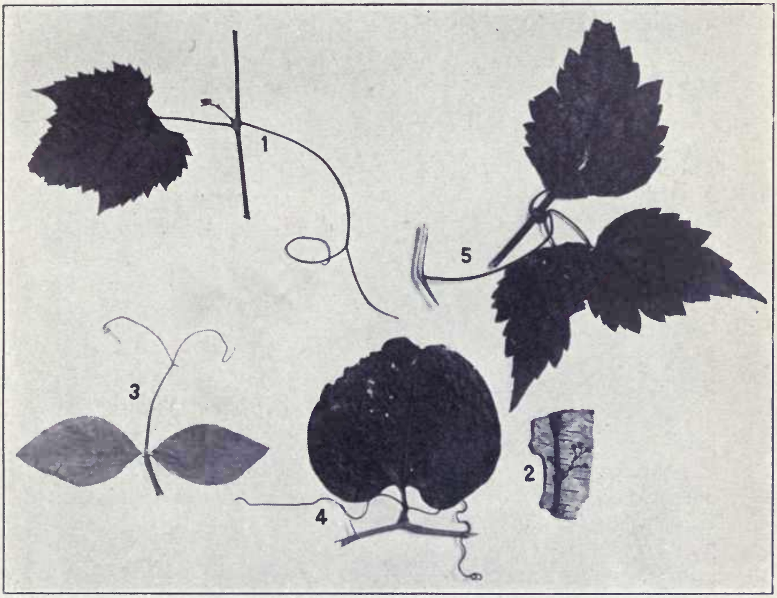

FIG. 81.—*Climbing Plant.* 1, Wild grape (*Vitis æstivalis*); 2, Virginia creeper (*Parthenocissus quinquefolia*); 3, sweet pea (*Lathyrus odoratus*); 4, wild smilax (*Smilax rotundifolia*); 5, virgin's bower (*Clematis virginiana.*)

The color of the stems of woody plants will vary greatly according to the age of the shrub or tree. In white birch, for example, the young branches are of a brilliant metallic red, but, as the tree grows older, the red becomes replaced by gray and finally by white bark. In linden the young twigs are lighter in color than the older forms. In practically every form the color of the stem will show a decided variation at different periods of its life history.

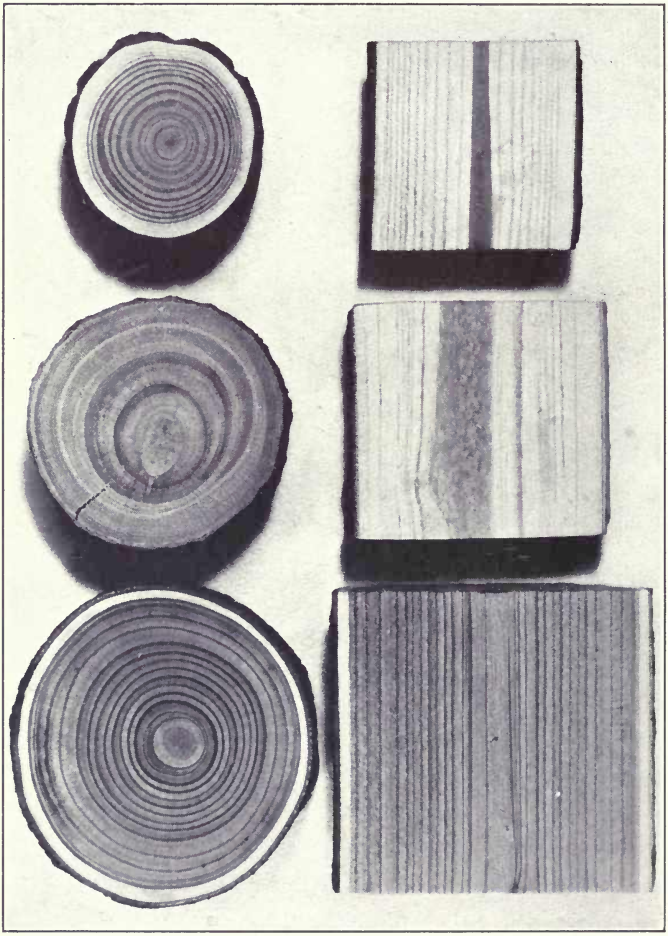

FIG. 82.—*Woody Stems.* Upper figures are cross and longitudinal sections of sassafras (*Sassafras Sassafras*). The middle figures are ailanthus (*Ailanthus glandulosa*). The lower figures are staghorn sumac (*Rhus hirta*). All the figures at the left show the central pith and annual rings. Staghorn sumac shows the dark heart wood and light sap wood. The figures at the right show the annual growth as parallel lines.

Surface.—The surface is *smooth* when there are no outgrowths; *spiny* when there are spines; *channeled* when the

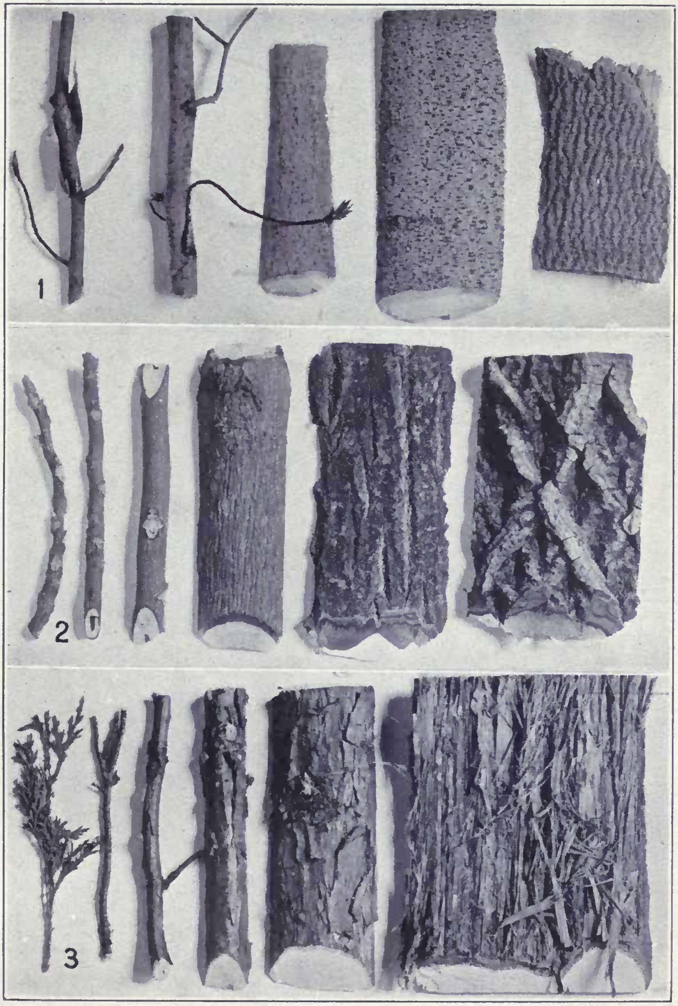

FIG. 83—*Barks.* 1, *Smooth bark*, beech (*Fagus grandifolia*); 2, *rough bark*, butternut (*Juglans cinerea*); *scaly bark*, red cedar (*Juniperus virginiana*).

internodes have deep parallel depressions and elevations; *winged* when the cortex grows out as a narrow prominent ridge as in broom tops; *hairy* when the surface is covered with hairs. The surface of trees is smooth, rough or scaly.

Fractures.—Some stems are too fibrous to be fractured; most stems, however, can be broken and their fracture is similar to the fracture of roots.

Outline of Sections.—Sections are circular, triangular, quadrangular, irregular or fluted in outline.

FIG. 84.—Strikingly colored bark of sycamore or buttonwood (*Platanus occidentalis*), the light portions showing where the old bark has scaled off.

Gross Internal Structure.—The study of the stem would not be complete without examining its cross section. In most stems the cortex, wood and pith are clearly seen. In herbaceous stems the pith makes up the greater part of the stem, while in woody stems the pith is greatly reduced and the wood makes up the bulk of the stem. In all cases observe carefully the diameter, color and markings of the cortex, wood and pith, and in addition observe whether the cambium zone is distinct and carefully note its color.

Odor.—Many stems are odorless, others have very pronounced odors. In all cases the odor is characteristic of the plant.

Taste.—Many stems are tasteless; most stems, however, have a very characteristic taste. Like roots, the most common tastes are mucilaginous, starchy, sweet, bitter, astringent, pungent, acrid, tingling and aromatic. If the stem has only one taste it is simple; if it has more than one taste it is complex.

CHAPTER XII.

BUDS AND LEAVES

BUDS

Buds are classified according to their nature, class, position, arrangement and relation to the stem.

Nature.—Buds are either (1) scaly or (2) scaleless.

1. *Scaly Buds.*—Most buds are protected by several layers of imbricate scales. These scales are frequently quite leaflike in structure, and differ greatly in form and size, even on the same bud. The outer scales, as in horse-chestnut, are short and broad, while the inner scales are much larger and are longer than broad. In the study of buds the number and rows of scales should be considered. Scales are *smooth* when they are free from outgrowths; *resinous* when they are coated with resin, as in horse-chestnut and balm of gilead; *hairy* when the epidermis develops hairs. When a scaly bud finally develops into a leaf or flower, the scales fall away from the twig and leave *scars* which clearly mark the location of the bud and which may be utilized to determine the age of the twig. The space from the apical or lateral bud to the first ring of scars represents one year's growth, to the second ring of scars two year's, to the third three year's, etc.

2. *Scaleless Buds* are not common in northern climates; in the tropics, however, many plants develop buds without an outer protective scaly covering.

Classes.—There are three classes of buds, namely; *leaf-buds*, *flower-buds* and *mixed buds*. Leaf-buds contain one or more rudimentary leaves; flower buds contain only a rudi-

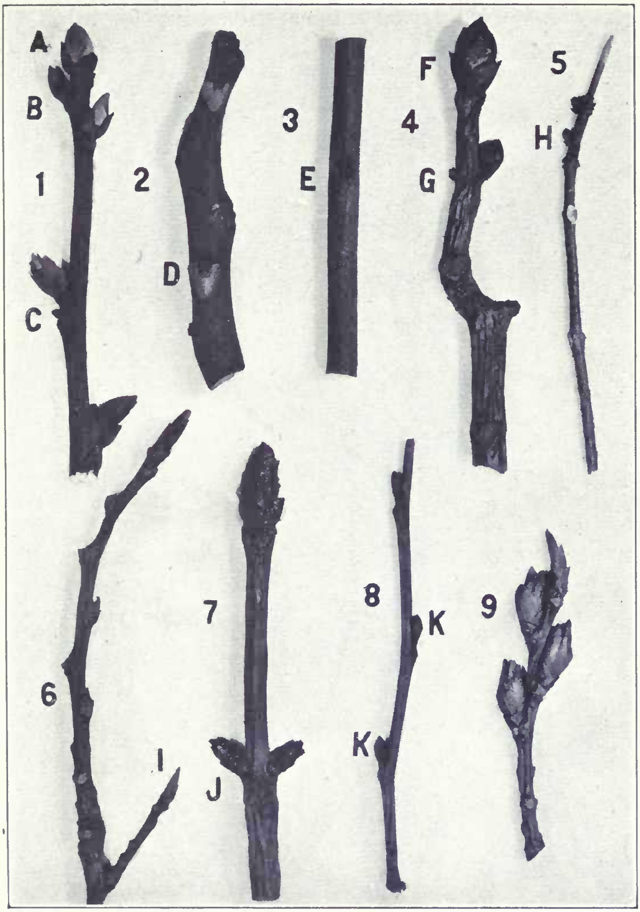

FIG. 85.—*Buds.* 1, *Hicoria alba* showing (*A*) terminal and hairy bud; (*B*) divergent bud; (*C*) accessory superposed bud; 2, *Ailanthus glandulosa* showing scaleless bud at (*D*); 3, Acer rubrum showing accessory collateral buds at (*E*); 4, *Œsculus hippocastanum* showing resinous bud at (*F*) and a dormant bud at (*G*); 5, *Acer rubrum* showing adventitious bud at (*H*); 6, *Populus deltoides* showing lateral bud at (*I*); 7, *Œsculus hippocastanum* showing opposite buds at (*J*); 8, *Alnus incana* showing stalked buds at (*K*); 9, *Populus deltoides* showing alternate arrangement and sessile buds.

mentary flower or flower cluster; mixed buds contain both leaves and flowers.

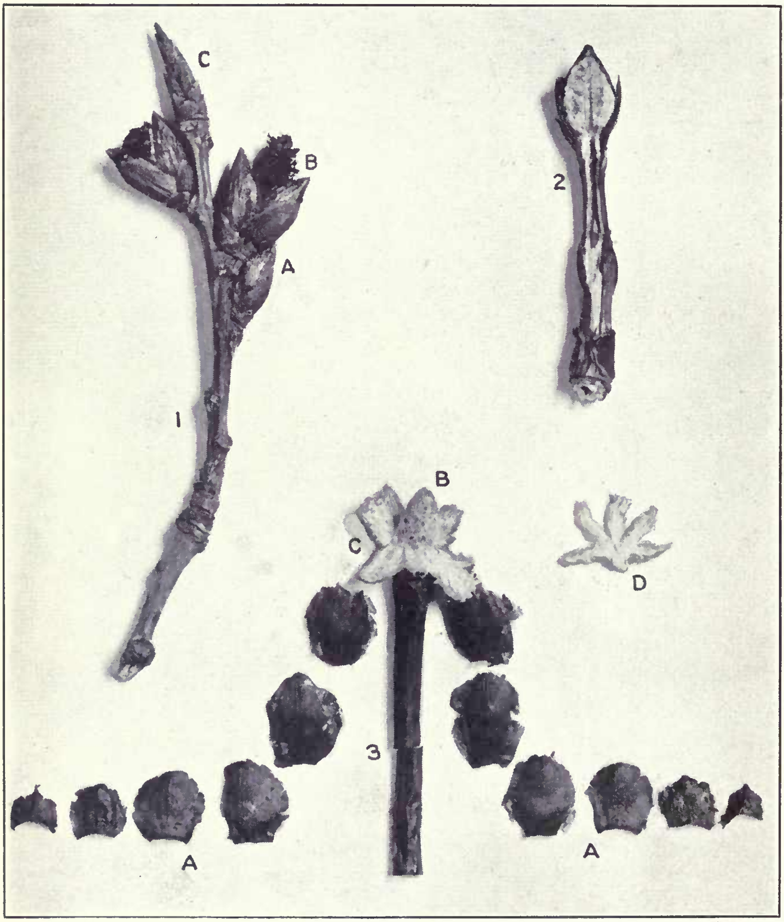

FIG. 86.—*Buds.* 1, *A*, Flower bud; *B*, open flower bud; *C*, leaf bud, all of Carolina poplar (*Populus deltoides*); 2, 3, mixed bud—leaf and flower bud of horse-chestnut, dissected to show *A*, the twelve outer resinous scales; *B*, flower bud; *C*, four rudimentary leaves covered with white hairs; *D*, young palmate leaf with five lobes.

It is not always possible to distinguish between a leaf bud, a flower bud and a mixed bud. Most leaf buds are readily differentiated from the flower buds because longer and of a smaller diameter.

Horse-chestnut has a typical mixed bud. The leaves are covered with a dense mat of white hairs and they surround and cover the larger flower bud.

Position.—Classified according to position, buds are apical, lateral, axillary, accessory, latent and adventitious.

The bud is *apical* when it terminates the stem as in horse-chestnut; it is *lateral* if it occupies the apex of a short branch; it is *axillary* when it occurs at the side of the stem and in the axil of the leaf, as in white ash, where the leaf scar is seen immediately below the bud; it is *accessory* when more than one bud occurs in the axil of the leaf, as in red maple.

The accessory bud is *superposed* if it is above the primary bud and *collateral* if it is at the side of the primary one; a bud is *dormant* or *latent* when it remains in the bud condition during the growing season or for several growing seasons but in an emergency, as when the normal buds are destroyed, it may develop into a leaf or flower according to its class. Finally, the bud is *adventitious* if it develops from the internodes or outside of the leaf axil.

Arrangement.—Buds, like stems, may be alternate, opposite or whorled.

Relation to the Stem.—The bud is *sessile* if it is attached directly to the stem, and *stalked* if it is attached to the stem by a stalk. If the bud is in close contact with the stem, as in ailanthus, it is *appressed;* if it projects more or less, as in shagbark hickory, it is *divergent;* if it is below the level of the surface of the stem, as in northern prickly ash, it is *sunken*.

LEAVES

Origin.—Leaves originate at the nodes from the leaf buds. The conducting strands of the veins are branches of the con-

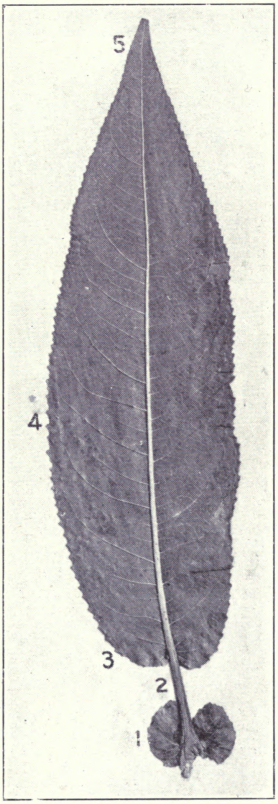

FIG. 87.—*Typical Leaf.* Willow (*Salix cordata*); 1, stipules; 2, petiole; 3, base; 4, margin; 5, apex.

ducting strands of the stem and the leaf epidermis appears as a continuation of the epidermis of the stem from which it originates. The tissues of the leaf are modified and arranged in such a manner that it is possible for the leaf to manufacture the food for the growing plant.

Parts of a Typical Leaf.—The point of attachment of the leaf to the stem is the *pulvinus*. The tissues at this point are modified for the purpose of separating the leaf from the

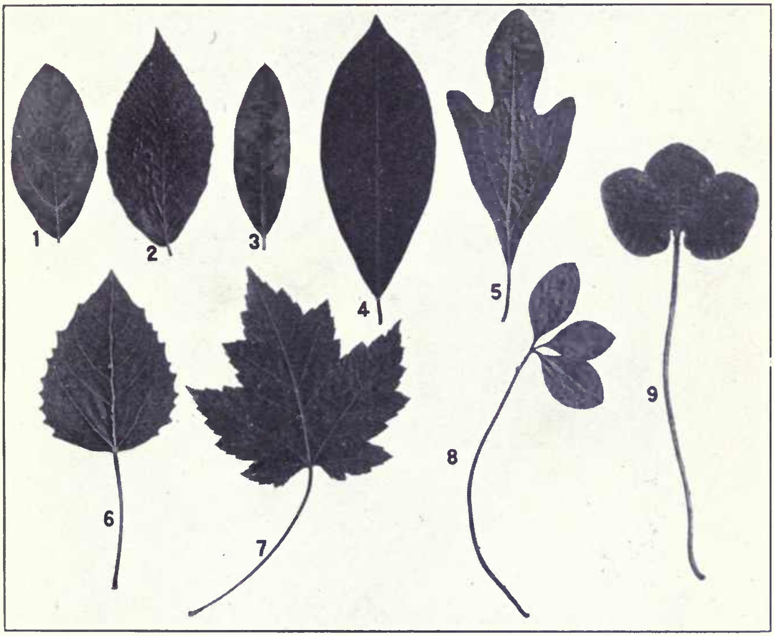

FIG. 88.—*Petioles*. Figures showing the comparative length of petioles of different leaves.

stem and healing the wound caused by such separation. *Stipules* are leaflike expansions of the petiole. In red clover, pea, and rose they are very characteristic; many leaves have no stipules. The stemlike part of the leaf is the *petiole;* the broad expanded part of the leaf is the *blade;* the part of the blade in contact with the petiole is the *base;* the outer edge of the blade is the *margin;* the end of the blade is the *apex;* the part of the blade normally exposed to the sun is the upper

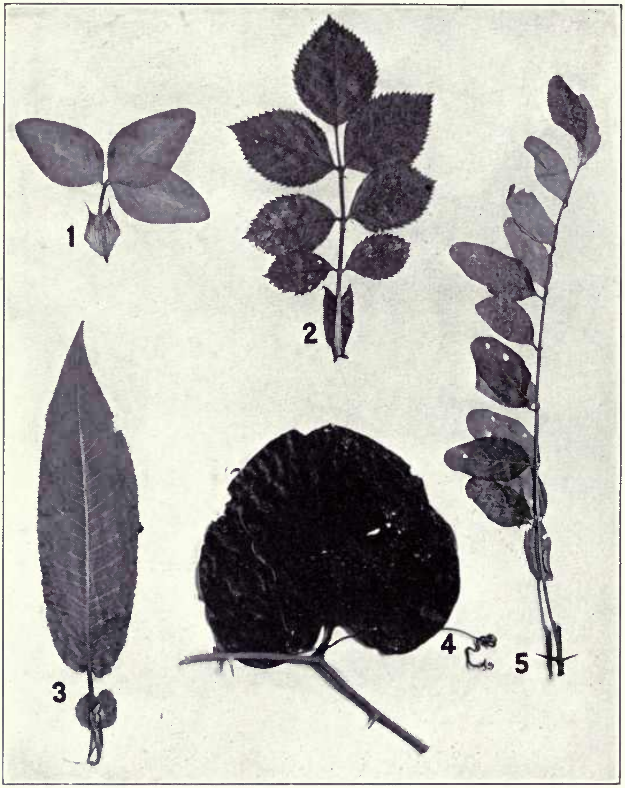

FIG. 89.—*Stipules and Modified Stipules.* 1, Red clover (*Trifolium pratense*); 2, rose (*Rosa Sp.*); 3, willow (*Salix cordata*); three forms of leafy stipules; 4, smilax (*Smilax rotundifolia*) with tendril stipules; 5, black locust (*Robinia Pseudo-acacia*) with thorn stipules.

or *ventral surface;* the surface not normally exposed to the light is the under or *dorsal surface.* The veins are usually more prominent on the dorsal surface.

Petioles.—The petioles of leaves vary greatly in length, width, color and outline. The *length* and *width* of the petiole vary in every species of plant, but in each the maximum length is fairly constant. The *color* of the petiole varies in

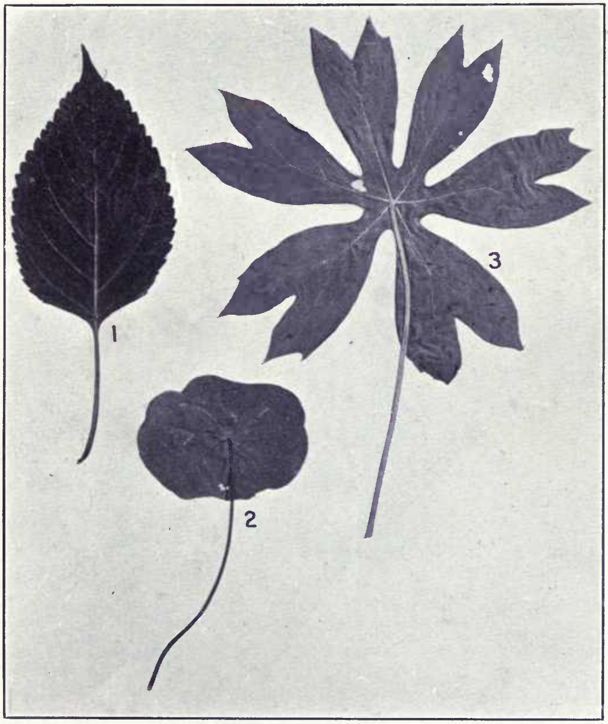

FIG. 90.—*Attachment of Petiole to Blade.* 1, Stoneroot (*Collinsonia canadensis*) normal attachment; 2, nasturtium (*Tropæolum majus*); 3, mandrake (*Podophylum peltatum*) peltate attachment.

different plants, being like the blade, more highly colored in spring and autumn. The *outline of sections* of the petiole may be circular, rectangular, oval, etc.

If the upper surface of the petiole is *sunken* below the surface it is *channeled;* it is *margined* if either side is bordered with bladelike tissue, as in digitalis; it is *laterally compressed* in the leaves of various species of poplar. Leaves with petioles are said to be *petioled;* those without petioles are *sessile.*

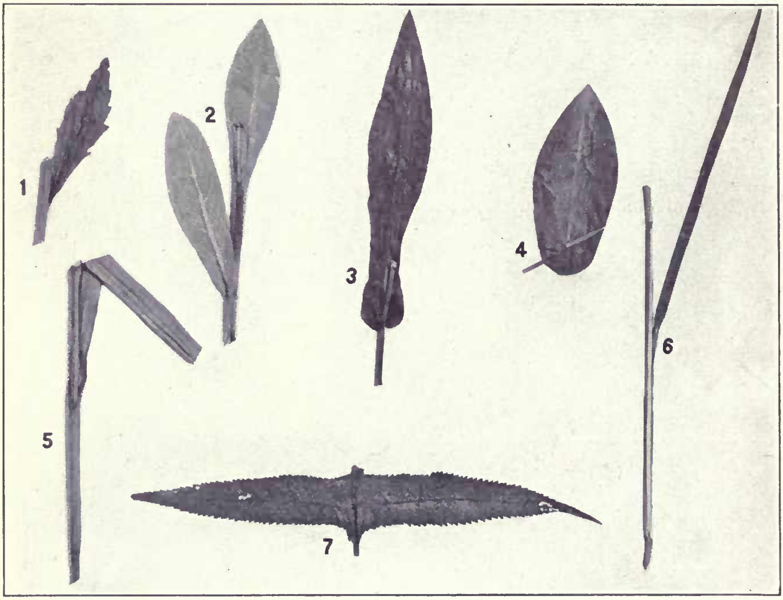

FIG. 91.—*Relation of Sessile Leaves to the Stem.* 1, Fleabane (*Erigeron canadensis*) normal attachment; 2, mullein (*Verbascum thapsus*) decurrent; 3, aster (*Aster phlogifolius*) amplexicaul; 4, bellwort (*Uvularia perfoliata*) perfoliate; 5, sedge (*Scirpus atrovirens*), closed sheath; 6, grass, open sheath; 7, boneset (*Eupatorium perfoliatum*), connate-perfoliate.

Attachment of the Peticle to the Blade.—The attachment is *normal* when the base of the blade is attached to the petiole; it is *peltate* when the petiole is attached to about the center of the dorsal surface, as in the nasturtium and mandrake.

Stipules.—Stipules vary greatly in different species. In willow they are scalelike, in red clover and tulip-tree leaflike.

In fact, most stipules have a structure and function similar to those of leaves. In smilax the stipules are modified as *tendrils;* in black locust the stipules are modified as *thorns* and these thorns are persistent for several years.

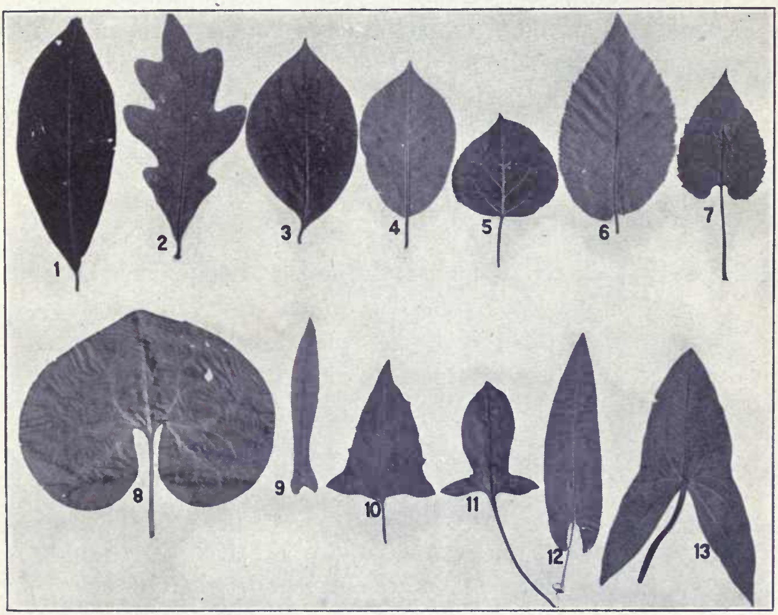

FIG. 92.—*Forms of Bases.* 1, Acute, spicebush (*Benzoin æstivale*); 2, cuneate, white oak (*Quercus alba*); 3, acute, dogwood (*Cornus Florida*); 4, obtuse, choke-cherry (*Prunus virginiana*); 5, truncate, poplar (*Populus tremuloides*); 6, oblique, slippery elm (*Ulmus fulva*); 7, cordate, aster (*Aster cordifolius*); 8, reniform, wild ginger (*Asarum canadense*); 9, auriculate, aster (*Aster novæ-angliæ*); 10, hastate, pigweed (*Chenopodium album*); 11, hastate, sheep sorrel (*Rumex Acetosella*); 12, sagittate, tear-thumb (*Polygonum sagittatum*); 13, sagittate, arrowhead (*Sagittaria latifolia*).

Relation of the Blade of Sessile Leaves to the Stem.—The attachment of sessile leaves to the stem is *normal* if the base of the blade is grown fast to the stem, as in Erigeron; it is *decurrent* if the blade is attached to the stem for a considerable distance, as in mullein; it is *amplexicaul* or clasping if the blade more or less completely surrounds the stem at the point of attachment, as in New England aster; it is *perfoliate* when the base of the blade grows together around the stem, as in bellwort; it is *connate-perfoliate* when opposite leaves cohere and surround the stem, as in boneset; it is an *open sheath* when the part below the blade surrounds the stem, often as far as the next node, but the margins are not grown together; it is a *closed sheath* when its margins are grown together around the stem.

Forms of the Base.—The base is *acuminate* when the blade tapers sharply into the petiole, as in spicebush; it is *cuneate* when it gradually tapers into the petiole and appears wedge-shaped, as in white oak; it is *acute* when it forms a sharp angle, as in dogwood; it is *obtuse* when it is blunt or rounded, as in wild cherry; it is *truncate* when it ends abruptly, the edge being nearly at right angles to the petiole, as in the aspen; it is *oblique* when it extends for a greater distance along one side of the petiole than the other, as in the elm; it is *cordate* when two rounded basal lobes extend below the point of attachment of the petiole, as in wild aster; it is *reniform* when the basal lobes are larger and broader than in the cordate form, the leaf being broader than long, as in wild ginger; it is *auriculate* when the lobes are small and rounded, as in aster; it is *hastate* when the two sharp pointed, basal lobes of the leaf point outward, as in pigweed and sorrel; and finally the base is *sagittate* when the basal lobes of the leaf point downward, as in tear-thumb and arrowhead.

Forms of the Margin.—The margin is *entire* if it is not divided or indented in any way, as in sassafras; it is *repand* when the margin is wavy, as in witch-hazel; it is *sinuate* when the undulate indentations are deep, as in chestnut oak; it is *crenate* when the margin has numerous rounded divisions separated by acute sinuses, as in catnip; it is *dentate* when the margin has numerous sharp pointed divisions and rounded sinuses, as in chestnut; it is *spinose* when the divisions end in a spine and are separated by rounded sinuses, as in holly;

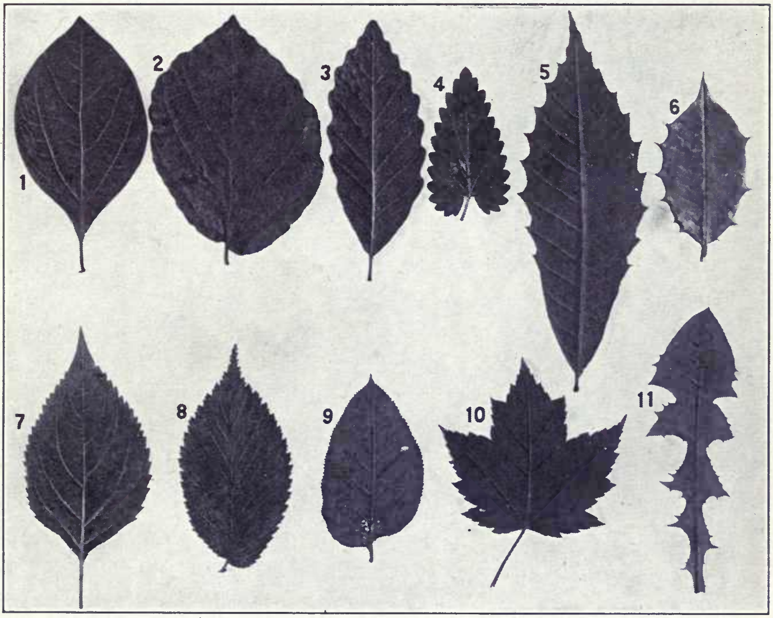

FIG. 93.—*Forms of Margin.* 1, Entire, sassafras (*Sassafras Sassafras*) 2, repand, witch-hazel (*Hamamalis virginiana*); 3, sinuate, chestnut oak (*Quercus prinus*); 4, crenate, catnip (*Nepeta cataria*); 5, dentate, chestnut (*Castanea dentata*); 6, Spinose, holly (*Ilex opaca*); 7, serrate, stoneroot (*Collinsonia canadensis*); 8, doubly serrate, slippery elm (*Ulmus fulva*); 9, serrulate, wild sarsaparilla (*Aralia nudicaulis*); 10, incised, red maple (*Acer rubrum*); 11, runcinate, dandelion (*Taraxacum officinale*).

it is *serrate* when the divisions and the sinuses are acute, as in stone root; it is *doubly-serrate* when each acute tooth is again divided into one or two smaller teeth, as in slippery elm; it is *serrulate* when serrate with diminutive teeth, as in wild sarsaparilla; it is *incised* when the divisions are sharp and of variable size as in sugar maple; and it is *runcinate* when the sharp-pointed larger divisions point downward, as in dandelion.

Lobed, Cleft, Parted and Divided Leaves.—The divisions of the margin are of a pinnate type when they extend toward

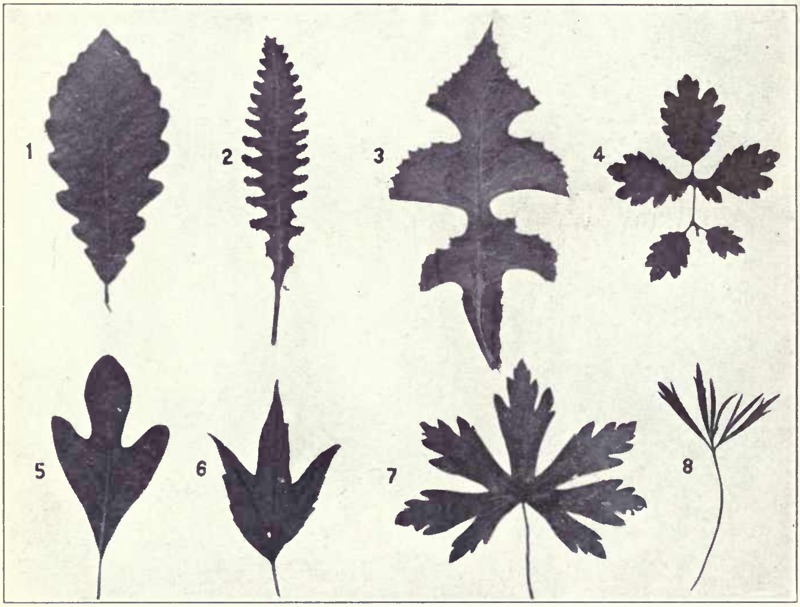

FIG. 94.—*Divisions of the Margins of Leaves.* 1, Pinnately lobed, chestnut oak (*Quercus prinus*); 2, pinnately cleft, lousewort or betony (*Pedicularis canadensis*); 3, pinnately parted, wild lettuce (*Lactuca spicata*); 4, pinnately divided, Celandine (*Chelidonium majus*); 5, palmately lobed, sassafras (*Sassafras Sassafras*); 6, palmately cleft, motherwort (*Leonurus cardiaca*); 7, palmately parted, wild geranium (*Geranium maculatum*); 8, palmately divided, bird's foot violet (*Viola pedata*).

the midrib, and of a palmate type when they extend toward the base. The margin is *lobed* when its divisions extend less than half way toward the midrib, as in the *pinnately lobed* leaf of oak; or less than half way toward the petiole, as in the *palmately lobed* leaf of sassafras; it is *cleft* when its divisions extend about half way to the midrib, as in the *pinnately cleft* leaf of wood betony, or about half way to the petiole, as in the *palmately cleft* leaf of motherwort; it is parted when its divisions extend more than half way to the midrib, as in the *pinnately parted* leaf of wild lettuce, or more than half way to the petiole, as in the *palmately parted* leaf of wild geranium; it is divided when the divisions extend to the midrib, as in the *pinnately divided* leaf of celandine, or to the petiole, as in the *palmately divided* leaf of birdfoot violet.

Forms of the Apex.—The apex is *attenuate* when it tapers gradually to a point, as in wild sunflower; it is *acute* when the apex tapers to form an acute angle, as in beech and dogwood; it is *mucronate* when the apex ends in an abrupt flexible or non-fibrous tip, as in apocynum; the apex is *cuspidate* when it ends in a sharp fibrous point which readily penetrates the skin, as in low juniper and Canada thistle; it is *truncate* when the apex appears as if cut at right angles to the petiole, as in tulip tree; it is *obtuse* when the apex is rounded, as in wintergreen; it is *retuse* when the rounded apex has a shallow notch, as in the leaflet of black locust; it is *emarginate* when the apex is decidedly indented, as in small leaved pilocarpus.

Outline of Simple Leaves.—The outline is *acerose* when it is very narrow and long and of an angled outline, as in white pine; it is *subulate* when the leaf is narrow and short and ends in a sharp point, as in low juniper; it is *linear* when it is long and narrow and of nearly uniform width, as in everlasting; it is *oblong* when the leaf is broad and long and of nearly uniform width, as in milkweed; it is *lanceolate* when it is several times longer than broad and tapers gradually to a point, as in smartweed; it is *falcate* when several times longer than broad, tapering to a point, and curved to one side,

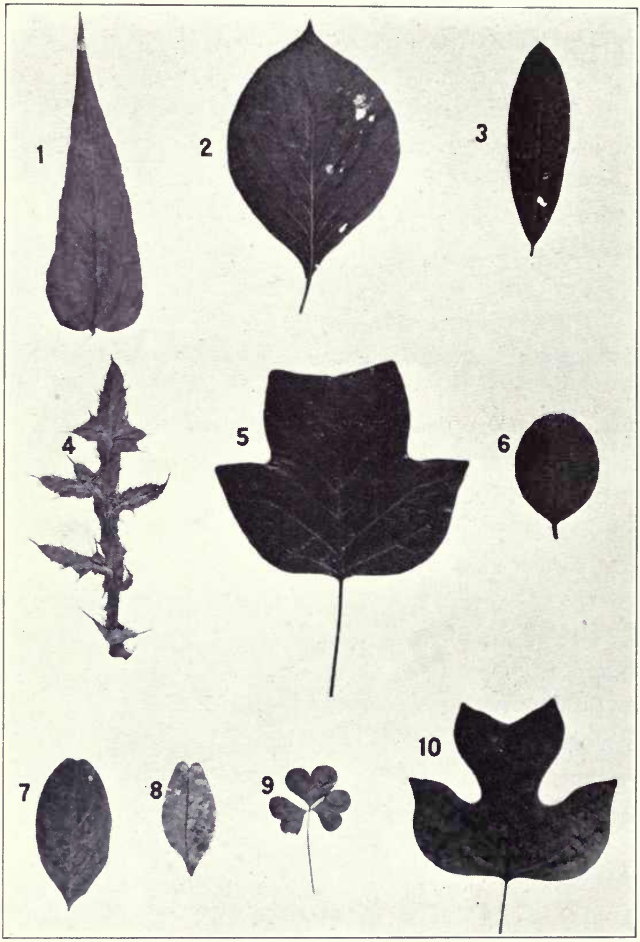

FIG. 95.—*Apex of Leaves.* 1, Attenuate, wild sunflower (*Helianthus divaricatus*); 2, acuminate, flowering dogwood (*Cornus florida*); 3, mucronate, dogbane (*Apocynum cannabinum*); 4, cuspidate, common bur thistle (*Cirsium sp.* 5, truncate, tulip tree (*Liriodendron tulipifera*); 6, rotund, wintergreem (*Gaultheria procumbens*); 7, retuse, black locust (*Robinia Pseudo-Acacia*); 8, emarginate, small-leaf jaborandi (*Pilocarpus microphyllus*); 9, obcordate, wood sorrel (*Oxalis stricta*); 10, notched, tulip tree (*Liriodendron Tulipifera*).

as in eucalyptus; it is *elliptic* when it is nearly twice as long as broad, widest in the center and the margins tapering gradually toward the apex and petiole, as in Canada tick

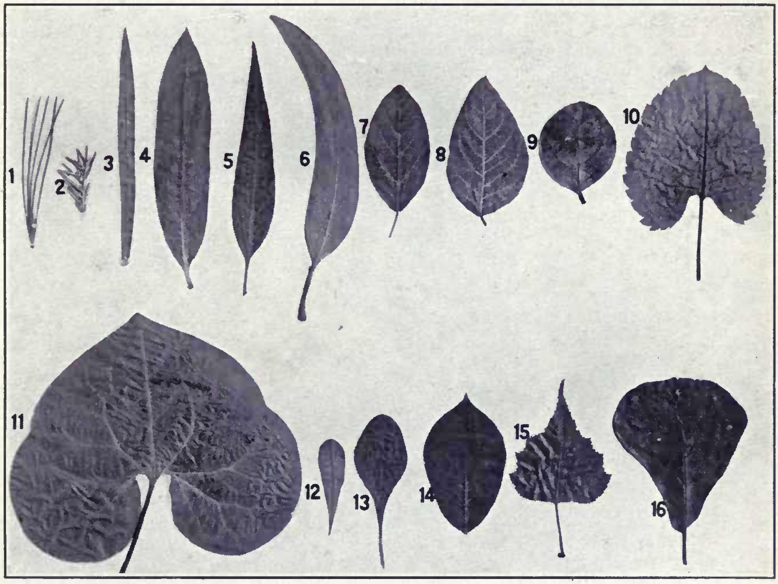

FIG. 96.—*Outline of Simple Leaves.* 1, Acerose, white pine (*Pinus strobus*); 2, subulate, low juniper (*Juniperus nana*); 3, linear, everlasting (*Anaphalis margaritacea*); 4, oblong, common milkweed (*Ascelpias syriaca*); 5, lanceolate, smartweed (*Polygonum hydropiper*); 6, falcate, blue gum (*Eucalyptus globulus*); 7, elliptic, Canada ticktrefoil (*Meibomia canadensis*); 8, ovate, dogbane (*Apocynum androsæmifolium*); 9, rotund, wintergreen (*Gaultheria procumbens*). 10, cordate, aster (*Aster macrophyllus*); 11, reniform, wild ginger (*Asarum canadense*); 12, oblanceolate, lupine (*Lupinus perennis*); 13, spatulate, everlasting (*Antennaria plantaginifolia*); 14, obovate, chokecherry (*Prunus virginiana*); 15, deltoid, gray birch (*Betula populifolia*); 16, cuneate, black oak (*Quercus nigra.*)

trefoil; it is *ovate* when it is rounded at the base, not much longer than broad, and broadest below the center, as in dogbane; it is *rotund* when the blade is nearly circular in outline, as in wintergreen; it is *cordate* when the leaf is longer than broad and there are two large rounded lobes at the base and an apex which tapers gradually to a point, as in aster; it is *reniform* when the leaf is broader than long and has two very

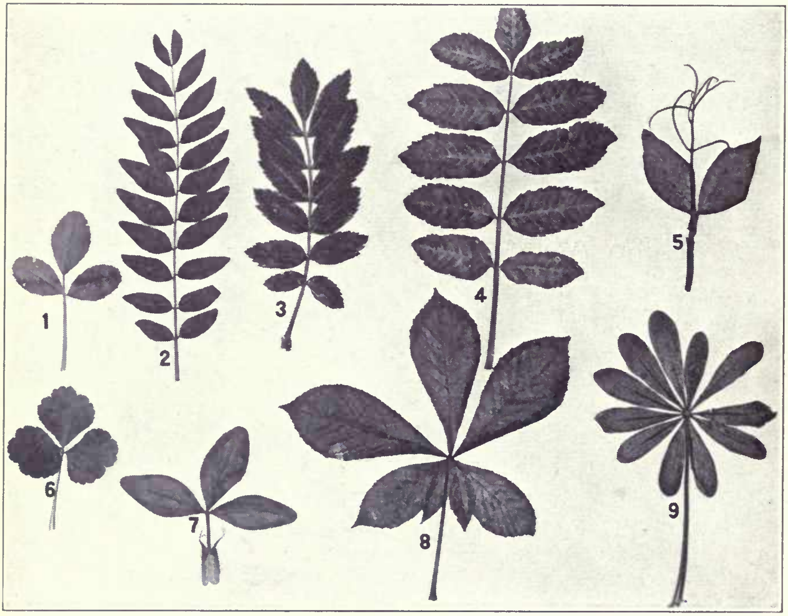

FIG. 97.—*Pinnate and Palmate Leaves Compound.* 1, Trifoliate-pinnate, yellow clover (*Melilotus officinalis*); 2, even-pinnate, black locust (*Robinia Pseudo-acacia*); 3, odd-pinnate, mountain ash (*Sorbus americana*); 4, odd-pinnate, sumac (*Rhus glabra*); 5, tendril-pinnate, sweet pea (*Lathyrus odoratus*); 6, trifoliolate-palmate, gold thread (*Coptis trifolia*); 7, trifoliate-palmate, red clover (*trifoliun pratense*); 8, septa-foliate, horse-chestnut (*Œsculus hippocastanum*); 9, palmate leaf of lupine (*Lupinus perennis*).

large basal lobes, as in wild ginger, it is *oblanceolate* when the apex is broad and rounded and the base tapers gradually into the petiole, as in the leaflet of lupine; it is *spatulate* when the apex is broad and rounded and the base tapers very gradually into the petiole, as in everlasting; it is *obovate* when it is rounded at the apex, not much longer than broad, and broadest above the center, as in chokecherry; it is *deltoid* when the outline is nearly triangular, as in poplar; it is *cuneate* when the apex is broad, nearly truncate, and the margins taper gradually into the petiole, as in barren oak.

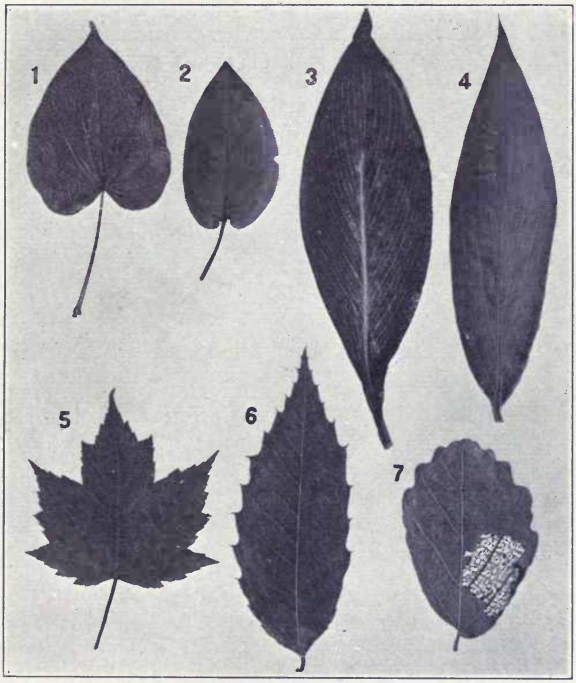

FIG. 98.—*Venation of Leaves. Palmately parallel veined.* 1, Wild yam (*Dioscorea villosa*); 2, two-leaved Solomon's seal (*Unifolium canadense*); *pinnately parallel veined;* 3, garden canna (*Canna sp.*); 4, (*Dracema sp.*), *palmately netted veined;* 5, red maple (*Acer rubrum*), *Pinnately netted veined;* 6, chestnut (*Castanea dentata*); 7, witch hazel (*Hamamelis virginiana*).

Compound Leaves.—A leaf is compound when the blade is separated into two or more parts or *leaflets*. When the leaflets are arranged along a stalk or rachis the leaf is *pin-*

nately compound, as in mountain ash. When a pinnately compound leaf ends in a pair of leaflets it is *even-pinnate*, as in black locust; when it ends in one leaflet it is *odd-pinnate*, as in sumac. In yellow sweet clover there are only three leaflets; in the black locust there are sometimes twenty-two leaflets. In sweet pea the pinnately compound leaf ends in

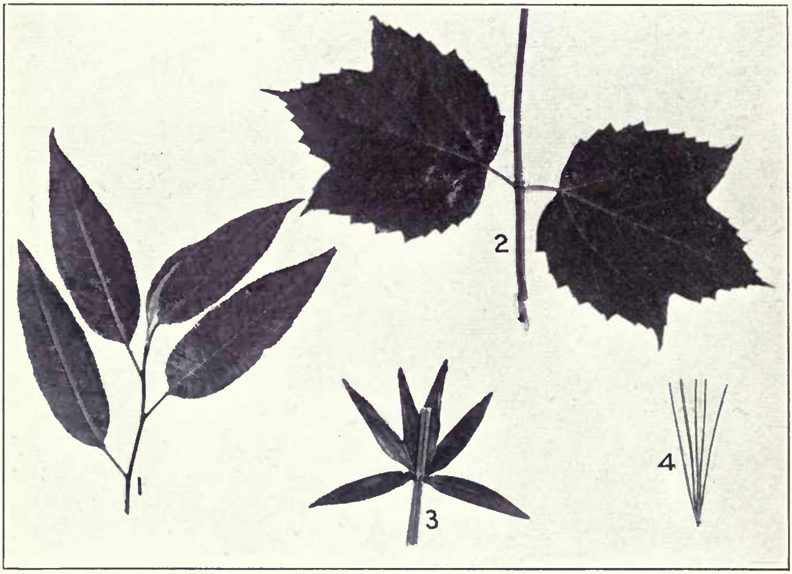

FIG. 99.—*Leaf Arrangement.* 1, Alternate, wild cherry (*Prunus serotina*); 2, opposite viburnum (*Viburnum acerifolium*); 3, whorled, yellow field lily (*Lilium canadense*); 4, fascicled, white pine (*Pinus strobus*).

tendrils. When the leaflets are arranged at the end of the petiole the leaf is *palmately compound;* the number of leaflets varies from three, as in gold thread and red clover, to eleven, as in the palmately compound leaf of lupine.

Forms of Venation.—A leaf is *parallel veined* when the veins run in the same general direction. Leaves in which parallel veins extend from the midrib to the margin of the leaf are *pinnately parallel veined,* as in canna; when the veins originate at the end of the petiole and extend upward and outward to

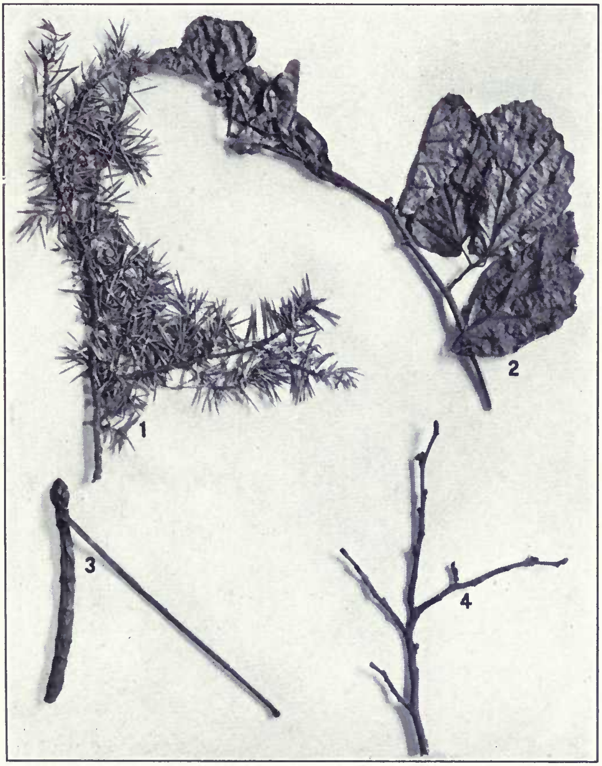

FIG. 100.—*Duration of Leaves.* 1, Evergreen, low juniper (*Juniperus nana*); 2, persistent, witch-hazel (*Hamamelis virginiana*); 3, persistent petiole, horse-chestnut (*Œsculus hippocastanum*); 4, branch of linden (*Tilia americana*) free of deciduous leaves.

the margin of the leaf, it is *palmately parallel veined,* as in wild yam. Leaves are *reticulate* when the veins branch and cohere to form a complete network, as in witch-hazel. Reticulate leaves with the larger veins starting from the midrib, as in chestnut and witch-hazel, are *pinnately reticulate.*

Fig. 101.—*Evergreen Plants.* 1, Prince's pine (*Chimaphilia umbellata*); 2, wintergreen (*Gaultheria procumbens*); 3, shin-leaf (*Pyrola elliptica*); 4, partridge berry (*Mitchella repens*); 5, gold thread (*Coptis trifolia*).

When the larger veins of a reticulate leaf start from the end of the petiole, as in red maple, it is *palmately reticulate.*

Leaf Arrangement.—When one leaf occurs at a node, as in wild cherry, the leaves are *alternate;* when two leaves occur at a node, as in viburnum, the leaves are *opposite;* when

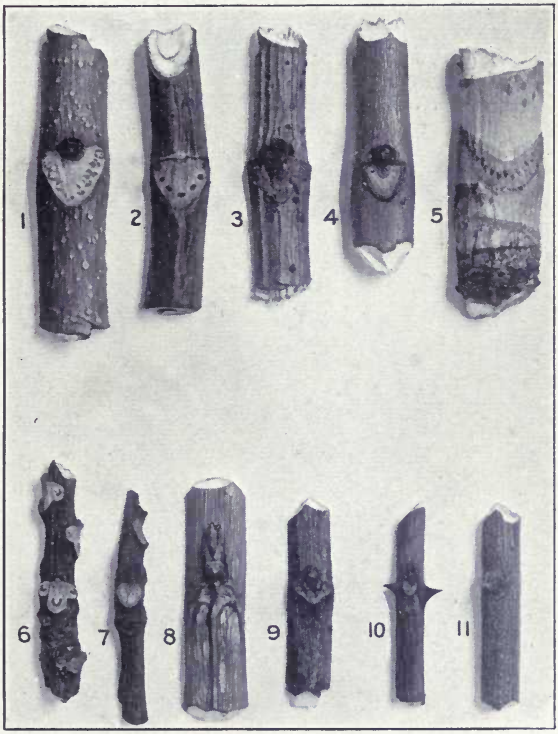

FIG. 102.—*Leaf Scars.* 1, Ailanthus (*Ailanthus glandulosa*); 2, horse-chestnut (*Œsculus hippocastanum*); 3, elder (*Sambucus canadensis*); 4 white ash (*Fraxinus americana*); 5, Hercules' club (*Aralia spinosa*); 6, butternut (*Juglans cinerea*); 7, shagbark hickory (*Hicoria alba*); 8, Carolina poplar (*Populus deltoides*); 9, linden (*Tilia americana*); 10, northern prickly ash (*Xanthoxylum americanum*); 11, staghorn sumac (*Rhus hirta*).

more than two leaves occur at a node, as in yellow field lily, the leaves are *whorled;* when the leaves are grouped in a cluster, as in white pine, they are *fascicled.*

FIG. 103.—*Modified Leaves.* 1, Insect-catching leaves, sundew (*Drosera intermedia*); 2, insect-catching leaves sundew (*Drosera rotundifolia*); 3, Venus flytrap (*Dionæa muscipula*); 4, hollow leaf which becomes filled with water and in which the insect dies, pitcher plant (*Sarracenia purpurea*); 5, hollow leaf serving as a floating organ, water hyacinth (*Piaropus crassipes*).

Duration of Leaves.—In the pine the leaves remain on the tree for two or three years and, since leaves are always present, such trees are called *evergreen*; in the oak the leaves are *persistent* since the dead leaves remain on the tree during the winter; in horse-chestnut and English ivy the blade falls but the *petiole is persistent* for a time. Leaves that fall at the close of the growing season are *deciducus*.

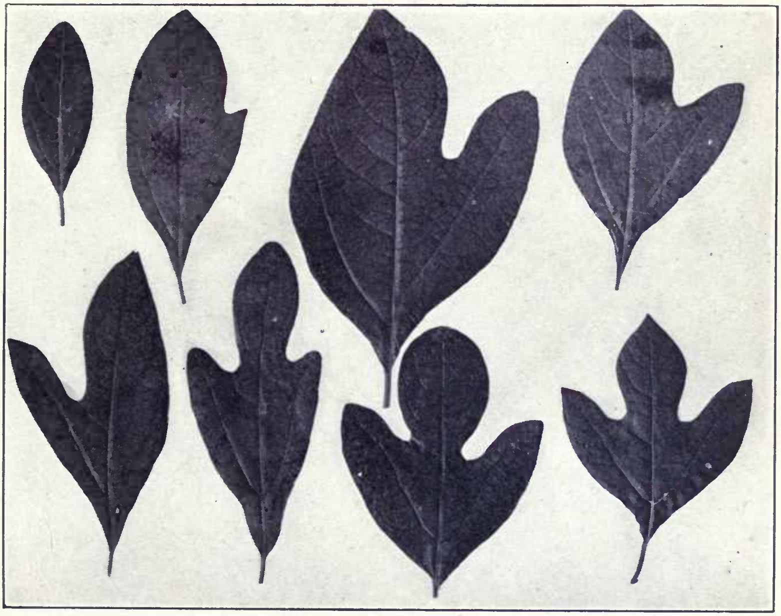

FIG. 104.—*Leaf Variation.* Eight leaves of sassafras (*Sassafras sassafras*), illustrating how leaves of one species may vary.

Leaf Scars.—Leaf scars are extremely variable in form, size, color and number of bundle traces. Leaf scars are in fact so characteristic that it is possible to identify trees and shrubs in winter by means of the leaf scars and buds.

Modifications.—In asparagus the leaves are reduced to minute scales without chlorophyll. In barberry the leaves are modified to form spines. In sundew the leaves are covered with stalked glandular hairs which assist in capturing and digesting insects. In Venus' flytrap the leaves will mechanically close upon an insect and remain closed until the insect

Fig. 105.—*Compound Leaves.* Honey locust (*Gleditsia triacanthos*). Nine figures showing the compounding of leaflets. In the ninth figure the leaf is twice compound or decompound.

is digested. In pitcher plants the leaves are hollow and are usually partly filled with water so that insects falling into the water are drowned and finally utilized as food by the plant. In water hyacinth, the petiole becomes greatly enlarged and serves as a float to keep the plant on the surface of the water.

Texture of the Blade.—The blade is *succulent* when it is thick and fleshy, as in live-forever; it is *coriaceous* when in is thick, fibrous and tough, as in chestnut; it is *membranous* when it is thin and papery in texture, as the leaves of most herbs.

Odor.—In many leaves glandular hairs or internal secreting tissues form odorous compounds, which are frequently of great economic or medicinal value. The oils of peppermint, spearmint, thyme, eucalyptus, catnip and many others are secreted by the leaves and give an aromatic odor to them. Leaves like stramonium and belladonna have a heavy aromatic or narcotic odor; most leaves are *odorless* or have no distinctive odor.

Taste.—All aromatic leaves have characteristic tastes; some are bitter, others astringent, etc.

Color.—To the untrained eye all leaves appear merely green, but, when one observes leaves carefully, there are seen to be innumerable shades of green. The color of the ventral surface is usually darker than that of the dorsal surface and in the poplars the under surface appears nearly white. The leaves of several species of everlasting are silvery white because of the long white hairs which cover the surface. In early spring and fall leaves are usually brilliantly and beautifully colored. Much of the charm of the autumn landscapes is due to the bright colored foliage.

CHAPTER XIII.

INFLORESCENCE

INFLORESCENCE is the arrangement of flowers. There are two types of inflorescence, indeterminate and determinate. In all forms of *indeterminate inflorescence* the lowest flower opens first; therefore, flowers may continue to develop as the stem elongates. In all forms of *determinate inflorescence* the first flower to open is located at the tip of the already mature stem. Such an inflorescence can have only as many additional flowers as there are buds at the time the terminal flower opens.

Parts of an Inflorescence.—The parts of the typical inflorescence are as follows: a *peduncle* or modified stem which bears the flowers; *pedicle* or the stem of the individual flower; a *bract* or modified leaf, in the axil of which the pedicle occurs; and a *flower* which bears the organs of reproduction.

It should be noted that the peduncle, a modified stem, is made up of nodes and internodes and that in some forms the internodes are so far apart that the flowers are separated, as in the raceme of digitalis. The *peduncle* of the spadix of sweet flag is elongated but the internodes have not developed; the nodes and therefore the flowers are close together. In the head of buttonbush the peduncle is spherical and all traces of the internodes have disappeared. In the umbel of milkweed the internodes are undeveloped but the flowers are separated, because each flower has a long pedicle. Other variations will be noted in studying the types of inflorescence.

Indeterminate Inflorescence.—A *spike* is a form in which the peduncle is elongated and the flowers are sessile. A *compound spike* is composed of several spikes formed by a branching peduncle. *Aments* or catkins are short, very

FIG. 106.—*Arrangement of Flowers. Spikes.* 1, Common plantain (*Plantago major*); 2, (*Plantago lanceolata*). *Compound Spike*; 3, blue vervain (*Verbena hastata*). *Aments.* 4, pistillate ament, willow (*Salix sp.*); 5, staminate ament, willow (*Salix sp.*); 6, staminate ament, speckled alder (*Alnus incana*). *Spadix.* 7, sweet flag (*Acorus calamus*); 8, wild calla (*Calla palustris*). *Heads.* 9, buttonbush (*Cephalanthus occidentalis*); 10, red clover (*Trifolium pratense*).

compact inflorescences made up, as in the willows, of either staminate or pistillate flowers, each subtended by a small bract. A *spadix* is a thick fleshy peduncle with reduced internodes bearing sessile flowers, as the inflorescence of sweet flag. The spadix is often, as in wild calla, subtended by a large bract or spathe. A *head* has a nearly spherical peduncle with no perceptible internodes and with closely set sessile flowers, as in buttonbush. The head of clover has a slightly elongated peduncle from which grow numerous flowers.

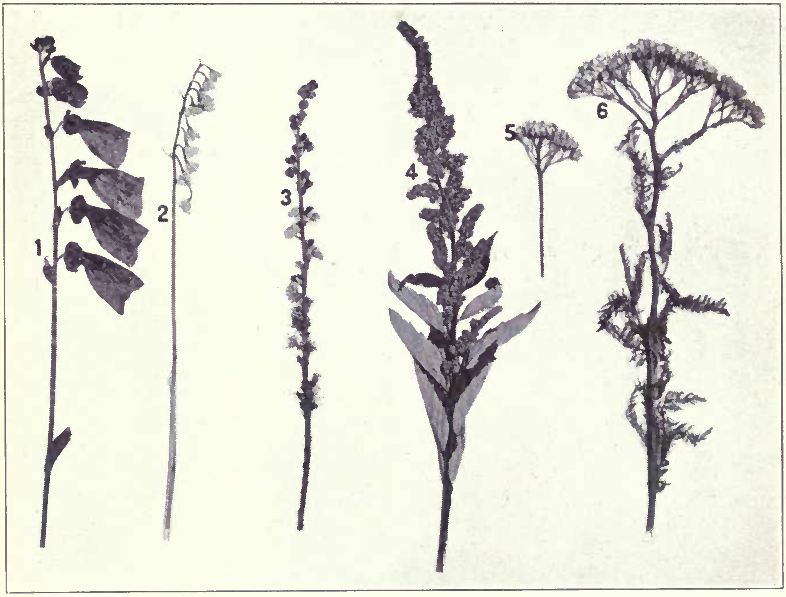

FIG. 107.—*Arrangement of Flowers. Racemes.* 1, Foxglove (*Digitalis purpurea*) with bract subtending the pedicle of each flower; 2, lily of the valley (*Convallaria majalis*); 3, black cohosh (*Cimicifuga racemosa*). *Panicles.* 4, steeple bush (*Spiræa tomentosa*). *Corymb.* 5, yarrow (*Achillea Millefolium*). *Compound Corymb.* 6, yarrow.

A *raceme* has an elongated peduncle with well developed internodes. From the nodes grow bracts and in the axils of the bracts pedicled flowers, as in digitalis, lily of the valley and black haw. A *compound raceme* or *panicle* is made up of several racemes, as in meadowsweet. A *corymb* is an inflorescence in which the peduncle branches and the pedicles are longer below and shorter above, so that the flower cluster is almost flat-topped. A *compound corymb* is composed of several corymbs, as in yarrow. An *umbel* has numerous

FIG. 108.—*Arrangement of Flowers. Umbels.* 1, Common milkweed (*Asclepias syriaca*); 2, wild sarsaparilla (*Aralia nudicaulis*), *Compound Umbels.* 3, water hemlock (*Cicuta maculata*); 4, American angelica (*Angelica atropurpurea*), *Anthodiums.* 5, ox-eyed daisy (*Rudbeckia hirta*), *Rayless Anthodium.* 6, tansy (*Tanacetum vulgare*). *Determinate Infloresence;* Cyme 7, bouncing Betty (*Saponaria officinalis*), *Compound cyme;* 8, mouse-ear (*Cerastium vulgatum*); 9, elder flowers (*Sambucus canadensis*). *Glomerule;* 10, dogwood (*Cornus florida*).

flowers with long pedicles growing from the end of the peduncle, as in milkweed and wild sarsaparilla. A *compound umbel* has numerous small umbels attached to peduncles developing and radiating from the main stem of the plant, as in water hemlock and American angelica. An *anthodium* is the compound inflorescence of the members of the daisy family or compositæ. In ox-eyed daisy the outer modified leaves are involucre scales and make up the involucre; the peduncle ends in the *receptacle* or compound torus which may be solid or hollow, concave or convex, smooth, pitted or hairy. The anthodium may be *rayed,* that is, it may have an outer circle of ray flowers and a central mass of disc flowers as in ox-eyed daisy; or the anthodium may be *discoid* or without ray flowers as in tansy.

Determinate Inflorescence.—A *cyme* is a determinate inflorescence in which the terminal or central flower of each cluster opens first, as in bouncing Betty. A *compound cyme* is composed of several cymes as in mouse-ear and elder. A *cymose head* or *glomerule* is a compact compound cyme, as in flowering dogwood where the flowers are surrounded by four large white or pink bracts.

CHAPTER XIV.

FLOWERS

FLOWERS are clusters of leaves and stems modified for the purpose of forming the reproductive organs and insuring pollination and fertilization. There are frequently special modifications of the calyx, corolla, andrœcium and gynœcium.

Parts of a Typical Flower.—The stem of the flowers is the *pedicle;* the modified end of the stem which bears the floral organs is the *torus;* the outer or first circle of parts developing from the torus is the *calyx* which is composed of *sepals;* the second circle of the flower is the *corolla* which is composed of *petals;* the third circle is the *andrœcium* and is made up of *stamens;* the fourth or inner circle of the flower is the *gynœcium* and is made up of one or more *pistils* which are composed of one or more *carpels*.

The Torus or Receptacle.—There is a great variation in the size, form, surface and texture of the receptacle in different flowers.

The torus in most flowers is nearly *flat*. The parts have a cyclic arrangement and the parts of each circle alternate, the inner set of parts standing opposite the sinuses of the outer circle or parts, etc. In other flowers the torus is *convex* or *elongated* and the flowers have a spiral arrangement, the sepals being at the base and the pistil at the apex of the spiral. In the rose the pistils are arranged on the sides of the *concave torus*, while the sepals, petals and stamens appear to grow from the upper edge of the torus.

The parts of the torus from which the circles of floral organs grow are the nodes and the spaces between the circles are the internodes.

The internodes may lengthen and separate any of the circles. When the elongation is between the calyx and corolla, it is an *anthophore;* when between corolla and andrœcium, it is a *gonophore;* when between andrœcium and gynœcium, it is a *gynophore;* and when the elongation of the torus elevates the carpels, as in anise and other Umbelliferæ, it is a *carpophore.*

The Calyx.—The sepals, which make up the calyx, are extremely variable in size, form, color and surface in different species of plants. In the typical flower the sepals are green and leaflike in appearance; in the yellow field lily, erythronium and many other species the sepals are similar to the petals and can be distinguished only by their position. When the sepals are not united the calyx is *chorisepalous;* when they are united it is *gamosepalous.* A gamosepalous calyx may and usually does assume many curious forms which will be explained in detail under forms of gamopetalous corollas.

Duration of the Calyx.—The calyx is *caducous* if it falls off shortly after the flower opens, as in bloodroot; it is *deciduous* when it falls after fertilization, as in most flowers; it is *persistent* when it remains and surrounds the fruit, as in Indian tobacco and ground cherry.

The Corolla.—The corolla which consists of *petals,* is the second circle of the flower when four are present and is usually the most conspicuous part of the flower. When the petals are not united the corolla is *choripetalous,* when they are united it is *gamopetalous.* Petals are usually brilliantly colored and sweet scented, because of the presence of volatile secretion products. The corolla also secretes nectar and, when gamopetalous, is extremely variable in form. When a flower has no petals it is *apetalous.*

FIG. 109.—1, Potato (*Solanum tuberosum*); 2, mountain laurel (*Kalmia latiflora*); 3, lily of the valley (*Convallaria majalis*); 4, great bindweed (*Convolvulus sepium*); 5, staggerbush, (*Pieris Mariana*); 6. vaccinium (*Vaccinium sp.*); 7, sweet William (*Cultivated sp.*); 8, wood botany, (*Betonica officinalis*); 9, violet, (*Viola sp.*); 10, wild columbine (*Aquilegia canadensis*); 11, sunflower (*Helianthus sp.*)

Forms of Gamopetalous Corollas.—A gamopetalous corolla is *rotate* when it is nearly flat, as in potato; it is *crateriform* when the united petals are saucer-shaped, as in mountain laurel; it is *campanulate* when the corolla is rounded below, longer than broad and expanded at the mouth, as in lily of the valley, it is *funnelform* when the corolla tapers gradually from the base to a broad, wide mouth, as in great bindweed; it is *cylindric* when terete and of nearly uniform diameter, as in staggerbush; it is *prismatic* when the corolla is angled and of nearly uniform diameter, as in vaccinium; it is *salverform* when the corolla forms a nearly flat limb and is tubular below, as in sweet William; it is *urceolate* when rounded below and slightly constricted near the ununited, expanded and recurved part of the corolla, as in bitter root; it is *bilabiate* when there are two less ununited parts of the corolla, as in wood betony; it is *personate* when the throat of a *bilabiate* corolla is closed by a *palate* or enlargement of the lower lip, as in yellow toad-flax; it is *gibbous* when the corolla is slightly protuberant at one side, as in buttercup; it is *saccate* when the enlargement forms a decided depression or pocket as in violet; it is *spurred* when there is a hollow or tubular extension of the corolla, as in columbine; it is *ligulate* when the corolla is connate around the pistil, but the upper part is flat and ribbon-like, as in sunflower.

The Andrœcium is usually made up of two sets or circles of stamens, so that normally there are as many stamens as there are sepals and petals. Frequently, as in American linden, one set of stamens will divide into several so that several sets appear to be present; in *progressive metamorphosis* change of form and function occurs, the petals changing into stamens, as in marsh marigold, buttercup and Saint John's-wort, so that there are an indefinite number of stamens. In the rose and other flowers under cultivation *retrograde metamorphosis* occurs, the stamens changing into petals with consequent development of double flowers. In

FIG. 110.—St. John's Woert (*Hypericum sp.*) showing progressive metamorphosis.

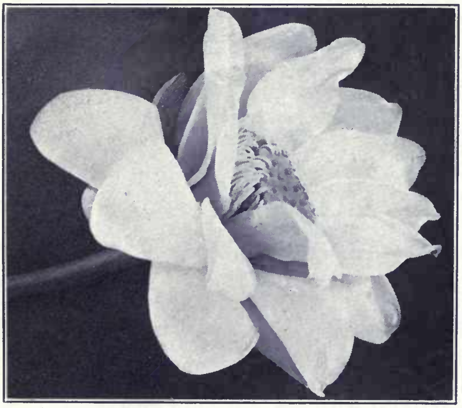

FIG. 111.—White water lily showing retrograde metamorphosis, the stamens changing into petals.

many flowers one set of stamens has been aborted so that only one circle remains.

Parts of the Stamen.—The slender stem-like part of the stamen is the *filament;* the enlarged apical part is the *anther*; each anther has two anther sacs separated by a *connective.* The anther sacs are sporangia bearing the pollen grains or microspores, which upon germination develop into the male gametophyte.

The *dehiscence* or opening of the anther sacs to discharge the spores is accomplished by *sutures* or splits in the surface, as in yellow field lily; by *pores,* as in potato; or by *valves,* as in sassafras.

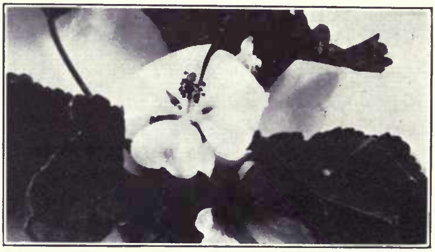

Fig. 112.—Monadelphous stamens of marshmallow (*Althaea officinalis*).

In members of the Compositæ there are usually five stamens and they are *syngenesious* or united by their anthers to form a tube. In mallow the stamens are united to form a *monadelphous* or single group of stamens. In sweet pea there are ten stamens of which nine are connate and form one group, leaving a solitary stamen; stamens so grouped are *diadelphous.*

Number of Stamens.—The number of stamens occurring in the flowers of representative genera of plants is extremely variable. A flower with one stamen is *monandrous;* one with two stamens is *diandrous;* one with three, *triandrous,* one with four, *tetrandrous;* and one with five stamens is *pentandrous.* If the stamens are very numerous they are said to be *indefinite.*

The Gynœcium is made up of one or more carpels which may constitute separate pistils or be united into a single one.

FIG. 113 A

FIG. 113 B

FIG. 113.—A, diadelphous stamens of sweet pea (*Lathyrus odoratus*); B, indefinite number of stamens of St. John's Woert (*Hypericum sp*).

If the gynœcium consist of one carpel it is *monocarpellary;* if of two, *dicarpellary;* if of three, *tricarpellary*, etc. If a

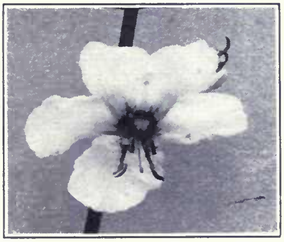

FIG. 114.—Tetrandrous flower of moth mullein (*Verbascum sp.*).

flower has two or more separated pistils it is *apocarpous;* a pistil formed by several carpels uniting is *syncarpous*.

Parts of the Pistil.—The enlarged terminal part of the pistil is the *stigma.* The stigma varies greatly in form, color, size and structure.

The *style* is the part of the pistil which extends from the stigma to the ovary.

The *ovary* is the hollow part of the pistil which bears the *ovules;* the ovules are attached to the placenta or ovule-bearing part of the ovary. Morphologically, placentæ are the margins of the carpellary leaves which are united and turned inward, forming for each carpel two placentæ. The placentæ are arranged in a number of ways; in syncarpous pistils the chief forms are the parietal, central and free central placentæ.

In the *parietal placentæ* the margins of the carpels meet and turn inward slightly to form the placentæ which bear the ovules. In the central placentæ the margins turn inward, meet at the center of the ovary and form as many locules or cavities as there are carpels. If this type of ovary is composed of five carpels, there will be ten placentæ and ten rows of ovules arranged in five locules and separated by septa or walls. In the *central* placentæ the septa between the locules do not develop. In an ovary of five carpels the ten rows of ovules remain attached to the ten placentæ at the center of the ovary. In the *free central* placenta it is not attached to the top of the ovary.

Parts of the Ovule.—The ovule of the higher plants consists of the following parts: a stem or *funiculus,* which when it adheres to the body of the ovule, as in the anatropous and campylotropous types, is called a *raphé;* a *chalaza* or point of origin of the integuments; two *coats* or *integuments,* consisting of an outer coat or *primine* and an inner coat or *secundine;* the *micropyle* or opening through the coats; the *nucellus* or stored food which surrounds the *macrospore.* The macrospore develops into the female gametophyte.

Forms of Ovules.—Ovules are atropous, anatropous, amphitropous or campylotropous. The ovule is *atropous* when the body of the ovule is erect on the funiculus; it is *anatropous* when the body is inverted and is in contact with the raphé; it is *amphitropous* when the body of the ovule grows at right angles to the raphé to which it is attached for about half its length; the ovule is *campylotropous* when the upper part of the body of the ovule bends downward so that the micropyle is nearly on a level with the chalaza.

Position of Ovules.—Ovules may be attached to the placentæ so as to be erect, ascending, horizontal, pendulous or suspended.

Relation of Andrœcium and Gynœcium.—Stamens are said to be *gynandrous*, when they are adnate to the pistil and appear to grow from it, as in the flowers of the Orchidaceæ.

Relation of the Calyx, Corolla, and Andrœcium to the Pistil.—The arrangement of the parts of the flower may be hypogynous, perigynous and epigynous.

In *hypogynous* flowers all sets of floral organs are free and are inserted beneath the pistil; in *perigynous* flowers the sepals, petals and stamens are borne on the margin of the *hypanthium* or enlarged summit of the peduncle, which forms a cuplike depression around the pistil, so that the floral organs arise around the pistil and above its point of insertion; in *epigynous* flowers the hypanthium is still further developed and adnate to the ovary, so that the floral organs appear to grow from its summit.

Types of Flowers.—Flowers are *complete* when they have sepals, petals, stamens and pistils; they are *incomplete* when one of these parts is missing. Flowers with both stamens and pistils are *perfect;* flowers which have stamens only are *staminate,* those having pistils only are *pistillate.* When the staminate and pistillate flowers occur upon the same plant, as in squash, the plant is *monœcious;* when the staminate and pistillate flowers occur on different plants, as in the willows,

Fig. 115.—Gynandrous stamens of moccasin flower (*Cypripedium acaule*)

the plant is *diœcious.* Both staminate and pistillate flowers are *imperfect.* When the flower has the same number or a multiple of the same number of parts in each circle it is *symmetrical;* when the number is not the same in each circle the flower is *asymmetrical.* When the parts of each circle are uniform in size and form the flower is *regular.* When

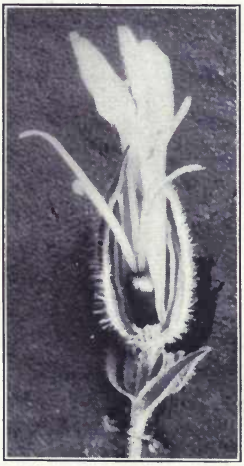

FIG. 116.—Hypogynous flower of campion.

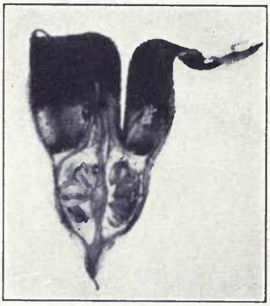

FIG. 117.—Epigynous flower of wild ginger (*Asarum canadense*).

FIG. 118.—Monœcious flowers of chestnut (*Castanea dentata*).

the parts of each circle are not uniform in size and form the flower is *irregular*.

Pollination, or the transporting of the pollen to the stigma of the flower, may occur in a number of ways. Pollination of a flower by the pollen from its own stamens is *self-pollination*, flowers which are fertilized by their own pollen while

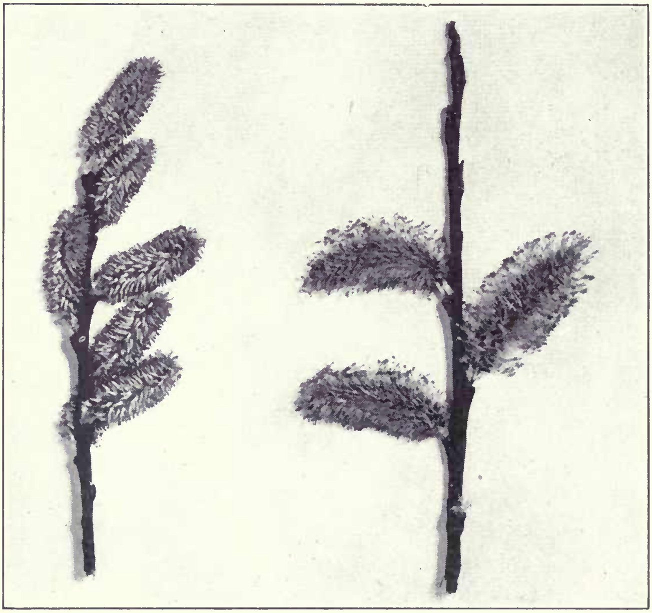

Fig. 119.—Diœcious flower of willow (*Salix sp.*)

in the bud condition are *cleistogamous*, as the closed flowers of the violet. The transportation of pollen from one flower to the stigma of another flower is *cross-pollination*. In *anemophilous* flowers cross-pollination is effected by the wind. Wind-pollinated flowers are not so attractive as insect-pollinated flowers, since they lack color, odor and nectar.

Wind-pollinated flowers secure pollination by growing in dense masses like wheat, rye and the grasses, by producing enormous amounts of buoyant pollen, by forming more staminate than pistillate flowers and by producing branching stigmas. In *entomophilous* flowers cross-pollination is accomplished by birds and insects.

How Plants Attract Birds and Insects.—Plants use various means in order to bring about cross-pollination. Some attract by odor, by nectar, by color, by form, by the *time of flowering*, by *modification of the floral structure*.

Odors.—*Odor* is an aid to pollination since it serves to bring insects to the flower. The odor of a flower is not always pleasant; it is frequently quite disagreeable, as in wake-robin and skunk cabbage. In contrast to these disagreeable odors there is the wonderful fragrance of roses, violets, carnations and hundreds of sweet-scented wild flowers. Many of the odorous flowers are very inconspicuous.

The petals of most flowers secrete a *nectar* or sweet substance which provides a pleasing *food* for the visiting insects. The *color* of the flower serves to attract insects and there are innumerable shades and tints of practically every color. There is also considerable variation in the color of a flower at different stages of its growth between the bud, mature and after-fertilization stage of the flower. Color is unquestionably a very great aid to the plant in attracting insects. Experiments have proved that certain insects will visit only flowers of certain colors, and in most instances the insects visiting such flowers are perfectly adapted to bring about cross-pollination. In thorn apple the flowers are white or bluish-white and are conspicuous at night, a fact of great service to the plant because the insect that brings about its cross-pollination flies only at night. In certain flowers the *form* will attract certain insects only and those attracted are the only ones that can bring about cross-pollination.

Dichogamy, which is the maturing of stamens and pistils at different times, has resulted in the formation of proterogynous and proterandrous flowers. In *proterogynous flowers* the pistil matures and is receptive of pollen before the stamens mature. In *proterandrous flowers* the stamens mature and the pollen is distributed before the pistil matures. In both of these kinds of flowers fertilization can occur only by cross-pollination.

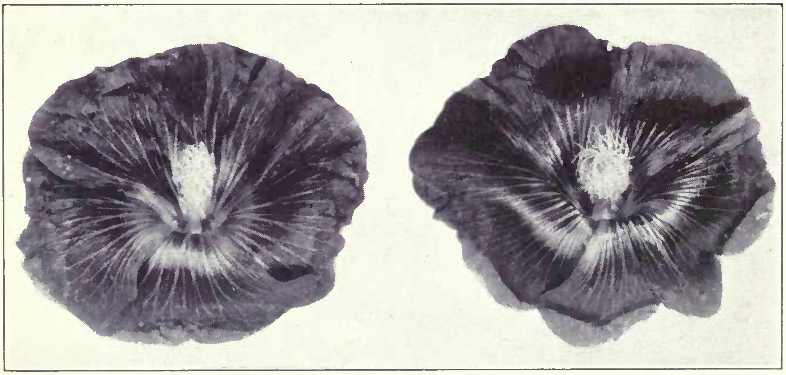

Fig. 120.—Hollyhock (*Athæa rosea*) mature stamens and undeveloped pistils to the left, mature pistils but withered stamens to the right.

Dimorphism.—When a plant produces two types of flowers, one having stamens with short filaments and pistils with long styles, and one having stamens with long filaments and pistils with short styles, such flowers are *dimorphous*; when there are three forms of flowers with stamens and pistils of three lengths, the flowers are trimorphous.

Position of Reproductive Organs.—In some flowers cross-pollination is secured by the position of the reproductive organs.

In moccasin flower the insect must push aside the pistil in order to reach the nectar and must rub against the anthers in leaving the flower. Thus the pollen of one flower is brought to the pistil of another flower.

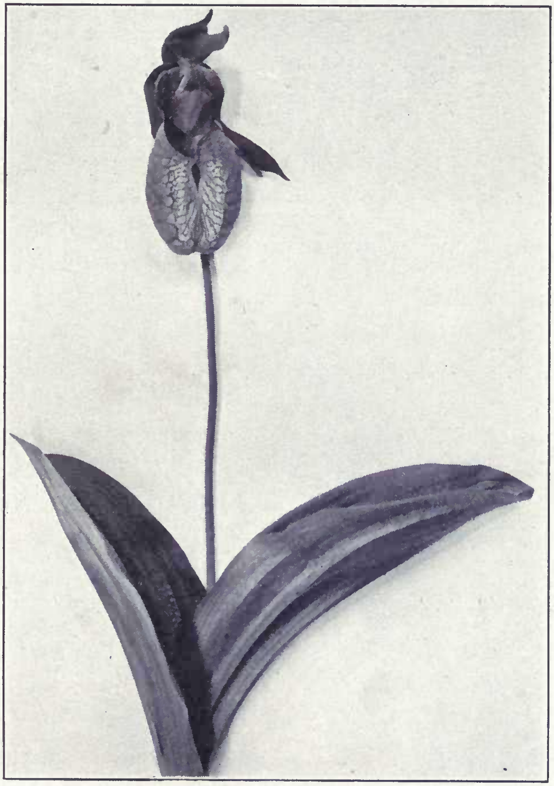

FIG. 121.—Moccasin flower (*Cypcipedium acaule*) which forces insects to bring about cross-pollination because of the position of the reproductive organs.

CHAPTER XV.

FRUITS

A FRUIT consists essentially of one or more ripened ovaries, frequently with other parts of the flower. Fruit development begins when the egg cell and endosperm nucleus are fertilized and ends at about the time the seed is full grown. The chief function of the fruit is to form, protect, nourish and distribute the seed.

Parts of a Fruit.—The fruit is composed of the pericarp and the seed. The pericarp, which normally consists of the ovarian walls, is divisible into the *exocarp* or outer layer, the *mesocarp* or middle layers, and the *endocarp* or inner layer. If the exocarp is a thin, skinlike covering it is called the *epicarp*; if the mesocarp is fleshy it is known as the *sarcocarp*; if the endocarp is hard and bony, as in the cherry and peach, it is called a *putamen*.

Classification of Fruits.—It is necessary to classify fruits in order to know them.

Fruits are first grouped into indehiscent, partially dehiscent and dehiscent fruits.

An *indehiscent* fruit is one that does not open to discharge its seed.

A *partially dehiscent* fruit is one that splits up into parts, each part containing a seed.

A *dehiscent* fruit is one that opens to discharge its seed.

The Indehiscent Fruits are divided into simple and accessory fruits.

Simple Fruits are formed from a single pistil. The simple fruits are divided into dry and fleshy fruits.

A dry fruit is one that becomes free of moisture at maturity.

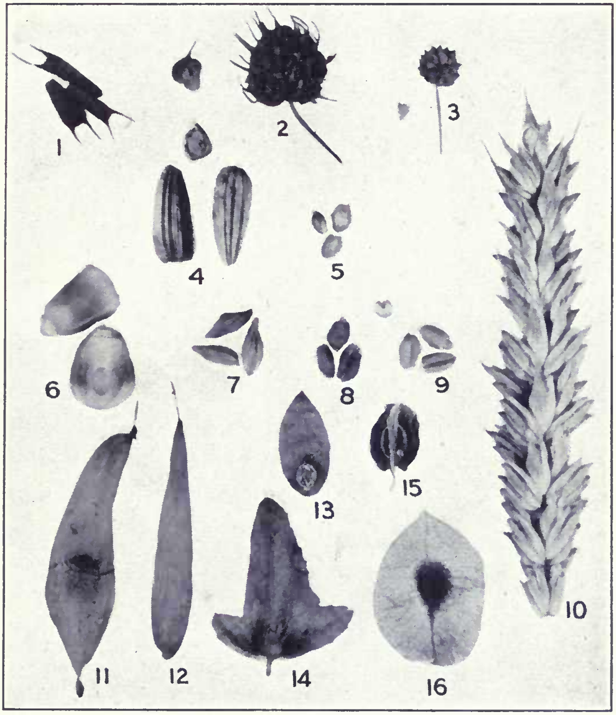

Fig. 122.—*Achenes.* 1, Beggar ticks (*Bidens frondosa*); 2, anemone (*Anemone sp.*); 3, buttercup (*Ranunculus acris*); 4, sunflower seed (*Helianthus annuus*); 5, hempseed (*Cannabis sativa*). *Grains*, 6, corn (*Zea mays*); 7, barley (*Hordeum sativum*); 8, rye (*Secale cereale*); 9, wheat (*Triticum sativum var. vulgare*); 10, stalk of wheat. *Samaras*, 11, ailanthus (*Ailanthus glandulosa*); 12, white ash (*Fraxinus americana*); 13, ironwood (*Ostrya virginiana*); 14, false ironwood (*Carpinus caroliniana*); 15, pie rhubarb (*Rheum rhaponticum*); 16, elm (*Ulmus americana*).

Indehiscent Simple Dry Fruits.—Indehiscent simple dry fruits include achenes, utricles, grains, samaras, nuts and nutlets.

An *achene* is a one-celled, one-seeded, dry, indehiscent fruit, as in the sunflower, hemp and anemone.

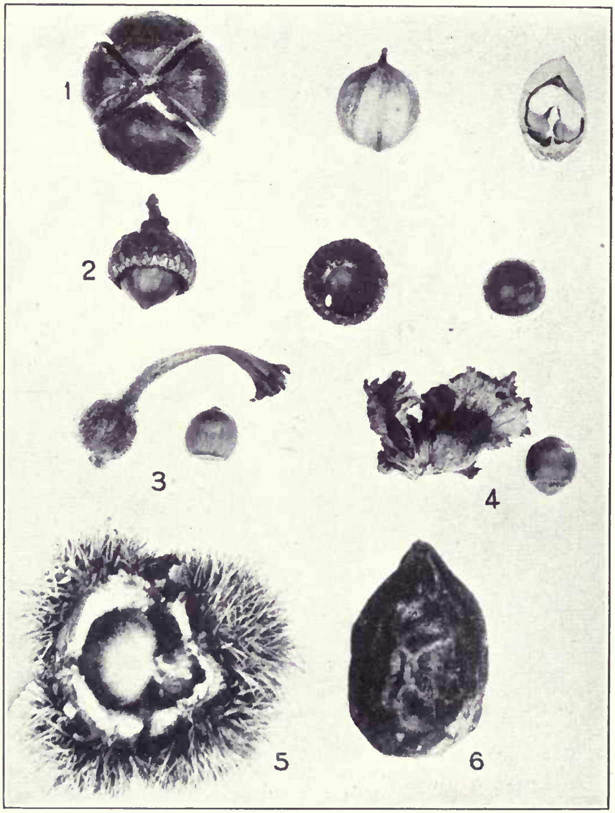

FIG. 123.—*Nuts.* 1, Hickory (*Hicoria alba*); 2, acorns of *Quercus sp.;* 3, beaked hazelnut (*Corylus rostrata*); 4, hazelnut (*Corylus americana*); 5. chestnut (*Castanea dentata*); 6, butternut (*Juglans cinerea*).

A *utricle* is a one-celled, one-seeded, dry, indehiscent fruit with a thin inflated pericarp.

A *caryopsis* or grain is a one-celled, one-seeded fruit in which the seed is grown fast to the pericarp, as in wheat.

A *samara* is a one-celled, one-seeded, indehiscent fruit with a membranous expansion or wing, as in gray birch, rhubarb, elm, ailanthus, ironwood, false ironwood and ash.

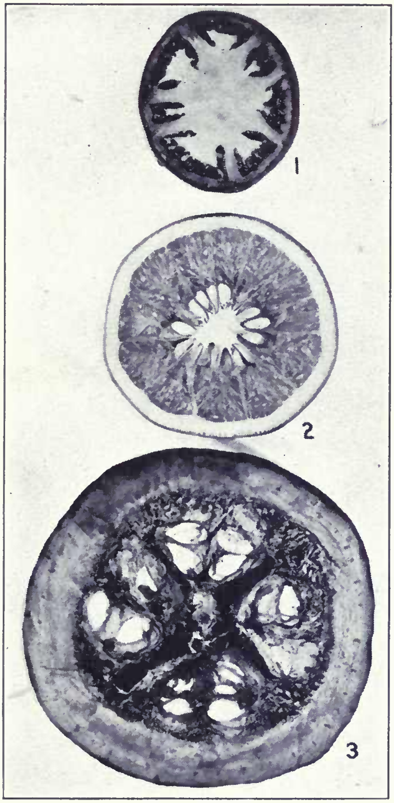

FIG. 124.—*Baccate fruits.* 1, *Berry* of tomato (*Lycopersicon lycopersicum*); 2, *Hesperidium* of grape fruit (*Citrus sp.*); 3, *Pepo* of squash (*Cucurbita maxima*).

A *nut* is a one-celled, one-seeded, indehiscent fruit as in acorn, hazelnut, hickory nut, chestnut, butternut.

A *nutlet* is a small nut, as in mint.

Indehiscent Fleshy Fruits.—A fleshy fruit is one that is succulent or moist at maturity. The fleshy fruits are grouped into baccate and drupaceous fruits.

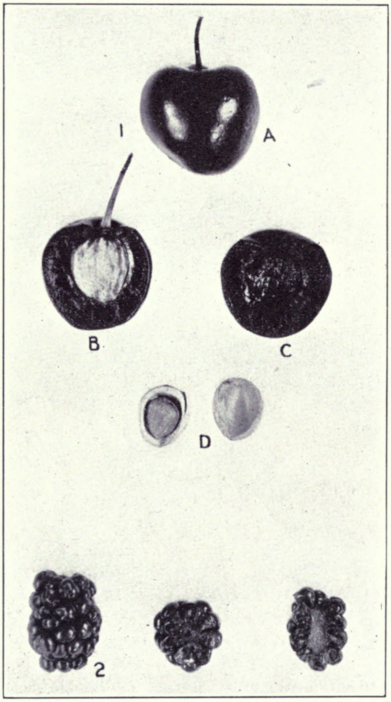

FIG. 125.—*Drupaceous fruits.* 1, Drupe of cherry (*Prunus cerasus*); (*A*) entire fruit, (*B*) drupe showing epicarp, sarcocarp and putamen, (*C*) putamen opened to show the seed, (*D*) putamen with enclosed seed; 2, *Drupelet*, the individual fruits of blackberry (*Rubus nigrobaccus*).

Baccate Fruits.—The berry, hesperidium and pepo are baccate or berrylike fruits.

A *berry* is a fleshy fruit with numerous seeds imbedded in the fleshy pericarp, as in the tomato and grape.

A *hesperidium* is a berry with a tough, flexible rind as in the orange, lemon and grape fruit.

A *pepo* is a berry with a hard, tough rind, as in the pumpkin and squash.

Drupaceous Fruits.—The drupe and drupelet are drupaceous or stone fruits.

A *drupe* is a fruit with an epicarp, a sarcocarp and a hard, bony endocarp or putamen that encloses the seed, as in the cherry and peach.

A *drupelet* is a small drupe, as in the fruits forming the blackberry.

Indehiscent Accessory Fruits.—An accessory fruit is one composed of a pistil or pistils and other parts.

Accessory fruits are classified as simple, aggregate and multiple.

Simple Accessory Fruits.—The *pome* is a simple, fleshy accessory fruit composed of a fleshy, hollow receptacle enclosing five ovaries and ten rows of seeds, as in the apple.

Aggregate Accessory Fruits.—Aggregate fruits are formed from several pistils of one flower.

An *etærio* is an indehiscent, fleshy, aggregate fruit composed of numerous drupes adhering to a fleshy receptacle, as in the blackberry, or of numerous achenes on a fleshy receptacle, as in the strawberry.

Multiple Accessory Fruits.—Multiple fruits are formed from the pistils of several flowers.

The pineapple, synconium of the fig, sorosis of the mulberry and the galbulus of juniper are *multiple accessory fruits.*

The pineapple is an indehiscent, fleshy, accessory, multiple fruit composed of the ripened ovaries of several flowers together with fleshy, modified scales, bracts and a floral axis.

A *synconium* is a fleshy, accessory, multiple fruit consisting of a fleshy stem and a hollow torus that bears the seed, as in the fig.

The *sorosis* is a fleshy, accessory, multiple fruit composed of fleshy bracts, perianths and ovaries, as in the mulberry.

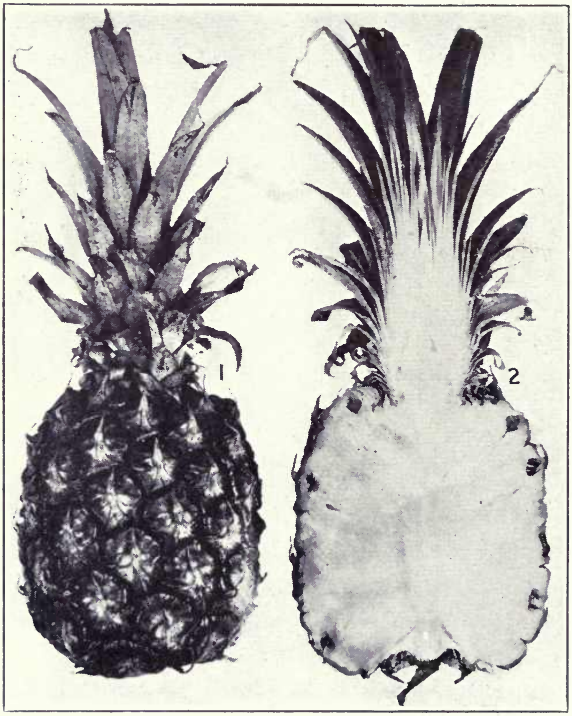

Fig. 126.—Accessory fruit. Pineapple (*Ananas ananas*); 1, surface view; 2, longitudinal section view.

A *galbalus* is a fleshy, accessory, multiple fruit, consisting of a fleshy spike and three perianths inclosing three seeds, as in juniper.

Partially Dehiscent Fruits.—Partially dehiscent fruits are divided into (1) schizocarps and (2) arthrocarps.

1. *Schizocarps* are splitting fruits and include the samara of the maple, the cremocarp, the carcerulus, which is longi-

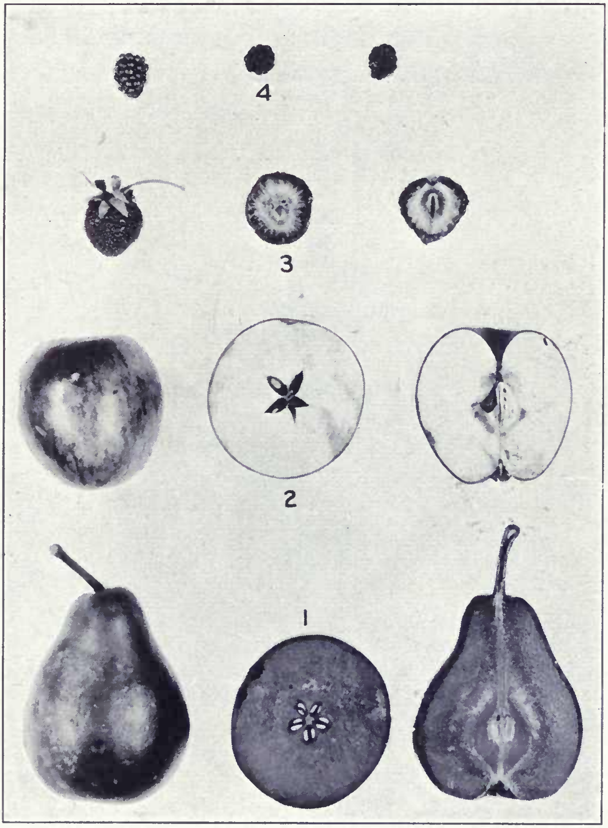

FIG. 127.—*Accessory fruits.* 1, Pear (*Pyrus communis*) entire, cross and longitudinal sections of the fruit; 2, *Pome* of apple (*Malus Malus*); 3, *Etærio* of the strawberry (*Fragaria virginiana*); 4, blackberry (*Rubus nigrobaccus*).

tudinally splitting, and the loment which is transversely splitting.

The *samara* of the maple is a two-seeded, two-winged fruit that splits at maturity into one-seeded parts.

A *cremocarp* is a fruit composed of two one-seeded parts or mericarps, whose inner, commissural surfaces are in contact. The mericarps are attached to a carpophore, from which they finally separate. as in sweet cicely and other umbelliferous fruits.

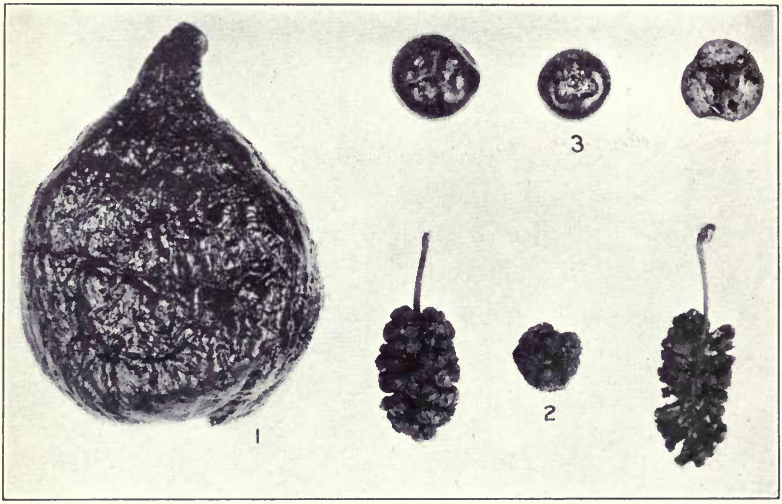

FIG. 128.—*Accessory fruits.* 1, *Synconium* of fig (*Ficus Carica*); 2, *Sorosis* of red mulberry (*Morus rubra*); 3, *Galbalus* of juniper (*Juniperus communis*).

A *carcerulus* is a fruit composed of an indefinite number of achene-like parts that split longitudinally into one-seeded parts, as in the hollyhock and mallow.

2. *Arthrocarps* are jointed fruits which break up into one-seeded parts.

A *loment* is a many-seeded fruit that divides transversely at maturity into-one-seeded parts, as in thlaspi arvense and meibomia.

FIG. 129.—*Schizocarps.* 1, *Samaras* maples (*Acer sp.*); 2, *Cremocarps* (*A*) angelica fruit (*Angelica atropurpurea*); (*B*) sweet cicely (1) mericarps separated above but not below; (2) mericarps separated, but attached to the branched carpophore; 3, *Carcerulus* of hollyhock (*Althæa rosea*) and low mallow (*Malva rotundifolia*); 4, *Loments* (*A*) *Meibomia sp.* and (*B*) (*Raphanus raphanis*).

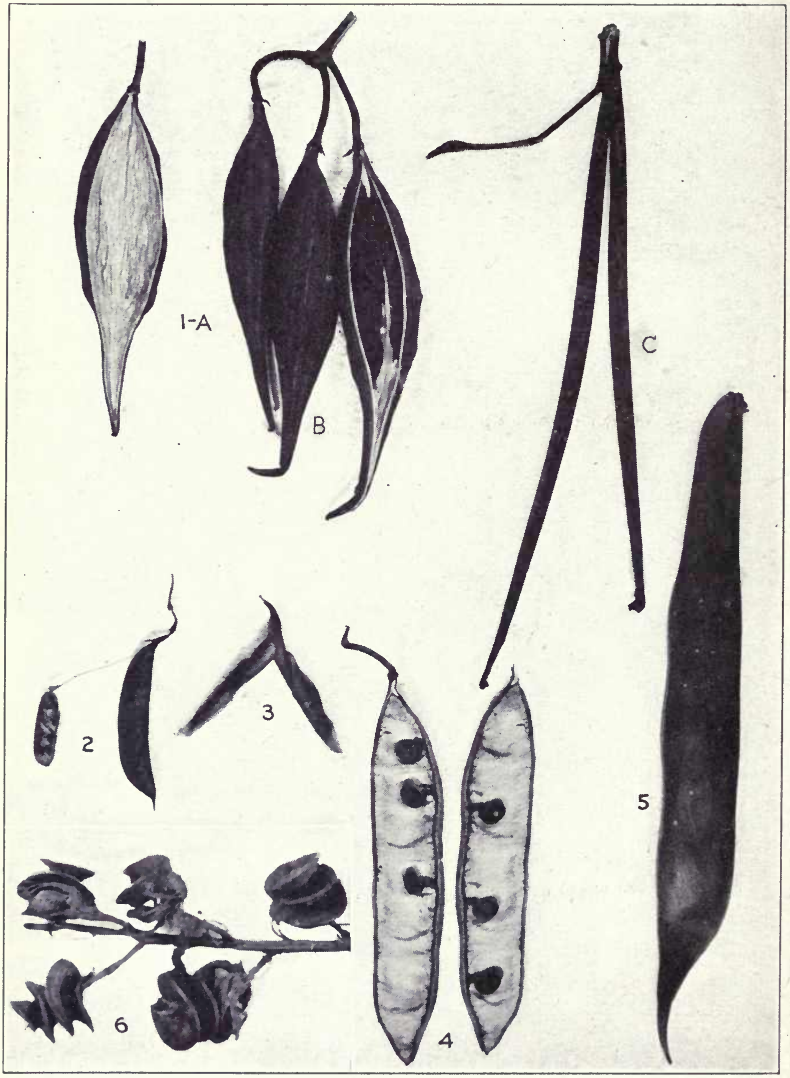

Fig. 130.—*Dehiscent fruits.* 1, *Follicles* (A) open follicle of milkweed (*Asclepias incarnata*); (*B*) open follicle with seed; (*C*) slender follicles of spreading dogbane (*Apocynum androsæmifolium*); 2, vetch (*Vicia americana*); 3, hogpeanut (*Falcata comosa*) entire and open fruit; 4, black locust (*Robinia pseudo-acacia*); 5, garden bean (*Phaseolus vulgaris*); 6, alfalfa (*Medicago sativa*).

Dehiscent Fruits.—The dehiscent fruits are divided into unilocular, multilocular and multiple fruits.

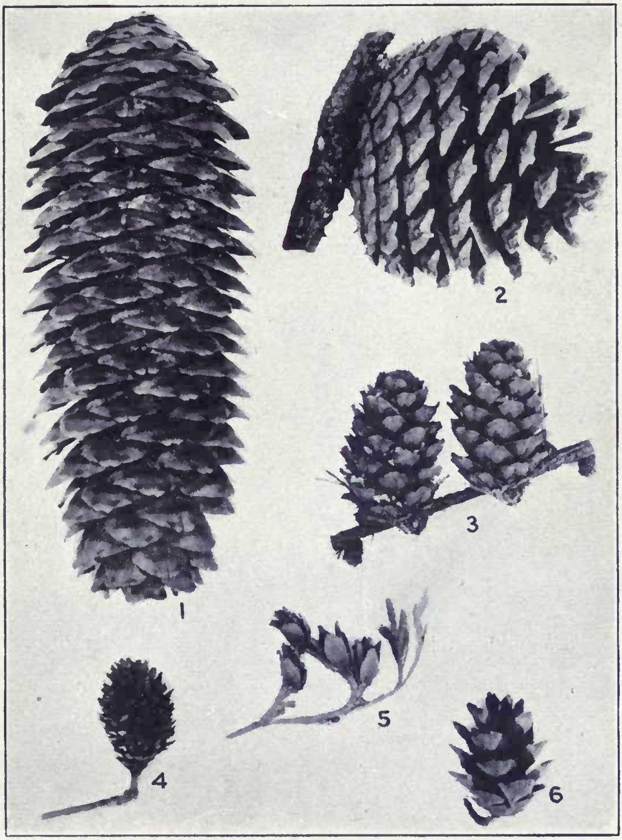

FIG. 131.—*Strobiles.* 1, Spruce (*Picea Abies*); 2, pitch pine (*Pinus rigida*); 3, larch (*Larix decidua*); 4, black birch (*Betula lenta*); 5, arbor vitæ (*Thuja occidentalis*); 6, hemlock (*Tsuga canadensis*).

Unilocular Dehiscent Fruits.—The follicle, legume and cochlea are simple unilocular fruits.

A *follicle* is a dry, one-carpelled fruit that dehisces by the ventral suture, as in milkweed and apocynum.

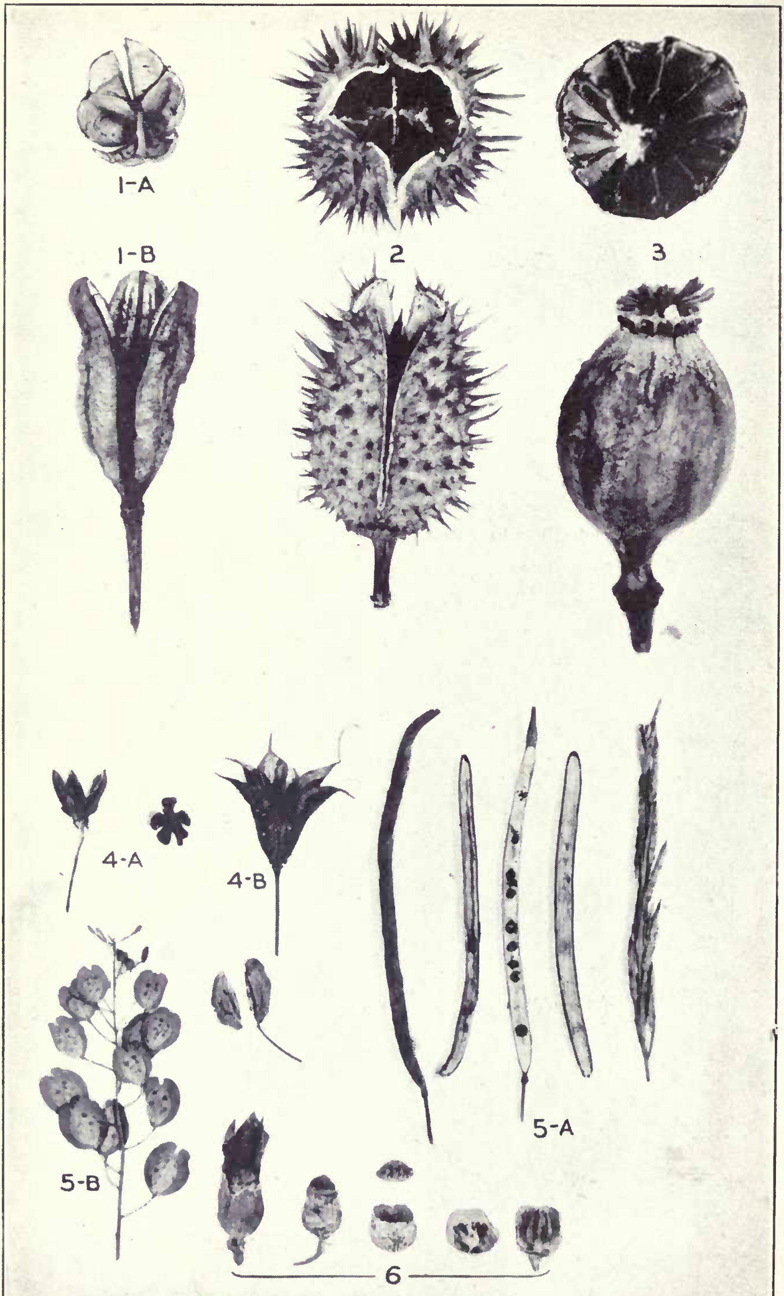

Fig. 132

A *legume* is a dry, unilocular fruit that dehisces by the ventral and dorsal sutures, as in the bean and pea.

A *cochlea* is a dry fruit composed of one pistil that is spirally coiled at maturity, as in alfalfa.

Multilocular Dehiscent Fruits.—The multilocular fruits are all capsules.

A *capsule* is a dry, dehiscent fruit composed of two or more carpels. Capsules are classified according to their method of dehiscence into loculicidal, septicidal, septifragal, circumscissile, poricidal and valvate capsules.

A *loculicidal capsule* dehisces through the dorsal sutures of each carpel, as in yellow field lily.

A *septifragal capsule* dehisces by the separation of the valves from the septum and from each other; as in stramonium.

A *poricidal capsule* dehisces by small circular openings or pores, as in the poppy.

A *septicidal capsule* dehisces through the septa or walls, thus dividing and separating the carpels that form the capsules; these later dehisce through their ventral suture, as in columbine and violet.

A *valvate capsule* dehisces by valves, as in the silique of cabbage, and the silicle of *Thlaspi arvense* where the two separate from the central partition.

Multiple Dehiscent Fruits.—A *strobilus* is a multiple dehiscent fruit composed of numerous dry, seed-bearing scales arranged on a stalk.

DESCRIPTION OF FIG. 132.

Capsules. 1, *Loculicidal*, yellow field lily (*Lilium canadense*); (*A*) cross-section, (*B*) side view of capsule; 2, *Septifragal*, thornapple (*Datura stramonium*); 3, *Porocidal*, poppy (*Papaver somniferum*); 4, *Septicidal* (*A*) violet (*Viola sp.*); (*B*) columbine (*Aquilegia canadensis*); 5, *Valvate* (*A*) cabbage (*Brassica oleracea*); (*B*) (*Thalaspi arvense*); 6, *Circumscissile* henbane showing the fruit enclosed in the calyx, free of the calyx, lid removed, end view of the capsule and a longitudinal section of the capsule.

CHAPTER XVI.

SEED AND FRUIT DISPERSAL

SEEDS

SEEDS are immature dormant plants containing or surrounded by reserve food and covered by a protective outer layer or *testa.* In the seed stage plants accomplish many things and live through conditions which would be impossible at other stages. At this stage the plant is distributed frequently at great distances from its parent. Seeds are the only means annual plants have of perpetuating themselves; they survive the winter season, the periods of no rainfall and other conditions adverse to plant growth.

The seed originates in the fertilization of the egg cell and endosperm nucleus in the ovule. As a result the parts of the ovule become modified to form the seed. The testa or seed-coats, the reserve food, and the embryo are the parts of the seed.

Testa.—The testa is essentially a protective layer, but in some seeds it is modified as a wing or spine. These modifications are the means of bringing about a wide distribution. In castor-oil seed an enlargement occurs on the testa known as a *caruncle* while the seed of nutmeg has a larger anastamosing partially attached outer coat or *aril,* which when separated from the seed forms mace, the well known spice of commerce.

The *texture* of the testa varies in different seeds. In most seeds it is very thick, hard, and resistive to cutting and crushing. The hardness is usually due to the stone cells and fibers which are nearly as tenacious and as resistive to crushing as similar-sized pieces of steel. In mustard seed the hardness is due to the outer mucilage cell layer. Frequently the hardness is not due to the testa but to the endosperm. The horny seeds of colchicum and nux vomica, seeds whose endosperms are made up of reserve cellulose are typical examples.

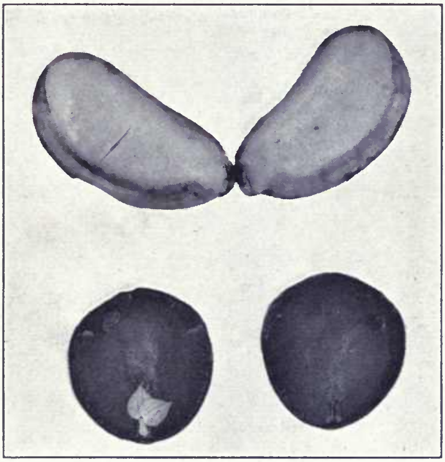

Fig. 133.—Ex-albuminous seed of calabar bean (*Physostigma venenosum*) above, and below albuminous seed of nux vomica showing the dark endosperm and the embryo with two well developed cotyledons and the hypocolyle.

A scar forms at the point of separation of the ovule from its stalk. This scar is called a *hilum*. The micropyle or opening in the integuments of the ovule through which the pollen tube enters to bring about fertilization, persists in the seeds as a small pit or depression and is known as the *micropyle-scar*.

Reserve Food.—Seeds are classed according to their method of storing reserve food as ex-albuminous and as albuminous seeds. In the *ex-albuminous seeds*, represented by the bean, pea, peanut and pumpkin, the reserve food all occurs in the cotyledons or seed-leaves. In *albuminous seeds* represented by coffee, nux vomica, castor oil and flaxseed, the reserve food is stored in the endosperm, a tissue which completely surrounds the embryo. It is the function of the endosperm and cotyledons to provide food for the germinating embryo.

The reserve material occurring in seeds consists of starch, reserve cellulose, aleurone, fats, oils, alkaloids, glucosides and bitter principles. Sometimes more than one of these substances occur in the same seed. Mustard seed contains aleurone, fixed oil of mustard, which is extracted by pressure, and volatile oil of mustard, which is obtained by maceration and distillation. The bean contains aleurone, oil and starch. Nux vomica contains reserve cellulose, which is changed by ferments to a plant food, and two alkaloids, brucine and strychnine, the latter a well known drug and poison. Linseed contains aleurone and fixed oil; the oil is pressed from the seed and used in the manufacture of paint and the crushed seed-cake with the oil removed is used as a cattle food.

Embryo.—The embryo or immature plant has well defined and differentiated tissues and organs.

Parts.—The typical embryo is differentiated into a bud or *plumule* which continues the growth of the plant, one or more *cotyledons* or seed leaves, a *hypocotyl* or stem below the cotyledons, and a caulicle which develops the primary root.

The *plumule* is the highly developed bud with formed leaves which occurs between the cotyledons; frequently the bud between the cotyledons is very small and no leaves are present. The plumule develops the stem and leaves of the seedling.

The number of *cotyledons* varies considerably in the seed bearing plants. In the gymnosperms, represented by white pine, the embryo is polycotyledenous, having five cotyledons; in the monocotyledons, represented by the lily, there is only one cotyledon; while in all dicotyledenous plants, represented by lobelia, there are two cotyledons.

The *hypocotyl* is the embryo-stem which bears the plumule and cotyledon or cotyledons.

The *caulicle* is the end of the hypocotyl and it develops the primary root.

In studying and identifying seeds it is necessary to note their outline, size, color, surface, texture, odor and taste.

Outline.—The outline of seeds is made up of curved surfaces, plane surfaces or of curved and plane surfaces. Refer to the chart on leaf outlines for typical forms.

Size.—There is the greatest possible variation in the size of seed but the maximum size of the seed of each species is fairly uniform. The cocoanut is one of the largest known seeds and the seeds of orchids, which are microscopic, are among the smallest. Between these two extremes there is a series of intermediate sizes, well represented by our common vegetable seeds.

Color.—The color of a seed should always be noted. Gray, yellow, brown, red and black are the common colors.

Surface.—There is a great variation in the surface of seeds. The surface is smooth, reticulate, furrowed, grooved, or hairy. The hairs of cottonseed constitute the cotton of commerce.

Odor.—Most seeds are odorless but many are fragrant because of the presence of aromatic volatile constituents.

Taste.—The taste of many seeds is very characteristic. The more common are pungent, sweet, astringent, bitter and acrid. In tasting seeds cut away the testa and apply the tongue. Such a procedure is not dangerous even in the case of such a poisonous seed as nux vomica.

Uses.—Seeds and their products are of great economic use. One has only to think of cotton, flaxseed, coffee, beans, peas, lentils, nux vomica, peanuts, mustard, nutmeg and hundreds of garden and flower seeds to realize the economic uses of seeds.

Dormancy or Rest Period.—Seeds when mature lose most of their water, a fact which enables seeds to perform their functions so successfully. Dormancy refers of course to the period which seeds usually remain under favorable conditions, before germinating. During this period respiration is reduced to the minimum and no new tissue is formed.

Longevity.—The life of the seed varies from one to several years. Often this period can be extended by selecting seed only from hardy plants, by keeping only mature seeds, and by proper methods of storing.

Viability.—The viability or the power of seeds to germinate is an important factor in the selection of seeds. All seedsmen and many dealers and planters apply the germination test to seed offered for sale or before planting. Most dealers will not offer seed for sale unless 75 per cent is viable.

Germination.—Germination is the development of a seed into a seedling. The time required for this varies.

Necessary Conditions.—For every seed there is a minimum amount of *water* and *heat* required and a maximum amount beyond which germination will not take place or which will retard further growth after germination has begun.

Stages of Germination.—There is no sharp line of demarcation separating the different stages of germination. These overlapping stages may be briefly summarized as follows:

1. Absorption of water and swelling of the seed.
2. Enzyme action on the reserve food rendering it soluble.
3. Absorption of food and oxygen and active respiration.

4. Cell division resulting in the elongation of the plumule and the formation of the radicle.

5. Rupturing of the seed coats.

6. Emergence of plumule and radicle from seed.

7. Elevation of the cotyledons and the development of the primary root.

8. Formation of chlorophyll.

9. Growth into the seedling.

The Seedling.—The seedling is formed as a result of the germination of the embryo. The embryo becomes a seedling when a true stem, leaves and roots have been formed and when all the reserve food has been used. The seedling then, because of its roots, stem, and leaves with chlorophyll, manufactures its own food and leads an independent existence.

DISPERSAL OF SEEDS AND FRUITS

It appears to be an established fact that plants distribute their seeds as far as possible, with the result that certain species of plants often cover large areas. A single pine tree will, under favorable conditions, form a pine forest from its offspring. Very frequently the forest can be seen in the making. Plants distribute their seeds by the wind, by water, by mechanical force, by animals and by birds.

Wind-carried.—Fruits like the winged fruits or samaras are easily carried about by air-currents. The seeds of the milkweed, and apocynum are blown about by means of an innumerable number of air-filled buoyant hairs.

Water-carried.—The seeds and fruits of many plants growing along streams are carried, frequently for long distances, by the water.

Mechanically Distributed.—The walls of the pod of witch hazel will, when dry, contract at the base and eject the seed far from the plant. The bean pod will throw its seeds widely when the valves open suddenly and coil. The

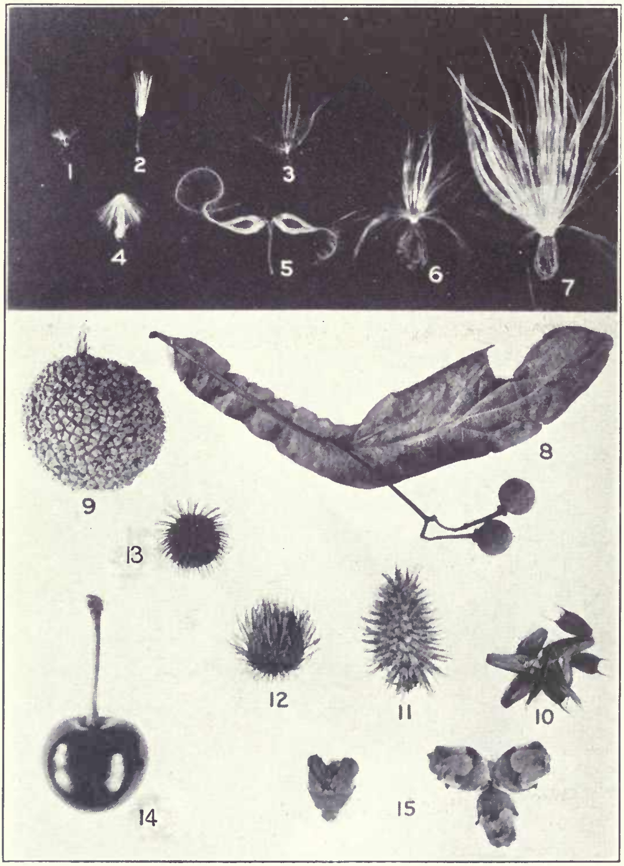

FIG. 134.—*Seed Dispersal by Wind.* 1, Boneset (*Eupatorium perfoliatum*); 2, arnica (*Arnica montana*); 3, spreading dogbane (*Apocynum androsæmifolium*); 4, sycamore (*Platanus occidentalis*); 5, clematis (*Clematis sp.*); 6, swamp milkweed (*Asclepias incarnata*); 7, common milkweed (*Asclepias syriaca*); 8, linden (*Tilia americana*). *By water*, 9, sycamore (*Platanus occidentalis*). *By animals.* 10, beggar-ticks (*Bidens frondosa*); 11, cockle-bur (*Xanthium echinatum*); 12, common burdock (*Arctum minus*); 13, avens (*Geum sp.*); 14, cherry (*Prunus cerasus*). *By mechanical force.* 15, witch hazel (*Hamamelis virginiana*).

violet will throw its seeds for a considerable distance when the three valves separate and bend outward.

Distribution by Animals.—Fruits and seeds that have spines, hooks and sharp pointed bristle-like hairs attach themselves to the fur of animals and the clothing of man. By this means seeds and fruits are frequently distributed many miles.

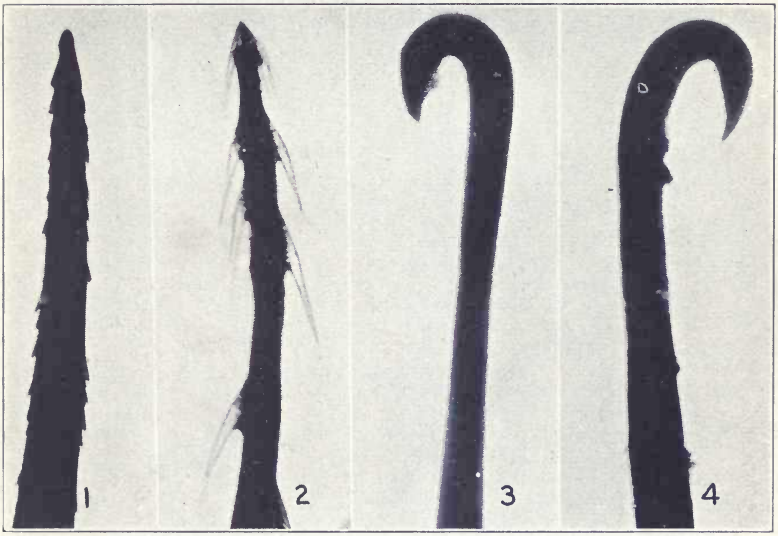

FIG. 135.—Microphotographs showing structure by means of which plants adhere to objects. 1, Burgrass (*Cenchrus sp.*); 2, beggar-ticks (*Bidens frondosa*); 3, common burdock (*Arctium minus*); 4, cocklebur (*Xanthium echinatum*).

Seeds Distributed by Birds.—Most wild and smaller cultivated fruits are distributed by birds. The distribution is of course due to the fact that the seed is not destroyed while passing through the bird's digestive tract. That wild plants producing edible fruits are numerous is due in part to the fact that birds distribute the seed.

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