ELEMENTARY BOTANY

COULTER-NELSON

A

TEXT-BOOK

OF

ELEMENTARY BOTANY.

BY

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PREFACE

This book has been prepared for use in schools in which elementary Botany is taught during the last half or last third of the school year.

It is believed that a course in Botany which is designed for those who are taking their first lessons in the subject and most of whom will not have opportunity to pursue it farther, ought to afford opportunity for scientific training as well as for obtaining some general information concerning the vegetable kingdom, particularly in relation to the growth and development of plants, their relationships, their uses, etc. Accordingly, directions for practical work, observation, and performing experiments have been offered throughout, but in immediate connection with the paragraphs of the text that pertain to the subject in hand. This has not interrupted the proper symmetry and logical arrangement of the topics that should be included in an elementary course for high schools.

The practical work indicated need not and should not be a *verification* of the text; that, it is true, would be an improvement over mere text-book work, but it lacks the very spirit and essential feature of scientific work. The observation and experimentation must be made *to find out* the facts in the case. This will afford scientific training and, besides, real knowledge will be gained. Whether all the practical exercises that are called for, can be carried out, will depend on the length of time at the disposal of pupils, but every course, *however short*, should include some work of this character.

The physiology of plants is given more attention than usual in school text-books, and some representatives of the important classes of vegetable products are included—innovations whose importance obviates the necessity of an apology.

The equipment for the experiments will doubtless be at hand in schools where physics or chemistry is taught. When that is not the case, a mere trifle in the outlay will be sufficient. A good pocket lens should be carried by every pupil, for use both in the class-room and in the field. Since each pupil cannot be furnished with a compound microscope, no special directions are given for practical work in histology, though when an instrument is available the teacher should use it constantly in demonstration.

Most of the figures have been heretofore used in the author's *Elements of Botany*, where their source is explained. Mention should be made that several of the experiments and a few figures have been given essentially as found in Oel's *Pflanzenphysiologische Versuche.* I have had the assistance of my wife in the preparation of the entire book, and to her, equally with myself, the credit, if any, should be awarded.

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ELEMENTARY BOTANY.

INTRODUCTION.

WHEN AND HOW TO STUDY BOTANY.

1. THE study of Botany is the study of plants. The beginner should therefore have specimens before him. It is not necessary to wait till spring or summer, since plants can be obtained at any season of the year. Fewer specimens can be obtained in midwinter, though the native trees and shrubs and cultivated plants are always available and therefore sufficient material is never wanting.

2. The common flowering plants and the Ferns with their allies (the Clubmosses and *Equiseta* or Horsetails), numerous as they are, by no means comprise the entire Vegetable Kingdom. The Mosses, Lichens, Fungi (*e. g.* Toadstools, Mushrooms, Rusts, Smuts, Moulds, Mildews, etc.) and Algæ include a very large number of species. There is scarcely a season of the year when numerous specimens of many of these groups are not obtainable in good condition for satisfactory study; besides, many kinds of material can be collected at the proper stage of development, dried, and laid away for winter study. The specimens can then be moistened and thus made pliant, when their form and structure can be examined, often as satisfactorily as when they were first collected. Some material can be kept, ready for use at any time, in alcohol or in a one to two per cent. solution of formalin.

3. Although collecting and identifying plants when in bloom is both interesting and profitable work—having also the addi-

tional merit of serving in numberless instances to incite to further study—it must be remembered that this in itself, including the preparative study of descriptive terminology, is a very inconsiderable portion, or perhaps it should not be considered a part, of real Botany. On the other hand, the mere study of a botanical text-book, though it may be made a drill in memorizing, or used as a basis of instruction in etymology or language lessons, cannot be properly designated a study of the science of Botany. This should comprise rather a direct study of the plants themselves; an examination of both their general or gross structure and their minute anatomy; an investigation of their general physiology and the functions of the several parts, also their affinities to each other, their relation to other objects in nature, their embryological development, their evolution through geologic time, and their past and present distribution; and finally a study of the application of the facts and principles of the science to every-day life.

4. It should be remembered that the paramount object in the study of Botany is as far as possible to obtain knowledge directly from the plants themselves. These must therefore be handled and carefully observed—the text-book and teacher being guides to systematic observation, and, where possible, to experimentation. The study of the text-book should *in all cases follow, not precede*, the study of the material and the execution of the experiments. It has seemed preferable to have the directions for practical work follow the paragraph or portion of the text devoted to the subject in hand, rather than to precede it; but the order of study of the material and the experimentation, and of the study of the text, should always be as suggested above. To attempt a complete examination of all the parts that are presented by any plant should not be attempted in the first lesson. If, for example, a leafless branch collected in winter is at hand, a study of the leaf-scars alone could advantageously occupy some length of time. It should include also a comparison of the leaf-scars of other species; the work would thus occupy many hours. The buds, their arrangement, size, shapes, coverings, struc-

ture, function, etc. could be taken up and somewhat exhaustively studied; the general characters of the twigs and branches of various shrubs and trees, the Lichens obtainable in open weather, Mosses which may be found in fruit at almost any time in the year, or still other objects, could be the first material for study. If the work be commenced in spring or summer, plants without number can be obtained, and the study could be commenced equally well with either roots, stems, leaves, flowers, or fruit. If the material needed can be obtained in sufficient abundance, it will be well to take up the several subjects in the logical order presented in the following pages.

5. One of the valuable, if not essential, aids to careful and systematic study is the making of an outline or tabulation of the points observed and the information gained from the material under examination. The note-book should always be at hand and judiciously used. To both pupil and teacher it should furnish evidence daily of increase of knowledge and growing ability to discern. No less important is it to represent by outline drawings all the parts studied. This necessitates a close and detailed examination which otherwise would in very many cases not be made. The pocket lens should be daily called into requisition whenever its use might be advantageous. Preservation of representative specimens of everything studied is also recommended. This will enable one at any time to review or re-examine that which has been previously subjected to complete or partial investigation. Besides, it is a convenient record of the labor performed. The Flora, constituting the last portion of this book, or any other manual of plants, can, after a few weeks of such study, be satisfactorily used in identifying the native plants of the region.

CHAPTER I.

SEEDLINGS.

1. Numerous seedlings of the common plants should be examined by the beginner. An outline sketch of one or more specimens should be made to insure a careful inspection of every detail. Like the mature plants, the seedlings have three evident parts or organs; namely, root, stem and leaves. These present numerous variations in form and mode of growth, which may be seen by examining specimens representing many different species of plants. They should be studied in the early stages of germination, and also observed at intervals until the ordinary foliage leaves appear upon the stem. This can be conveniently done if the following directions are heeded.

Germinator.—Provide a shallow box of sand (or soil or sawdust, but if sawdust is used, that of the Oak and Chestnut must be avoided), and in this plant a number of different kinds of seeds. Any or all of the following may be used:[1] Bean, Pea, Castor Bean, Mustard, Coreopsis, Maple, Radish, Larkspur, Sunflower, Phlox, Squash, Four-o'clock, Mallow, Touch-me-not, Morning Glory, Eschscholtzia, Wild Cucumber, Onion, Corn, Wheat and Pine. Keep sufficiently warm and moist to insure quick germination. Use the seedlings for study in connection with the paragraphs that follow. The germinator should be kept in the class-room or other convenient place. It should be so ample that each pupil may have all the specimens desired for each lesson. In case of large classes several boxes should be used.

2. Shortly after the seeds have been subjected to a proper degree of temperature and moisture, the embryo or plantlet (popularly called the "germ") begins to grow. A slender

[1] If all the seeds named are used, *all of the conspicuous* variations in cotyledons, etc., will be shown; but the Bean, Morning Glory, Corn, Wheat and Pine might be taken as desirable examples, if but a few can be used.

stem, or **Caulicle,** breaks through the coverings of the seed, and grows downward to form the root. In case of some species but one root develops directly from the seed. In others two or more appear almost simultaneously; these are really branches from the caulicle. When the development of the embryo is so far advanced that the testa (covering) of the seed is thrown off, or that the stem appears above ground, many peculiarities present themselves. For the investigation of these the germinator if properly managed will furnish ample material.

3. It will be seen that in many cases there are two seed-leaves (for example, the two halves into which a pea or bean splits) called **Cotyledons.** All plants having two cotyledons belong to the group called **Dicotyls.** In these, great variation is seen in the form of the seed-leaves; some are narrow, others are broad; in a few cases they are unequal; some are sessile—*i. e.* without a stem to the blade or broad part; others are on long petioles (leaf-stems). They generally have an entire margin, but some are scalloped or lobed, or they may be notched at the apex or even two-cleft or three-cleft. Some cotyledons are lifted above the surface of the soil by the lengthening of the caulicle, expand more or less and become green so that they strongly resemble ordinary foliage leaves. In other cases they do not increase in size, but remain within the seed-covering underground; they do not then become green, nor have any resemblance to leaves, and they soon disappear.

The seedlings from the germinator will show these variations if they are studied at the proper time. They should be examined and sketched in detail, by each pupil before a recitation is called for, or before the text is studied. This will require many hours' work and should form several lessons. The specimens should be saved, when possible, for subsequent reference. The pupil should also collect for illustration seedlings from the woods, fields, etc., during the growing season. Such specimens can be dried between folds of paper under pressure, and then glued to sheets of cardboard, or thick white paper, of uniform size—eight and one-quarter by eleven and one-half inches (this being just half the size of standard sheets for botanical specimens).

4. Those seedlings which instead of two (opposite) cotyledons, have but one, as the Lily, Onion, Corn, Wheat, Barley, etc., belong to the group of plants called **Monocotyls.** The seed-leaf of the Monocotyls seldom resembles a foliage leaf. It is aërial in the Lily family, and in case of some other plants of this group, but it remains mostly underground in or attached to the seed, making its real nature difficult to determine. In seedlings of members of the **Pine family** the number of cotyledons varies in different genera and species, often also in different individuals of the same species. Sometimes there are only two, but often four to six, or even as many as ten, forming a whorl at the top of the caulicle. In botanical classification the Pine family is not included in either of the two groups, Dicotyls and Monocotyls, but forms a separate class (Gymnosperms) whose characteristics will be explained later.

5. In some seeds the leaves are thick and said to be *fleshy.* These together with the caulicle may occupy the entire cavity within the seed-covering. They are distended by reason of the nourishment with which they are gorged. It is at the expense of this reservoir of food that the embryo or seedling is developed. When the seed-leaves are thin or small the nourishment is stored up around but yet in contact with them. This they absorb for food during the early period of the development of the seedling. This stage is called **Germination.** When nearly or quite all the nourishment has been drawn from the seed and seed-leaves, the latter disappear. By this time roots and leaves in sufficient number have been developed to provide food for the plant.

6. There may be seen between the two cotyledons in case of the bean and many other seeds, a small though conspicuous bud. This is called the **Plumule.** It is present, though usually minute, in every germinating seed; a lens should be used in its examination. It terminates the upper end of the axis (caulicle); the opposite (root) end of this axis has a different structure and it is called the **Radicle.** The development of the plumule results in the production of the stem

and leaves of the plant. The leaves that first appear are almost invariably quite unlike the cotyledons. They are usually the typical or ordinary foliage leaves of the species. In some cases, however, they are mere scales, as seen in the Pea, Oak, etc. The first one or few leaves that appear are usually simpler than those developed later. They may be simple if the typical leaves are trifoliate, or trifoliate if the foliage is pinnate, etc. If the species has lobed or palmate leaves, the first one or more developed are usually entire or heart-shaped. Of as simple type or pattern as the first leaves generally are, they are by no means so nearly uniform in shape and appearance as the seed-leaves. In reference to the latter a writer has said that "Cotyledons are a survival of the universal foliage of deciduous trees in olden geologic days, ere time had differentiated them into their present varied forms."

CHAPTER II.

ROOTS.

1. The **Roots** serve the double purpose of fixing the plants securely in the soil, and of absorbing the nourishment which is largely contained in solution in the soil-water. They branch irregularly, and subdivide repeatedly, finally ending in a multitude of very small rootlets. A portion, near the tip only, of each rootlet is thickly covered with very small hairs. These absorb the soil-water. As the rootlet elongates new hairs are produced, the older ones quickly dying and leaving no scar. Both the rootlets and hairs are most abundantly developed in fertile soils that contain a moderate amount of moisture. The hairs are not developed at all when the roots grow in water. The older roots and older portions of the rootlets are destitute of hairs and they do not perform the function of absorption, or to an inconsiderable extent only. In the resting or dormant (winter) stage of plants, when no new roots nor root-hairs are being developed, but little absorption takes place. At this time transplanting can be done with less injury than if done during the growing season.

Numerous plants should be pulled or dug up and their roots examined. The germinator previously described, if provided early enough, will furnish a variety of examples. Also make a root-cage by tying together two panes of glass, kept one-fourth inch apart by narrow strips of wood placed near the edges on three sides. Fill the space between the panes of glass with fine sand or soil and plant a seed of Sunflower or Corn (or other plants) near the upper open edge; supply moisture, keep at a proper temperature, and watch the root-development from day to day. Make sketches and notes of the observations.

2. The **Root-hairs** (called *rhizoids*) apply themselves very closely to the minute particles of which the soil is composed.

Each of the soil particles has a very thin adherent film of moisture, and this it is that the root-hairs absorb. In this manner the dissolved mineral food is conveyed into plants to be converted into organic (vegetable) matter for building up all their parts. Solid particles are not taken up by the plant. However, the tip of the root-hairs is often acid—as test with litmus paper will demonstrate—and the hairs are therefore capable of dissolving to some extent the mineral particles to which they affix themselves.

Place a number of seeds, as Corn or Wheat and Bean or Sunflower (previously soaked in water), on the surface of wet sand in a shallow box or tray—first covering one-half of the area with a thin sheet of white paper. Cover the box with a pane of glass to prevent evaporation. The seeds which germinate on the paper will in two or three days furnish good examples of root-hairs visible to the unaided eye, but seen more satisfactorily with a pocket lens. The roots of the other seedlings, not prevented from penetrating the soil, when pulled up will have a mass of particles clinging to them, some of which can scarcely or not at all be washed off (soak for a few moments and then use a camel's-hair brush)—showing that the hairs have taken firm hold on the minute mineral particles.

3. Though granite, limestone and other rock-materials are usually said to be insoluble, yet the rain water, percolating through the soil and there becoming more or less charged with carbon dioxide and alkalies, does slowly dissolve even these refractory mineral matters. While each root-hair absorbs but a tiny drop of this soil-water, the countless myriads combined, take up for the plant a stream that furnishes the food-material required from the soil. That rootlets can disintegrate mineral matter is shown experimentally by their perceptible corrosion of a piece of polished marble with which they may come in contact.

Place a small piece of marble, with one face polished, near the bottom of a box or pot of soil. Plant seeds so that the roots of the seedlings will touch and spread over the polished face as they grow. After an interval of time (fifteen to thirty days) remove the piece of marble and see the corroded lines where the roots have been in contact. Rubbing the surface with vermilion will render the corroded parts more conspicuous.

4. Since all soils are porous—even the finest clay has space

between its particles—the roots find entrance and force their way vertically and laterally with but little hindrance. The point of growth and elongation is situated near the tip, which is therefore continually thrust forward. The tissue forming the root-cap, though suffering loss by abrasion against the soil-particles, protects the delicate growing portion, and by the latter it is constantly renewed. In case of contact with a solid particle, growth is not impeded on the side that is free; hence the rootlet, by the continued growth on one side, becomes curved and passes around the obstacle. Darwin showed in his experiments with the radicles that "if the tip perceives the air to be moister on one side than on the other it transmits an influence to the upper adjoining part, which bends toward the source of the moisture." Presently the roots contract longitudinally—the central portion shortening so much, that folds or irregularities on the surface, or in the cortical portion, may be seen. This contraction, amounting sometimes to ten per cent. of the length, has the same effect as tightening the ropes to a ship's mast, and therefore anchors the plant more securely in its position.

5. The higher plants, such as the common herbs, shrubs and trees, and the ferns, have **true roots**, the growing point being covered by a root-cap. But in the Mosses, Liverworts, Lichens, Fungi, and Algæ true roots are wanting. Rhizoids (root-hairs) are present in the Mosses and in the Liverworts, and they perform the same functions as true roots.

6. The primary (first) root often persists and remains conspicuous instead of being soon lost in branching. In this case it is called the **tap-root**. It may become enlarged or fleshy as in the Turnip, Carrot, etc. The branches that sometimes proceed from the radicle in place of, or accompanying the primary root, are often designated as multiple primary roots though really they are secondary. In the Sweet-potato, Dahlia, etc. they become enlarged, serving, like the tap-root, as reservoirs of plant food; they are in this case said to be *tuberous*. In Grasses and many other plants the roots are *fibrous;* that is, numerous and thread-like.

7. In case of many plants, the so-called **annuals,** the roots and other parts live but one season. The roots of **biennials,** such as the Carrot, Teasel, etc. live through two seasons. **Perennial** roots continue to live from year to year, though the stem in some cases dies down at the end of each season. Secondary roots may arise from different parts of the plant—stems and branches—whether above or below the ground. Such are called **adventitious roots.** They are common in creeping plants, especially at the joints, and their production is usually favored by contact with moist soil. In the Trumpet Creeper, Poison Ivy, etc., they assist the plant in climbing, and since they do not grow into the ground they are called **aerial roots.** In some rare cases the aerial root is a tendril, as in *Vanilla aromatica.* In some species of Jussiæa (swamp plants) some of the adventitious roots develop into floats.

8. **Aerial roots** are more common in moist tropical countries, especially in deep forests where the light is partially excluded—it being unfavorable to their development. A notable example is furnished by the Banyan-tree of India, and some other Fig-trees. Their outstretched branches send down adventitious roots, that grow into the soil and thus become supporting columns. The Screw-pine is sometimes lifted up by roots that are exposed some distance from the ground. The Sugar-cane produces aerial roots from many joints similar to those near the base of Indian Corn. The seeds of the Mangrove of the West Indies sprout before falling from the tree, and send a long root down into the mud, in which these trees grow, thus gaining a foothold before severing their connection with the parent tree.

9. Aerial roots, whose function is somewhat different from the above, are found in **Air-plants,** or epiphytes (Gr. *epi*, upon; *phyton*, plant). They generally grow on other plants, as their name signifies, but their roots serve merely to give the plant attachment, and the food is derived wholly from the air. Many of the beautiful Orchids of the tropics are of this nature. The *Epidendron*, or Tree Orchis (growing on a species of Magnolia), and the *Tillandsia*, or Spanish Moss (hanging in

tufts or festoons from trees) of the Southern States, are epiphytes.

10. Certain plants not only fix themselves to other plants, but also draw their nourishment from them. Such are **Parasites.** They send their roots, or what corresponds functionally to them, into the tissue of their host and absorb the nourishment which the latter had prepared for its own use. True parasites are destitute of the green substance in leaves, which is called *chlorophyll.* When this is present the plant can in sunlight convert the inorganic matter into plant food.

11. The **Fungi** (as Rusts, Smuts, Blights, Moulds, etc.) are either parasitic on living plants or draw their nourishment from decaying substances. The leafless *Cuscuta*, or Dodder, is a slender yellow flower-bearing parasite of peculiar nature. The seeds sprout in the ground, and the plantlet, as soon as it appears above the surface, seeks for a support around which to twine; if unsuccessful it soon dies, but if it finds a proper host-plant, it closely entwines the same producing suckers by means of which it absorbs sufficient nourishment for its growth and development. The lowest portion of the stem of the parasite then dies, and thus severs its connection with the soil.

12. The Mistletoe of Europe and the False Mistletoe of this country have chlorophyll in their leaves, and are therefore capable of converting inorganic into organic (vegetable) matter; that is, of preparing their own food. Yet they do this only in part. They draw a portion of their food from the trees on which they grow, and to that extent are parasitic. The nature of the yellowish or whitish leafless plants, as the Indian-pipe and Cancer-root, which are fixed to the ground, should not be misunderstood. They do not draw their nourishment from the soil, but from underground roots on which they are parasitic. Neither should all subterranean parts of plants be regarded as roots, since stems sometimes grow underground. Stems, however, are easily recognized by the buds and scales (modified leaves) which they produce, and by the presence of a pith which may be seen by examining a transverse section; in roots no pith is formed.

CHAPTER III.

THE STEM.

1. Besides the distinction of stems based on their duration —as annual, biennial and perennial—they may also be designated as herbaceous and woody. Illustrations of **woody** stems are seen in all shrubs and trees. **Herbaceous** stems are composed of soft or succulent tissue. They are usually green and contain no wood except in the slender and often indistinctly distinguishable woody strands. A few stems and branches have special names, as **culm**, which is the jointed, often hollow stem of the Grass and Sedge families; **stolons** and **runners**, which are slender, trailing, rooting branches; **tendrils**, which are slender, elongated, twining branches; **spines** and **thorns**, which are the hardened, pointed, sometimes merely stunted branches.

Collect illustrative specimens of the various kinds of stems for examination in the class-room. Draw outline figures of each kind. In case of the woody stems, the leaf-scars should receive attention. Make an outline figure giving the exact shape, which will be uniform for each species of plant. Note the dots regularly distributed in the scar. These are the ends of the severed woody strands that passed from stem to leaf. Note the numerous but somewhat indistinct scars, very close together, situated at a considerable distance from the end of the twig. The portion beyond this point is the growth of the last season. The scars indicate the position of the bud-scales of the terminal bud of that season.

2. **Underground stems** sometimes resemble roots, but they are distinguished by having nodes (joints) and scales. The latter represent leaves, above which, or in whose axils, buds may be detected. They are also terminated by a bud. **Rhizome** is the name applied to the elongated slender form, and **tuber** to the short and much thickened stem. The under-

ground stems of the Mint illustrate the former, and the Irish Potato the latter. A **bulb** is a very short stem or root-stock, covered by bases of leaves in the form of thickened scales, and bearing roots below. A **corm** is likewise short and thick, bearing roots below, but destitute of scales. The Onion is a familiar example of a bulb; the Indian Turnip and Cyclamen furnish examples of the corm. These thickened stems and scales are reservoirs of nourishment.

3. Some stems, as the corn-stalk, have woody strands scattered irregularly through the whole interior and commingled with the pith (Fig. 1). Such strands are found, though not always so easily recognized, in stems of the Lily, Spiderwort, the Orchids, Solomon's Seal, Asparagus, Flag, Palms and many others. The plants with stems of this kind are, with very few exceptions, **Monocotyls**[1]—that is, they have but one cotyledon or seed-leaf to each seed. When the woody strands attain their full development, there is no further increase in the thickness of the stem (except in Palms and a few others), though the plant may continue to live for some time. This is clearly seen for example, in the stems of Lily, Asparagus, Corn, etc., where the thickness of the stem when a few inches or a few feet high has reached its limit and thereafter the diameter remains the same. The strands in such stems are, as shown by microscopic examination, composed of only two kinds of tissue, namely, **wood** and **bast.**

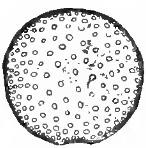


FIG. 1.

4. If a transverse section of a stem of Bean, Bindweed, Mint, Sunflower, Nightshade, Buttercup, Dock, etc., be made and examined with a lens, a central pith will invariably be found, though sometimes it is torn, making the stem hollow. Surrounding the pith but often indistinctly seen, are the isolated woody strands, usually few in number, forming a circle (Fig. 2). **Dicotyls** (with but few exceptions) have such stems.[1]

[1] In older books the terms *endogenous* ("inside-growing") and *exogenous* ("outside-growing") have been erroneously used to designate the monocotyledonous and dicotyledonous stems.

In many cases during the middle and latter part of the season, the strands become numerous and join each other so as to make a continuous ring or cylinder. This is always true of shrubs and trees.

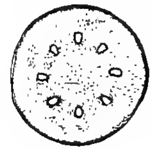


FIG. 2.

5. The strands in stems of the Dicotyls consist of **wood** and **bast** with a thin intervening layer of delicate tissue, called **cambium**. The woody portion of each strand is next to the pith, and the bast portion is always toward the surface of the stem. Therefore when the strands become numerous and large enough to join, their fusion will necessarily result in the formation of a **woody ring** next to the pith, a thin **ring of cambium** next to the wood, and a **ring of bast** outside the cambium. The cambium layer will, each succeeding year, grow and produce an additional layer (or ring) of wood—the annual rings thus revealing the age of the tree. The bast is also constantly renewed by the cambium—the outermost portion gradually dying, becoming furrowed, withering away, or exfoliating as dead bark.

Select some twigs and branches of any common tree, say the Linden, and make thin transverse sections. Those from twigs of one year's growth will have the pith in the centre, a ring of wood adjoining, then a ring of bast, with the original epidermis and cortex exterior to the bast. The sections from stems of two years' growth will show the pith and two distinguishable though cohering rings of wood. Likewise the age of the others will be indicated by the number of rings of wood-growth. Notice the narrow radiating lines of tissue, some of them beginning at the pith. These are the **Medullary Rays**. Use the pocket lens. Draw enlarged figures of the sections. Make sections of twigs of various other species and compare the relative size, shape and color of the pith, the distinctness of the annual rings and the differences in the medullary rays.

6. The **Buds** on twigs and branches are disposed regularly, either at points opposite—rarely in a whorl of three or more —or but one at a node (joint). They are at approximately regular intervals and there is a terminal bud to each stem or twig. Below each of the lateral buds will be seen a scar (leaf-scar), indicating that each was developed just above (that is, in the axil of) the leaf; the buds are therefore axillary and

have the same arrangement on the stem as the leaves have. In a few cases, as in the Soft Maple, etc., there are **accessory** buds, that is, one or more buds added to the side of the axillary bud. When the buds develop at irregular places they are said to be **adventitious.**

7. When a bud is carefully dissected it is seen to consist externally of scales, usually numerous and overlapping each other in an imbricate manner. These scales are really small leaves. They cover and protect the central portion of the bud, which is the delicate **growing end** of the branch. Often the outer scales are covered with resin or varnish or the inner scales bear woolly hairs, protecting the growing point very effectually against rain and the extremes of temperature. The following season some of the buds—especially the uppermost and a few of the lateral ones—develop into branches. The others remain dormant, or in some cases may be forced later into development. The buds referred to in this paragraph are sometimes spoken of as leaf-buds in contradistinction to flower-buds, or those which develop directly into flowers.

Short twigs of the common shrubs and trees should be collected in the early spring to illustrate the arrangement of the buds and to show the variations in shape, size and other characters. Draw outline figures of each. For preservation the twigs can be attached to a sheet of cardboard by thread or by means of narrow gummed paper strips or narrow strips of court plaster. The name of the plant from which each twig is taken should be written under the specimen. Large buds (as the Lilac, etc.) should be selected for dissection and for slicing vertically (from below upward) through the centre to exhibit the growing point surrounded by the scales. Use the lens and make an outline figure showing all the parts. Make drawings also of separate bud-scales.

CHAPTER IV.

THE LEAF.

1. THE leaves of plants ordinarily present a large surface expansion. They are perforated by minute pores, called **Stomates.** Through these oxygen and carbon-dioxide enter the leaf, and water in the form of vapor escapes from it. Nearly all of the water that is taken up by the roots, thence conveyed through the stem and branches to the leaves, passes out through the stomates. The leaf retains the minerals that were dissolved in the water. It also decomposes the carbon-dioxide (CO_2) which it takes from the atmosphere, retaining the carbon but liberating the oxygen. These several elements of inorganic matter are formed into organic or vegetable material, which the plant uses in building up all its parts. The leaf, then, has evidently very important functions to perform, for which it is specially adapted by its structure. Only the ordinary foliage leaves fully perform these functions ; they may be said to exhibit the typical form. Besides these, there are many modified forms, some of which have departed so far from the type that their true nature can be understood only when we see all the intermediate forms or gradations connecting the two extremes. Such are cotyledons, scales, spines, tendrils, pitchers and fly-traps.

Illustrations of everything (or with few exceptions) to which reference is made in this chapter can be obtained everywhere and in great abundance. The pupils should examine, compare, make outline figures and thoroughly study this illustrative material, which of course will be work for *many days.* Then the text can be studied to advantage.

2. The two halves into which a pea, bean, etc., readily divide are called the **Cotyledons,** or seed-leaves. If they be observed

in the case of the Pumpkin and certain other plants, some time after germination it will be found that they have changed their shape somewhat and become green, like ordinary leaves. As a rule, however, the cotyledons change but little, and simply furnish the nourishment for the plantlet during germination. In the bulb-scales is stored up food for the early growth of the plant the following season. This nourishment is consumed in such bulbous plants as the Hyacinth, etc., by the production of flowers early in the season, or in advance of the leaves.

3. The leaves of underground stems are generally reduced to mere scales. The **Bud-scales**, which protect the tender parts within, are modified leaves. A gradual transition between them and the first foliage leaves may often be traced, as in the Lilac, Hickory, etc. When **spines** occupy the place of leaves, they are modified forms of the latter. In the Barberry all gradations may be seen on a single shoot. The leaf, or a portion of it, may become changed into a **tendril** for climbing, as in the Pea, Vetch, etc. (Fig. 3.)

4. Very interesting modifications of leaves are furnished by

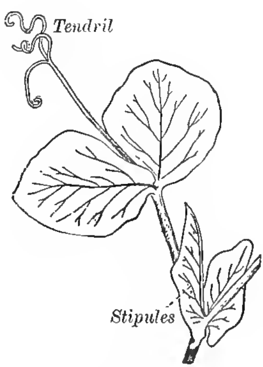


FIG. 3.

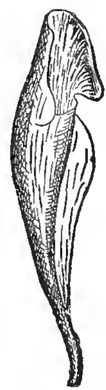


FIG. 4.

the Pitcher-plant (*Sarracenia*), Sundew (*Drosera*), and Venus's Fly-trap (*Dionœa*). The leaves of Sarracenia are hollow cups or tubes (Fig. 4) inwardly covered with hairs directed downward. They are generally half full of a liquid into which insects may fall and become macerated, and their juices are then absorbed by the plant. The Drosera is also carnivorous, feeding on small insects which alight on and are held fast by the viscid tentacles on the upper side of the leaf.

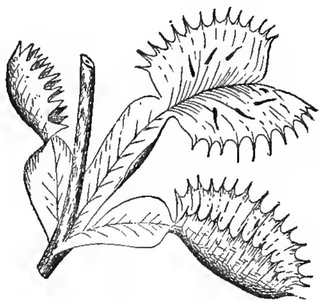


FIG. 5.

FIG. 6.

The leaves of Dionœa (Fig. 5) have at the top, two or three lobes furnished with a marginal row of stout bristles, and three or four slender ones on the upper surface. When the bristles on the upper surface are touched by a small insect,

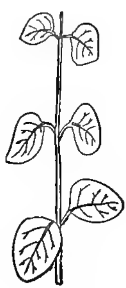


FIG. 7.

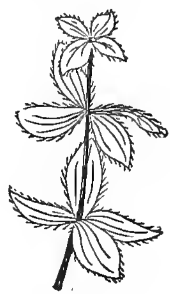


FIG. 8.

the lobes suddenly close in upon it and the prisoner is then digested and consumed.

5. The leaves are said to be **alternate** (Fig. 6) when there is a single leaf at each node or joint of the stem. Examples

of this arrangement are very numerous, as the Apple, Oak, Elm, Willow, Dock, etc. If two leaves occur at each node, they are said to be **opposite** (Fig. 7), as the Maple, Ash, Peppermint, Catnip, etc. Sometimes there are three or more leaves at each joint, as in Cleavers (*Galium*), Trumpet-weed (*Eupatorium purpureum*), etc. In this case the leaves are said to be **verticillate** (Fig. 8). In the Pines and Larch the needle-shaped leaves are in clusters, that is, they are said to be **fasciculate.** If leaves grow from the base of a stem, but appear to come out of the ground, they are **radical** (Lat. *radix*, root). Those leaves inserted in the stem are **cauline** (Lat. *caulis*, stem).

6. On a straight, leafy shoot of an Elm, Cherry, Apple, Oak, Willow, etc., pass a thread from the lowest leaf to the one next above, and continue it around the stem in the same direction to the successive leaves above. The thread will be seen to take a spiral course; the leaves are therefore **spiral** in their arrangement on the stem. In the Elm the third leaf stands directly over the first, and to reach it the thread has passed once around the stem, or, as is usually said, the cycle is complete when the third leaf is reached, and it is expressed by the fraction $\frac{1}{2}$. The numerator denotes the number of turns; the denominator the number of leaves encountered. Experimenting in a similar manner with Alder, the fraction $\frac{1}{3}$ is obtained, and with the Cherry $\frac{2}{5}$. In the latter case the stem would be encircled twice before a leaf is found (the sixth), which is inserted directly over the first, and five leaves are contained in the cycle. In a similar manner the fraction $\frac{3}{8}$ with the Flax, $\frac{5}{13}$ with the Flea-bane, $\frac{8}{21}$ with the Houseleek, $\frac{13}{34}$ with cones of some Pines would be obtained.

7. A leaf may have three parts, namely; the **Blade** or **Lamina,** which is the expanded portion; the **Petiole,** which is the stem of the leaf; and **Stipules,** which are the appendages at the base of the petiole (Fig. 9). The stipules are very often wanting, in which case the leaf is said to be **exstipulate.** If the blade is inserted directly on the stem (which is the case

when the petiole is absent), the leaf is said to be **sessile.** The blade consists of a frame-work of **veins** or skeleton of woody tissue, and the soft, green tissue between the veins, called **parenchyma.** When one central vein surpasses the others in size it is called the **midrib**; its branches are the **veins,** and the branches from the veins are the **veinlets.** When the venation of a large number of different kinds of leaves is examined, three types are found to prevail. In most of our common Fern-leaves the veins are separate their entire length and have **free** ends, though they are often forked one or more times. In the other two types the smaller veinlets (and sometimes the veins) anastomose. One is represented by the leaves of most Monocotyls, as the Lily, Flag, Grass, Corn, Wheat, etc. In these a number of conspicuous veins extend from the base to the apex of each leaf, approximately parallel to each other, and this fact has suggested the name **parallel-veined** (Fig. 10). The term *striated* may be used instead. The third type is seen mostly in Dicotyls, as the Oak, Elm, Maple, Catnip, Mallow, Dock, etc.; the veins

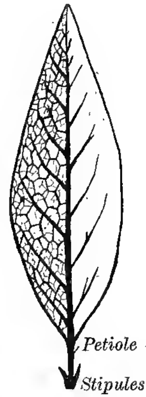


FIG. 9.


FIG. 10.

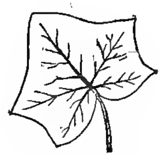
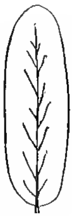


FIG. 11.

and veinlets here form a conspicuous network, and are said to be **netted-veined,** or *reticulated.* Of the latter, there are two sorts: the veins may branch from a midrib (Fig. 9), when they are **pinnately-veined** (Lat. *pinna,* feather); or they may branch from 3, 5, 7 or more ribs (Fig. 11), in which case they are **palmately-veined** (Lat. *palma,* palm).

8. The principal terms used to designate the shape of the leaves are :—**linear,** narrow, long, and of the same breadth throughout (Fig. 12); **lanceolate,** long and narrow, tapering upwards and downwards (Fig. 13); **oblong,** twice or thrice as long as broad (Fig. 14); **elliptical,** oblong with a flowing





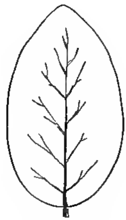
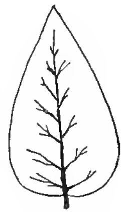
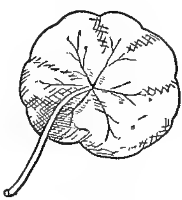



FIG. 12. 13. 14. 15. FIG. 16. FIG. 17.

outline (Fig. 15); **oval,** broadly elliptical (Fig. 16); **ovate** shaped like an egg, the broader end downwards (Fig. 17); **orbicular,** circular in outline, or nearly so (Fig. 18); **oblanceolate,** like lanceolate, except with the more tapering end downwards (Fig. 19); **spatulate,** shaped like a spatula, that is,



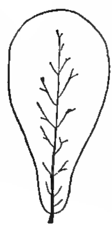
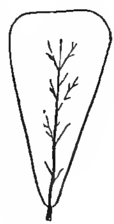




FIG. 18. FIG. 19. 20. 21. 22.

round above and narrow below (Fig. 20); **obovate,** ovate, with the narrow end downwards (Fig. 21); **cuneate** (Lat. *cunea*, wedge), shaped like a wedge (Fig. 22).

9. As to the base, leaves may be :—**cordate,** heart-shaped (Fig. 23); **reniform,** kidney-shaped (Fig. 24); **auriculate** (Lat. *auricula,* little ear), with ears or blunt projections (Fig. 25); **sagittate** (Lat. *sagitta*, arrow), with pointed projections downwards (Fig. 26); **hastate** (Lat. *hasta*, spear), with pointed pro-

jections outwards (Fig. 27); **peltate** (Lat. *pelta*, shield), when the petiole is attached to the under surface near the middle

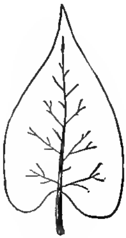


Fig. 23.

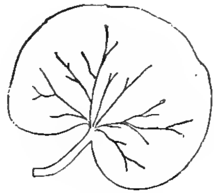


Fig. 24.

(Fig. 18). The apex of leaves may be:—**acuminate**, ending in a prolonged point (Fig. 28); **acute**, ending in an acute

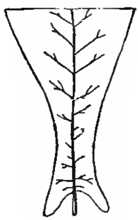


Fig. 25.

Fig. 26.

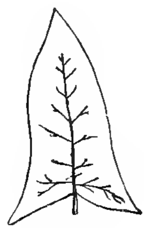


Fig. 27.

angle (Fig. 29); **obtuse**, with a blunt point (Fig. 30); **truncate**, with the end as if cut square off (Fig. 31); **emarginate**, notched at the end (Fig. 32); **obcordate**, with a deep notch,

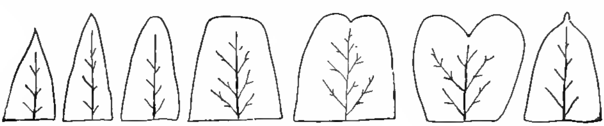


Fig. 28. 29. 30. 31. 32. 33. 34.

or inversely heart-shaped (Fig. 33); **cuspidate** (Lat. *cuspis*, point), tipped with a sharp stiff point (Fig. 34); **aristate** (Lat. *arista*, awn), with a long bristle or awn.

10. The margin of leaves may be:—**entire**, that is, the edge

is an even line without any notches or teeth; **serrate** (Lat. *serra*, saw), with teeth like a saw projecting towards the apex (Fig. 35); **dentate** (Lat. *dens*, tooth), with teeth pointing out-

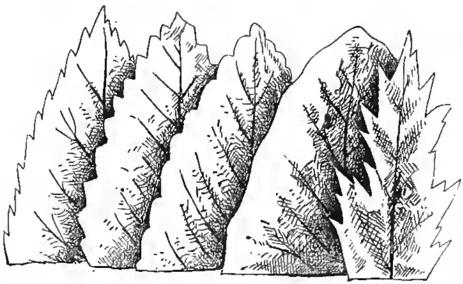


Fig. 35. 36. 37. 38. 39.

ward instead of forward (Fig. 36); **crenate** (Lat. *crena*, scallop), scalloped (Fig. 37); **undulate** (Lat. *undula*, wave), wavy (Fig. 38); **incised**, when the edge is cut and jagged (Fig. 39). When leaves are deeply cut, the divisions are called **lobes**. If the incisions extend more than half-way from the margin to

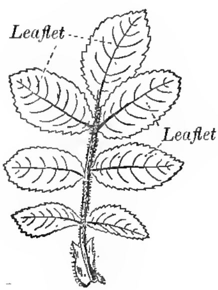


Fig. 40.

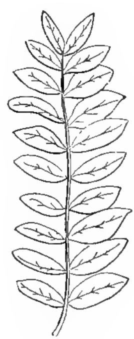


Fig. 41.

the midrib, the leaf is said to be **cleft**; the number of segments is indicated by the terms **bifid** (two-cleft), **trifid** (three-cleft), **multifid** (many-cleft), etc. If the incisions extend almost to the midrib, the leaf is said to be **parted**; if they extend quite to the midrib, the leaf is **divided**; and thus a single leaf, or one with a lamina in a single piece, is converted into a **compound leaf**—that is, one with the blade divided into several parts (Fig. 40). Each of the divisions is called a **leaflet.**

11. Corresponding to the pinnate and palmate type of venation, there are pinnately and palmately compound leaves. The **pinnate** leaves have the leaflets or pinnæ arranged on each side of the rachis. If the leaflets are in pairs throughout, the leaf is said to be **abruptly pinnate** (Fig. 41); if a single leaf terminates the rachis, the leaf is said to be **odd-pinnate** (Fig. 40). **Palmate** leaves (sometimes called **digitate**) have the leaflets borne on the extreme end of the leaf-stalk (Fig. 42).

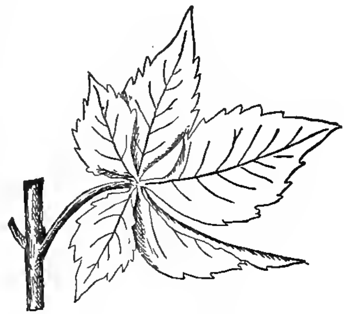


Fig. 42.

12. The primary divisions of the blade may be again divided, which is expressed by the terms **bi-pinnate** (Fig. 43), or **tri-pinnate** (thrice divided). When the leaf is several times

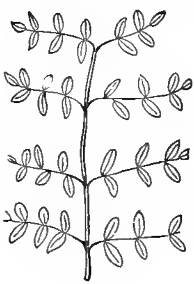


Fig. 43.

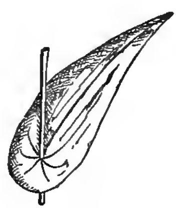


Fig. 44.

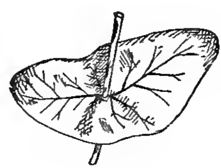


Fig. 45.

compound, it is said to be **de-compound.** Of numerous other forms not yet mentioned, the following are conspicuous. **Perfoliate** (Lat. *per*, through; *folium*, leaf), in which the stem appears to pass through the leaf near its base (Fig. 44), as in the Uvularia. In Honeysuckles the opposite leaves are sometimes united at their bases, rendering them **connate-perfoliate** (Fig. 45). Several kinds of leaves have no distinction of blade and petiole; as the sword-shaped, **ensiform** (Lat. *ensis*, sword), leaves of the Daffodils; the needle-shaped, **acicular** (Lat. *acus*, needle), leaves of the Pine; and the scale-shaped, **squamose** (Lat. *squama*, scale), leaves of the Junipers. The surface of leaves differs in various species of plants. It may be glabrous (smooth), or scabrous (rough); it is often hairy, indicated by such terms as pubescent (with short hairs), hirsute (with stiff hairs), villous (with long, soft hairs), lanose (woolly).

13. The **Stipules** are sometimes free, leaf-like appendages, as in the Pea (Fig. 46), and perform the ordinary function of

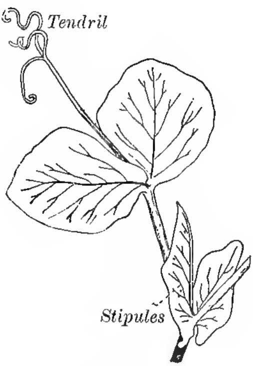


FIG. 46.

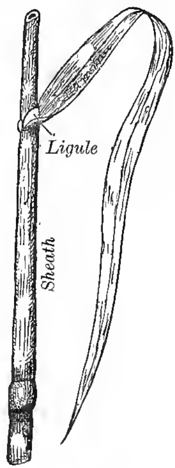


FIG. 47.

the leaves; ordinarily, however, they are very much reduced in size, as in the Bean; sometimes they take the shape of bristles or prickles, as in the Locust. In the Smilax they have the shape of tendrils. When united to the base of the petioles, as in the Rose and Clover, they are said to be **adnate.**

The stipules of the Tulip-tree serve as bud-scales, falling off soon after the leaves unfold. In some plants, as the Dock, the Buckwheat, etc., they unite and form a sheath around the stem. The sheath of the Grasses represents the petiole, for it bears the blade at its summit; the small appendage commonly found at the top of the sheath, called a **ligule** (Fig. 47), is of the nature of a stipule.

Specimens should be collected to illustrate all the points mentioned in the chapter, and figured, as suggested above. Illustrative specimens for preservation should be pressed till dry, and then mounted on cardboard or heavy white paper. They can be attached by means of liquid glue, or by using strips of gummed paper or white court plaster. Opposite or below each the points illustrated should be indicated by the appropriate term.

CHAPTER V.

THE INFLORESCENCE.

1. The term **Inflorescence** indicates the mode of flowering, or the situation and arrangement of the flowers on the plant. That this is quite various in different species of plants can be seen by noting the numerous examples to be found any time during the growing season. If the flowers develop from lateral buds the inflorescence is said to be **indeterminate**, since the shoot, terminated by a leaf-bud, may continue to grow in length.

Collect specimens of numerous flower-clusters of both native and cultivated plants, securing as many forms and variations as possible. Compare these in detail, and arrange so as to show affinities. Make a diagrammatic figure of one of each kind. As noted elsewhere, all illustrative specimens should be saved for use in review; in this case, after drying under pressure, attach to cardboard or to thick sheets of white paper.

2. If the flowers develop from terminal buds the inflorescence is **determinate**, so-called because the length of the axis is thereby determined; it cannot grow longer. The indeterminate inflorescence is also **centripetal**, that is, the outermost flowers (when the cluster is level-topped) or the lowest on the stem open first, and those higher follow in regular succession, until finally the one in the centre or at the top expands. Examples are furnished by the Lily of the Valley, Currant, Plantain, Shepherd's Purse, etc. The determinate inflorescence is **centrifugal**, inasmuch as the flowering begins in the centre or at the top and proceeds outward or downward. This is exhibited in the Chickweed, Dianthus, Hydrangea, etc.

3. The following are varieties of indeterminate inflorescence: raceme, corymb, umbel, spike, spadix, catkin, head and panicle. The **raceme** has the pedicellate flowers scattered on an elongated axis (Fig. 48). The **corymb** is the same as a raceme, with the lower pedicels elongated so as to make the flower-cluster level-topped (Fig. 49). In an **umbel** the axis

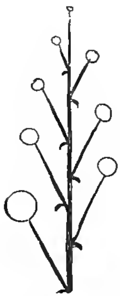


Fig. 48.

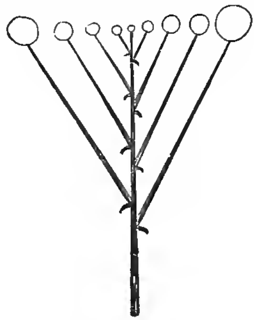


Fig. 49.

is reduced, and all the pedicels proceed from a common point (Fig. 50). The **spike** is similar to a crowded raceme, with

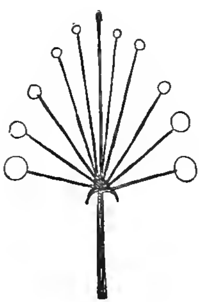


Fig. 50.

Fig. 51.

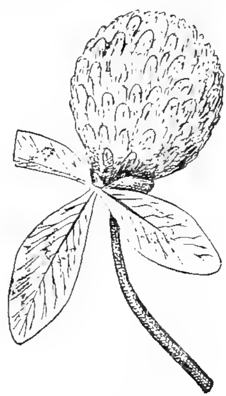


Fig. 52.

the flowers sessile (Fig. 51). Two forms of the spike have special names: the **spadix** (Fig. 56), which is fleshy and commonly surrounded by a modified leaf, called the spathe; and the **catkin** or **ament**, which is scaly. The **head** differs from a spike in that the axis is reduced, crowding the flowers into a head-like cluster (Fig. 52). A **panicle** is an open or more or less compounded raceme or corymb (Fig. 53).

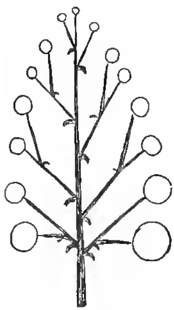


Fig. 53.

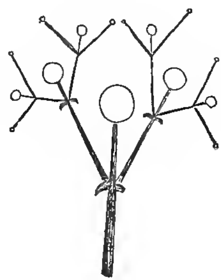


Fig. 54.

4. The **cyme** is a determinate or definite flower-cluster, with a flat or convex top. It resembles the corymb somewhat, except that in the latter the flowering is centripetal, while in the cyme it is centrifugal (Fig. 54). A crowded cyme is called a **fascicle**. Many of the clusters are often compound, as compound umbels, compound cymes, etc. The two classes of inflorescence may be represented in one and the same plant; thus the Mint family has cymes or fascicles, which are centrifugal in their flowering, but these are generally composed of spikes or racemes, which are centripetal in their order of flowering.

CHAPTER VI.

THE FLOWER.

1. If a leafy shoot be reduced in length, the leaves will be brought close together; if the internodes (portions of the stem between the joints) are wanting entirely, the leaves will be in whorls, or form a rosette. If now these leaves undergo certain changes in form and function, a **Flower** will be formed. This change or modification of one part or organ into another is called *metamorphosis*. The flower is a metamorphosed branch, and the different parts are modified leaves. Proofs of this are found in the partial or complete reversion of floral organs back into ordinary leaves. For example, in almost any "double" flower, as a rose, holyhock, etc., stamens (the slender bodies near the centre) may be found that have partly reverted to petals (the showy parts); often other parts have become changed from their usual form, so as to resemble more or less closely the ordinary foliage leaves. On the other

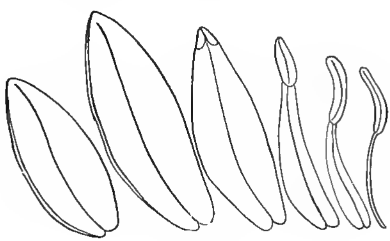


Fig. 55.

hand numerous intermediate forms may be found which exhibit a gradual transition from foliage leaf to the most highly modified organ (pistil). The flower of the Water-Lily is a partial illustration (Fig. 55).

There can be no lack of easily obtained material for *direct study* of what is outlined in the following paragraphs. The *order* in which the several topics of the chapter are given need not be scrupulously followed in the practical work of the class-room; though all of them should be brought out by a study of abundant and suitable material *before* the text is assigned for class recitation, or review. The note-book should be daily used, the lens called into requisition when desirable, and drawings made directly from the specimens to illustrate all the structures that beginners should see. The advantage of preserving illustrative specimens can here, as elsewhere, be seen.

2. The stem or stalk, which supports a flower-cluster or a solitary flower, is called the **peduncle**. If the peduncle is wanting, the flower is inserted directly on the stem, and is said to be *sessile*. When the peduncle arises from the ground it is called a **scape**. The minute branches of the peduncle, or slender stalks which support the individual flowers, are called *pedicels*. The **bracts** are generally diminutive leaves which subtend the flower-cluster, or from whose axil the flower-stem proceeds. When a single enlarged bract encloses the flower-cluster, it is called a **spathe** (Fig. 56). If the bracts are numerous and form a conspicuous cup under the flowers,

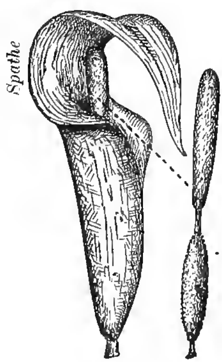


Fig. 56.

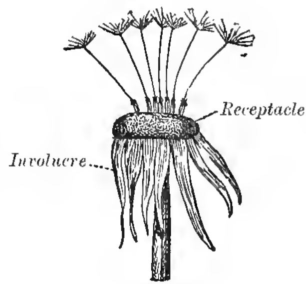


Fig. 57.

or an imbricated covering around a head of flowers, they form an **involucre** (Fig. 57). The term **receptacle** (Fig. 57) is applied to the axis of a flower-cluster when it is disk-like or short, so that the flowers are crowded into a head.

3. The purpose of the flower is the production of seed. Four distinct parts may be present, each having a distinct function to perform. In a flower such as the Buttercup, Crab-Apple, Morning Glory, Phlox, etc. there will be found as the outermost part, a **calyx,** or cup-like portion. This consists of several parts, either distinct or united, which more or less resemble ordinary foliage leaves. Each leaf or portion of the calyx is called a **sepal.** Within this whorl of leaves forming the calyx is a second whorl, either of distinct or more or less united parts, called the **corolla.** This is commonly the most showy part of the flower. Its component parts are called **petals,** and they usually depart farther from the ordinary form and texture of foliage leaves than do the sepals.

4. Within the corolla are slender bodies called **stamens.** They sometimes revert to petals or sepals, showing that they are also modified leaves. These organs are sometimes excessively numerous; and when few are rarely less in number than the parts of the corolla or calyx. Within these and occupying the central part of the flower, are the **pistils**; in the lower enlarged part of which, called the **ovary,** the seeds are produced. The pistils, like the stamens, may be numerous, but are very often fused together or reduced to one. There can be no production of seed without both stamens and pistils, and for this reason they are together called the *essential organs* of the flower. The calyx and corolla may or may not be present without directly influencing the production of seed. They are called the **perianth** (Gr. *peri*, around; *anthos*, flower), a term that is used especially when the sepals and petals more or less closely resemble each other.

5. A flower with the four parts present is called a **complete** flower; but if one or more of the parts are absent, the flower is said to be **incomplete.** If the essential organs are present it is called a **perfect** flower. Those with stamens but no pistils, called *staminate* flowers, and those with pistils but no stamens, called *pistillate* flowers, are imperfect. If the several

parts are exactly alike, that is, all the sepals alike in shape and size, all the petals alike in shape and size, and all the stamens alike in shape and length, the flower is said to be **regular.** If this likeness in shape, size, etc. does not obtain in any one or more of the organs, the flower is said to be **irregular.** If the petals, sepals and stamens are of the same number, or the latter may be twice or thrice as many, the flower is said to be **symmetrical**; but if the number is different in different whorls, the flower is said to be **unsymmetrical.**

6. When the relative **insertion** of the floral parts is examined, two types are found to prevail. In one case each petal is inserted directly in front of, or within, a sepal, and each stamen directly in front of, or within, a petal; the parts are then said to be **opposite.** But in the other case the petals are in front of, or directly within, the spaces between, that is, alternate with the sepals, and the stamens alternate with the petals; then the parts of the flower are said to be **alternate.** When the parts of the flower, especially of the calyx and corolla, are each three in number, the flower is said to be *three-parted. Monocotyls* generally have three-parted flowers. If the parts are each four or five in number, the flowers are respectively four- or five-parted; the five-parted flowers are generally characteristic of *Dicotyls.*

7. When the sepals are free or distinct from one another, the calyx is said to be **chorisepalous** (Gr. *choris*, asunder), and when the petals are free, the corolla is **choripetalous.** The terms polysepalous and polypetalous, instead of the preceding, have generally, though incorrectly, been used in descriptive botany. The sepals may be united edge to edge, so that only their upper ends are free, by which the number forming the cup or calyx may be determined. The calyx in such case is said to be **gamosepalous** (erroneously called monosepalous). When the petals are united the corolla is **gamopetalous** (Fig. 58). The term monopetalous is erroneously used with the same signification. This union of similar parts, or *cohesion*, gives rise to a variety of forms of the calyx and corolla, prominent among which are:—rotate, salverform, campanulate, funnelform, tubular, labiate and ligulate.

8. A **rotate** (Lat. *rota*, wheel), or wheel-shaped calyx or corolla, is one in which the tube is very short or wanting, and the lobes spread at once (Fig. 58). In the **salverform** corolla, the

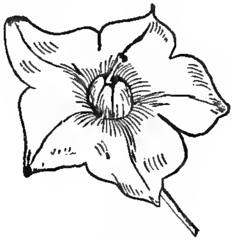


Fig. 58.

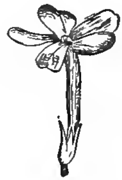


Fig. 59.

Fig. 60.

spreading limb or border is raised on a narrow tube, and forms a right angle with the latter (Fig. 59). The **campanulate** (Lat. *campanula*, bell) denotes a bell-shaped calyx or corolla (Fig. 60). The **tubular** form spreads above but little. The two upper petals may unite closely and form a kind of upper lip, and the three lower ones unite to form a lower lip. In such case the corolla is **labiate** (Lat. *labium*, lip). The calyx may also be labiate, or two-lipped.

9. Examine a flower-head of a Sunflower; it will be seen to consist of numerous florets, with tubular corollas interspersed with the bristles or chaff. There will also be found a row of marginal flowers, called *ray flowers*. These have strap-shaped corollas, which are said to be **ligulate** (Lat. *ligula*, tongue). In the Dandelion all of the florets are ligulate. A curious shape is presented by the Pea or Bean. The corolla is choripetalous, very irregular, with a vague resemblance to a butterfly, and for this reason it has received the name **papilionaceous** (Lat. *papilio*, butterfly); the upper and larger petal is called the *banner*, the two side petals are called the *wings*, and the two anterior ones, generally cohering slightly and enclosing the stamens and pistil, are called the *keel*. The flowers of the Cress, Mustard, Cabbage, etc. have four petals, arranged two and two opposite, somewhat like a Greek cross, and they are said to be **cruciform** (Lat. *crux*, cross).

10. A conspicuous irregularity in the flower is caused by the production of appendages of various kinds. One petal in the Violet is prolonged so as to form a **spur**; this organ is tubular and generally contains nectar, or sweet substance secreted by the flower. Some species of Dicentra are two-spurred. All the petals of the Columbine have spurs. Sometimes there is only a gentle swelling or blunt outward projection (as in *Adlumia*), which is denoted by the word **saccate**. Sometimes sepals or petals are eared or crested; or they have, like the pink, a projection (*corona*) at the point where the claw or narrow part of the petal joins with the spreading lobe or limb.

11. When there is no *adhesion* or growing together of the calyx and corolla, the former is plainly inserted below the points of insertion of the corolla, stamens and pistils. In such cases (Fig. 61) the calyx is said to be **free or inferior**; or the calyx and corolla are said to be **hypogynous** (Gr. *hypo*, under; *gyna*, pistil). The cohesion may

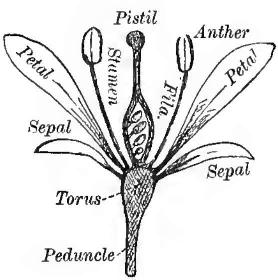


FIG. 61.

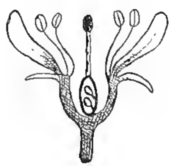


FIG. 62.

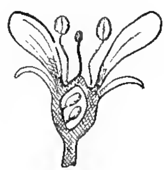


FIG. 63.

be to the extent shown in Fig. 62, where the petals and stamens are inserted on the calyx-tube. The petals are then said to be **perigynous**, though the calyx is free. The calyx-tube may be consolidated with the lower part of the pistil or ovary; the calyx is then **adherent** or **superior**; in this case the parts appear to be inserted upon the pistil (ovary), and are therefore said to be **epigynous** (Fig. 63). If the adhesion does not extend so far up (half-way), the calyx is said to be **half-superior.**

12. The stamens consist of two parts, namely, the **filament** (Lat. *filum*, thread), or slender stem; and the **anther**, or en-

larged upper end. That portion of the filament between the anther-lobes is called the *connective.* The filament is not an essential part, and when wanting the anther is said to be sessile. When the filaments are united into a tube surrounding the pistil, as in the Mallow, they are said to be **monadelphous.** If they are united into two sets, as in Dicentra, they are **diadelphous**; if in three sets, **triadelphous,** and so on. The anthers are united into a tube (syngenesious) in the *Compositæ* (Sunflower, Dandelion, etc.). Make a transverse section of the anther; two or four cavities may be seen with the aid of a lens, and these are filled with a yellow dust, which on examination with the microscope proves to be small, round bodies, called **pollen.** The opening, **dehiscence,** of the anther at maturity for the discharge of the pollen commonly takes place along a line the whole length of each cell. But in the Sassafras, Barberry, etc. the opening is by a lid or valve. In the Azalea, Pyrola, etc. the pollen escapes by a pore at the top of the anther.

13. The number of stamens may vary from one to many in the flowers of different species. They are, however, definite and few in number in the majority of cases. Their size, length and place of insertion may also vary. In the Mint family often two of the stamens are long and the other two short; they are then said to be **didynamous** (Gr. *di,* two; *dynami,* power, strength). In the Mustard family four of the stamens are long and two are short (Fig. 64), called **tetradynamous** (Gr. *tetra,* four). As regards the insertion of the stamens, they are **hypogynous** when attached below the pistils; **perigynous** when attached to the calyx tube surrounding the pistil; and **epigynous** when situated with the sepals on the ovary. They are **epipetalous** when attached to the corolla.

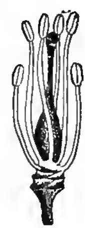


FIG. 64.

14. The pistil (Fig. 65) consists of three parts—namely, the **ovary** or lower enlarged part which contains the ovules or seeds; the **style** or slender part above the ovary; and the **stigma,** the more or less enlarged upper end of the style. The style may be want-

ing, which renders the stigma sessile. According as the pistil (or "carpel," as it is sometimes called) is formed of a single carpellary leaf or of several leaves, it is simple or compound. In a **simple pistil,** formed by a single leaf folded edge to edge, the seeds are borne on the part of the inner wall which corresponds to the line of union of the edges. This seed-bearing line or part is called the **placenta.** If two placentas are present, they must have resulted from the union of two leaves, edge to edge; if three placentas, from the union of three leaves, etc. Therefore the presence of two or more placentas is proof of a compound pistil. The number of styles often corresponds to the number of leaves entering into the formation of the carpel.

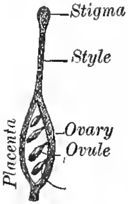


FIG. 65.

15. **Compound pistils** may have a single seed-cavity, or *loculus*, or they may have many cavities (*loculi*). When the carpellary leaves have united with each other, edge to edge (Fig. 66) there will be but one cavity. The placentas, or seed-bearing lines, will be situated on the ovary wall, as in the simple pistil; that is, they will be **parietal.** If each sepa-

FIG. 66.

FIG. 67.

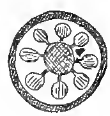


FIG. 68.

rate carpellary leaf unites edge to edge, and then all the carpels join (Fig. 67) the ovary will have as many cavities as there were carpellary leaves; the seed-bearing lines will be crowded to the centre and form **central placentas.** The walls which separate the cavities from one another in case of a multilocular ovary may become obliterated, leaving the seed-bearing column in the centre of a continuous or monolocular cavity, and thus a **free central placenta** is formed (Fig. 68). Examples of this are found in the Purslane, Chickweeds, Pinks, etc.

16. The ovary and calyx-tube may be united with each other as already explained. The ovary is then said to be **inferior**, and the calyx-tube *adherent*. If the adhesion extends half-way up, the ovary is said to be **half-inferior.** If there is no adhesion of the ovary with other parts, it is said to be **free** or **superior.** The ovules or small bodies which are to become seeds, are enclosed by the pistil; the latter is, therefore, said to be **angiospermous** (Gr. *angios*, vessel; *sperma*, seed). In the Pine family the ovules lie exposed in the cone, on the upper surface of the base of the scales. The scale is, therefore, to be regarded as the pistil. This condition is indicated by the term **gymnospermous** (Gr. *gymnos*, naked; *sperma*, seed).

CHAPTER VII.

POLLINATION AND FECUNDATION.

1. It is necessary that the ripe pollen, which is produced in the anther, be deposited upon the mature stigma; otherwise no seeds will be produced. The transference of the pollen is called **Pollination,**[1] a process that is effected by several agencies and aided by numerous contrivances. When both the essential organs (stamens and pistils) are contained in one and the same flower, as the Rose, Lily, Buttercup, Mint and Grass, it is called a **hermaphrodite** flower. Many plants possess, either in the same cluster or on different branchlets, both fertile (or *pistillate*) and sterile (or *staminate*) flowers, and they are said to be **monœcious** (Gr. *monos*, one; *oikos*, house); such are the Oaks, Hickories, Alder, Corn, Nettle, etc. Others have the fertile and sterile flowers on different trees, as the Willows, Poplars, Ash, Hemp, etc., and they are described as **diœcious** (Gr. *di*, two; *oikos*, house). In monœcious and diœcious plants it is evident that the transport of the pollen from the staminate to the pistillate flowers must in some way be effected in order to accomplish fecundation. Even in hermaphrodite flowers it is rarely the case that the pollen, wholly unaided, falls on the stigma of the same flower.

The topics treated in this chapter *call for observation in the field*, as well as careful study at the table in the class-room. The structures that are directly or indirectly concerned in pollination must not only be studied anatomically

[1] The term "fertilization" has been used to indicate the transference of pollen as well as to denote the *fecundation* which follows. To fertilize is to furnish nourishment and it is best to use the word only in that sense. For the terms self-fertilization and cross-fertilization used in Darwin's writings and elsewhere, the words self-pollination and cross-pollination may be substituted.

(for which no additional directions need be here repeated), but also be seen by each pupil when the agencies are in actual operation. Therefore make daily observation at various hours, carefully state the results in the note-book and report in the class-room. The behavior of the various insects visiting the flowers, their mode of obtaining nectar, and their agency in transferring pollen and incidentally depositing some of it on the stigma, should be especially observed. The flowers whose pollination is effected by the wind as well as those pollinated through the agency of insects, should be critically studied. The teacher can prolong this phase of the work according to disposable time and opportunity for visiting blooming plants in sufficient variety.

2. When the pollen from the anthers of a perfect flower is applied to the stigma of the same flower the process is called **self-pollination,** or *close-pollination.* But if the pollen of one flower is applied to and germinates on the stigma of a different flower, it is called **cross-pollination.** It would naturally be expected that in hermaphrodite, *i. e.* perfect flowers, self-pollination would almost invariably obtain. But it is known that cross-pollination is the rule and self-pollination the exception. In fact, there is in the majority of cases something in the structure of the flower to prevent self-pollination. Some plants, however, as the Oxalis, Violet, etc. have two sets of hermaphrodite flowers—a showy form, in which cross-pollination occurs, and an inconspicuous form where self-pollination necessarily takes place.

3. When the transport of the pollen is effected by the wind, the flowers are said to be **anemophilous** (Gr. *anemos*, wind; *philos*, loving). Such are the Pines, Oaks, Hickory, Walnut, Alder, Grasses, Sedges, Hemp, Hops, etc. They are characterized by the production of an enormous quantity of pollen. This insures the contact with the stigma of at least a small portion of the pollen. It is light, dry, incoherent, and readily transported great distances. The flowers are mostly greenish, or of dull colors and inconspicuous. The stigmas are generally large, often furnished with hairs or dissected into plumes, for the retention of the grains that may come in contact with them. The anthers are often suspended on capillary filaments so as to be more directly exposed to the action of the wind.

4. When pollination is effected by insects, the flowers are said to be **entomophilous** (Gr. *entomon*, insect; *philos*, loving). In these the amount of pollen produced is not so great, there being but little waste as compared with the loss when transported by the wind. It is not so dry and incoherent as in the anemophilous flowers; the grains are generally moist or slightly viscid, often provided with projections or entangling threads. In the Orchids and Milkweeds the pollen is in masses, supplied with viscid pedicels. All these contrivances tend to insure the adherence of the pollen grains or masses to the head, legs, or usually hairy body of the insects which visit the flowers, and thus incidentally effect the transportation of the pollen to the stigmas of other flowers. Such flowers are further characterized by the possession of a large colored corolla or other showy parts of (or adjacent to) the flower, or of odor, or by the secretion of nectar; they are often gamopetalous and frequently irregular; or they may furnish all these attractions combined.

5. Of the special adaptations in hermaphrodite flowers to insure cross-pollination, **dichogamy** is an important one; it means that the stamens and pistil of the same flower do not come to maturity at the same time, hence self-pollination is impossible. The flower is **proterandrous** (Gr. *protos*, first; *andres*, stamens) when the anthers ripen and discharge the pollen before the stigma reaches maturity. If the stigma is in a receptive condition before the pollen escapes, the flower is **proterogynous** (Gr. *protos*, first; *gyna*, pistil). Among the anemophilous flowers the common Plantain furnishes an example of proterogyny. The long, slender, hairy stigmas may be seen protruding from the unopened perianth while the anthers are yet enclosed. Only pollen from other flowers, therefore, can effect the pollination. Later the stigmas wither, and the corolla expands; the four anthers now appear supported on long, delicate filaments and their pollen is carried to stigmas of other Plantain flowers which may have a synchronous maturity.

6. A proterogynous example among entomophilous flowers

is furnished by the Fig-wort (*Scrophularia*). The flowers are visited by bees for the nectar, which is secreted by glands at the bottom of the corolla. The lower lobe of the irregular corolla serves as a landing-place for the bees. The mature pistil projects (Fig. 69) when the flower first opens; and pollination now takes place, the pollen coming from another flower of the same sort. The position of the unripe stamens at this time is not seen, for the filaments are curved and the unripe anthers are deep down in the corolla. A day or two later, the anthers, now mature, appear at the mouth of the corolla (Fig. 70). By this time the stigma previously pollinated is no longer in a receptive condition, and lies half-withered on the lower petal. Bees visiting the flower, would come in contact with the anthers, and the pollen grains that adhered to them would be carried to the next Fig-wort (*Scrophularia*) visited by them. The pistil, if ripe, would retain some of the grains, and pollination would thus be accomplished.

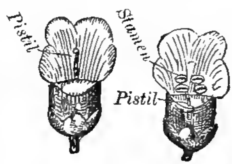


FIG. 69. FIG. 70.

7. As an example of a proterandrous flower, may be mentioned "*Clerodendron thompsoniæ*," a verbenaceous, tropical African climber, now common in conservatories. The adaptations in this flower are exquisite. The crimson corolla and bright, white calyx in combination, are very conspicuous. The

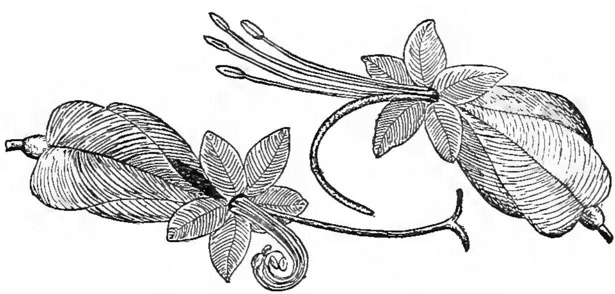


FIG. 72. FIG. 71.

long filiform filaments and style, upwardly enrolled in the bud, straighten and project when the corolla opens; the stamens remain straight, but the style proceeds to curve downward and backward, as in Fig. 71. The anthers are now discharging pollen; the stigmas are immature and closed. Fig. 72 represents the flower on the second day, the anthers effete and the filaments recurved and rolled up spirally, while the style has taken the position of the filaments, and the two stigmas, now separated and receptive, are in the very position of the anthers the previous day. The entrance, by which the proboscis of a butterfly may reach the nectar at the bottom, is at the upper side of the orifice. The flower cannot self-pollinate. A good-sized insect flying from blossom to blossom and plant to plant, must transport pollen from the one to the stigma of the other." (Gray.)

8. The composite flowers, such as the Rudbeckia, Heliopsis, Sunflower, etc., are additional examples of proterandry. The anthers are united so as to form a tube, the pollen being early discharged within. It is pushed out of the tube by the elongating pistil, which is not as yet in a receptive condition. Moreover the pollen cannot be applied to the stigmatic surfaces, for they are on the inner sides of the forks or branches of the tip of the style. They do not spread until the pistil has acquired its full length, and then curving outward, the adjacent pollen is still prevented from access to the stigma. The conspicuous ray-flowers doubtless serve for the attraction of the many visiting insects, and they, by their more or less hairy bodies, convey the adhering pollen from some of the flowers to the exposed stigmas of others; and thus cross-pollination is effected. Other proterandrous flowers are the Gentians, Epilobium, Campanula, Parnassia, Lobelia, etc. The stamens in Lobelia are like those in the Sunflower family, that is, united by their anthers and forming a tube around the upper portion of the style. The pollen is discharged while the style is yet so short as to be concealed deep down in the tube (Fig. 73). As the stigma approaches maturity, the style elongates and pushes the pollen out before it; the mouth of the tube is so situated

that insects entering the throat of the corolla, for the purpose of getting nectar, would necessarily brush the pollen on to

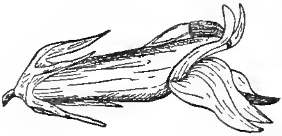


FIG. 73.

FIG. 74.

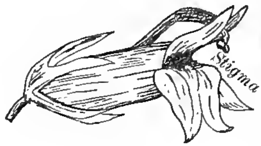


FIG. 75.

FIG. 76.

their bodies from the end of the protracted stigma (Fig. 74). The stigmatic surface finally becomes exposed (Figs. 75, 76). It is evident that self-pollination is impossible; and cross-pollination by the insects, which transport the pollen from flowers in the first stage of maturity to those in the second stage, must take place.

9. **Dimorphism** (Gr. *di*, two; *morphe*, form) denotes the existence of two kinds or forms of hermaphrodite flowers of the same species. It is often an adaptation for intercrossing. An example is furnished by the Houstonia. One set of flowers has long stamens and a short pistil (Fig. 77), and the other set has short stamens and a long pistil (Fig. 78). A bee visiting the different flowers would brush some part of its body against

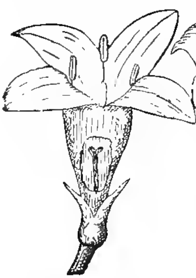


FIG. 77.

FIG. 78.

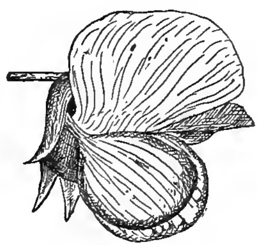


FIG. 79.

the anthers of the long stamens, and another part against the anthers of the short stamens; and these same parts (which, of course, would have pollen adhering to them) coming in contact with long and short pistils respectively, the pollen of one flower would in each case be applied to the stigma of another flower; or, in other words, cross-pollination would necessarily result. It is found, besides, that the pollen grains of the two sets of stamens are of different sizes, and each less active upon its own stigma than upon the stigma of another flower. In some genera three sets of flowers with stamens and pistils of differing lengths exist (*trimorphism*), evidently designed for intercrossing.

10. There are other adaptations for cross-pollination besides dichogamy and dimorphism. . An interesting case is furnished by papilionaceous flowers; for example, the Pea (Figs. 79–81).

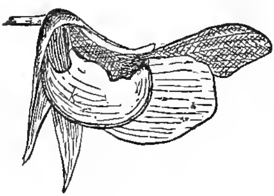


FIG. 80.

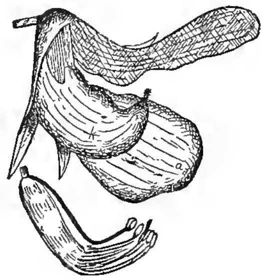


FIG. 81.

The ten stamens and single pistil are enclosed within the keel. There are hairs on the style below the stigma, and these loosely retain the pollen which is discharged early by the anthers, the latter remaining in the keel. When a bee alights on the wings and keel of the flower, they are together pressed downward, and the pistil protrudes in consequence. The stigma strikes the abdomen of the bee, and the style also brushes against it. When the bee visits the next flower, the stigma of that one strikes the abdomen as before, but it has been dusted with pollen from the previous flower, and of course a portion of it is retained by the stigma, thereby effecting cross-pollination. In like manner pollen from that flower is carried to the next, and so on.

11. A slight variation from the foregoing is seen in the Bean blossom, where the keel is coiled into a snout. Within this are the stamens, also the pistil with an oblique stigma and a hairy style, the latter loosely retaining the early discharged pollen. When a bee, in alighting to search for nectar, presses the wing-petals downward, the stigma and hairy style loaded with pollen protrude, striking the front part or side of the insect. Therefore, visiting a succession of flowers, the bee transports pollen from one to another. In the Mountain Laurel (*Kalmia*) the anthers of the ten stamens are lodged in cavities in the corolla, and the filaments are curved backward as the flower expands (Fig. 82). Bumble-bees, hovering over the

FIG. 82.

FIG. 83.

FIG. 84.

flowers, searching for nectar, liberate the stamens by occasional contact, which, in springing back straight, discharge the pollen from pores (Fig. 83) at the top of the anthers. Some of the pollen-grains which strike the under side of the bumble-bee and adhere to it, will, when the next flower is approached, be deposited on its stigma, thus bringing about cross-pollination.

12. The most varied and wonderful contrivances for crossing are found in the family of Orchids (Fig. 84). The stamens are generally reduced to one and this is united in a column with the pistil, indicated by the term **gynandrous** (Gr. *gyna*, pistil; *andres*, stamens). In case of some of the species the pollen in each anther-cell is united into a mass, and furnished

with a little stem, or caudicle, which has a very viscid disk. These two disks are so placed that when an insect visits the flower and thrusts its proboscis into the spur for the nectar, they will touch and adhere to its head, and be dragged from their place when the insect departs. The pedicels dry quickly and curve downward; when, therefore, the insect approaches another flower of the same kind, the pollen masses, or *pollinia* as they are called, strike against its viscid stigma, and a portion of the pollen is retained. The pollinia of this flower are in the same manner transferred to the next visited, and so on. When access to insects is prevented, no seeds are produced, showing that self-pollination is impossible.

13. Many tropical plants cultivated in the conservatories invariably fail to produce seed. The cause of this is to be found in the fact that the tropical insects which alone can effect their pollination are not present. It is not at all seldom that only a certain species, or at most, only a few species, of insects can pollinate a particular kind of flower. Thus in case of the Yucca, a certain minute insect (*Pronuba*), after inserting its eggs in the ovary, ascends the stamens and procures pollen; it then mounts the pistil and deposits the pollen on the stigma. In the absence of this species of insect no seeds are formed. Many of the adaptations for crossing, it should be remembered, do not absolutely prevent self-pollination, so that if insects fail to visit the flowers a few seeds may, nevertheless, be produced. When the flowers are evidently arranged to favor self-pollination and prevent crossing, they are said to be **cleistogamous** (Gr. *kleistos*, closed; *gamos*, union). But no known species is altogether cleistogamous.

14. Examples of cleistogamy are furnished by one set of flowers of Viola, Oxalis, some Grasses, etc. "Their petals are rudimentary, or quite aborted; their stamens are often reduced in number with anthers of very small size, containing very few pollen-grains, which have remarkably thin, transparent coats, and generally emit their tubes while still enclosed within the anther-cells; and, lastly, the pistil is much reduced in size, with the stigma in some cases hardly at all

developed. These flowers do not secrete nectar, or emit any odor; from their small size, as well as from the corolla being rudimentary, they are singularly inconspicuous; consequently insects do not visit them, nor could they find an entrance if they did. Such flowers are, therefore, self-pollinated yet they produce an abundance of seed. In several cases the young capsules bury themselves beneath the ground, and the seeds are there matured." (Darwin.)

15. The pollen that has been deposited on the mature stigma absorbs some of the moisture that is present, and immediately germinates. The outer and more brittle layer in the covering is ruptured; the inner and more delicate layer protrudes in the form of a tube (Fig. 85). This grows downward through the style, absorbing nourishment from the loose tissue through which it passes. It finally reaches the ovule, or organ in the ovary that is to become the seed. The ovule is at this time an oval or roundish body—being an outgrowth from a portion (the placenta) of the interior of the ovary. It is enclosed in one or two coats (integuments) that have grown up over it from the base. The integuments do not unite at the top, but leave a small orifice—designated by a term having this meaning, namely, **micropyle.** It is through the micropyle that the pollen-tube passes into the interior of the ovule and reaches the enlarged cell or sac called the *embryo-cell* (Fig. 85). The protoplasmic contents of the pollen-grain pass into and down the pollen-tube. A nucleus from the pollen-tube fuses with a nucleus contained in the embryo-cell. This process is called **Fecundation.**[1] As a result of fecundation a course of development begins which results in

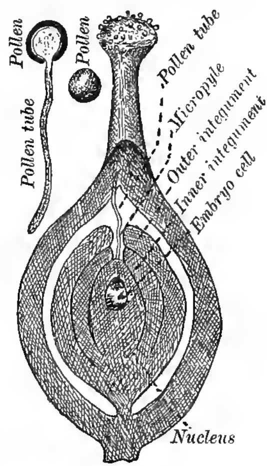


FIG. 85.

[1] The less appropriate term "fertilization" has generally been used in text-books.

the formation of an embryo, or minute plantlet. This gradually encroaches upon the tissue within the ovule, absorbing a part or all of it for its own growth. In some species the embryo at maturity is comparatively small; in others it occupies the entire volume of the mature seed, covered only by the testa or seed-coat.

16. The embryo consists of a slender stem, or caulicle, having at one end a bud called the **plumule**, and at the other a root-tip called the **radicle**; it also has one or more seed-leaves called **cotyledons.** The nourishment which is stored up in the seed to nourish the plantlet during germination, may be largely in the tissue of the seed that surrounds the embryo; or it may be wholly deposited in the cotyledons, which in that case are much thickened or fleshy. The number of cotyledons is constant for the two large groups of plants, as their names indicate, *Monocotyls* and *Dicotyls.* As already pointed out, the plants constituting the group called Monocotyls have generally the following associated characters:—(1) One cotyledon, (2) woody strands irregularly scattered through the pith, (3) parallel-veined leaves, and (4) usually three-parted flowers. The Dicotyls have (1) two cotyledons, (2) woody strands or a woody cylinder encircling the pith, (3) netted-veined leaves, and (4) mostly five-parted flowers. But few exceptions to the preceding statements occur in our flora.

All the points enumerated in the last two paragraphs cannot be fully studied without the aid of the compound microscope. If the teacher can exhibit prepared microscopic specimens, the statements of the text can be more satisfactorily understood and appreciated.

CHAPTER VIII.

THE FRUIT.

1. THE first great purpose of the plant is to attain its own development as an individual organism. The second, equally important, is the production of seeds, or reproduction of its kind. The seeds with the ovary which surrounds them, and any additional adnate parts that may be present, constitute the **Fruit.** The ripened ovary with the enclosed seeds form the fruit in a very large number of our common plants, as the Buttercups, Bean, Larkspur, Tulip, Wheat, etc. In the apple and similar fruits the calyx-tube which adheres to the ovary becomes very much enlarged and juicy. The fruit in this case consists of the ripened ovary and adnate calyx. The strawberry consists mainly of the enlarged and juicy end of the stem—which is called the *torus.* In case of the Rose, the fruit—called the *hip*—is a hollow torus containing the ovaries, being almost closed at the top. The fig is a similar fruit, but within the torus were many flowers instead of a single one (Fig. 86) as in the Rose. The pineapple, mulberry, pine-cone, etc. also result from the union of several flowers. Such are designated as **multiple fruits.**

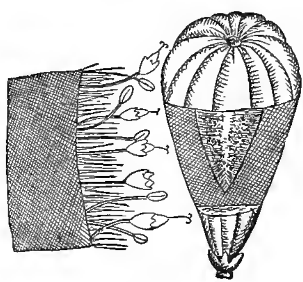


FIG. 86.

A search for fruits of the native plants will result in a collection of representatives of all the kinds mentioned in this chapter. These should be carefully studied in the class-room and properly arranged. Figures of the various kinds of appendages designed for assistance in the dispersion of seeds, should be made. In short, practical work of the kind mentioned in previous chapters should also here be faithfully carried on. Fruits and seeds should as far as possible accompany herbarium specimens of the species of plants (see last part of Chapter XI.). They can be enclosed in paper pockets, which are to be glued to the species sheet.

2. Many of the dry fruits are dehiscent, that is, break open at maturity. Examples of such are those of the Columbine, Shepherd's Purse, Pea, etc. Indehiscent fruits, or those that remain closed at maturity, are seen in case of the Maple, Thistle, Gourd, Apple, Grape, etc. This class includes both *dry* and *fleshy* fruits. Very many kinds of fruits have special names, only the most common being here mentioned. Two monolocular dehiscent fruits that are formed of a *simple pistil* are the follicle and legume. The **follicle** ruptures at maturity along one side only—that which corresponds to the united edges of the carpellary leaf (Fig. 87). The fruit of the Peony, Larkspur, etc. are examples of the follicle. The **legume** splits into two parts at maturity—one line of separation corresponding to the united edges, and the other to the mid-rib, of the carpellary leaf (Fig. 88). The pods of the Pea, Honey-locust, Redbud, Clover, etc. represent the legume.

3. The term **capsule** denotes a dehiscent fruit or pod of any compound pistil, as of Purslane, Violet, etc. A modification of this is seen in the fruit of the plants of the Mustard

FIG. 87.

FIG. 88.

FIG. 89.

FIG. 90.

family, where the pod has two parietal placentas, from which the two valves forming the wall separate; it is called a

silique (Fig. 89). A very short silique like that of the Shepherd's Purse, Pepper-grass, etc. is called a **silicle** (Fig. 90). A winged one-seeded indehiscent fruit is called a **samara** (Fig. 91). The fruit of the Elm, Ash and Wafer-Ash are examples; that of the Maple is a double samara. In the Sunflower, Dandelion, Wild Lettuce, Anemone, etc. the fruit is dry, monolocular, one-seeded and very much resembles a seed itself; such a fruit is called an **akene.** The **nut,** as the hazelnut, acorn, hickory, is like an akene but larger and is often enclosed or surrounded by a kind of involucre called a **cupule** (Fig. 92).

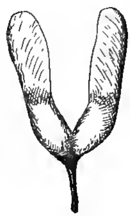


FIG. 91.

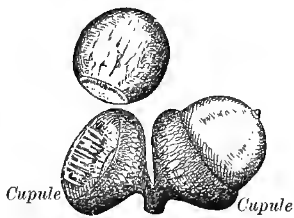


FIG. 92.

4. The most common fleshy fruits that have received special names are the drupe, pome and berry. The **drupe** is illustrated by examples like the peach and the cherry; the outer part is fleshy and the inner is hard or stony. The **pome** has several carpels of parchment-like or stony texture surrounded by a fleshy covering. The apple, pear, quince, and Hawthorn fruit are familiar examples. The **berry** is a fruit which is fleshy throughout, as the grape, tomato, currant, cranberry, banana, etc.

5. Very many fruits are furnished with appendages which are important organs for their dissemination. Conspicuous among these may be mentioned the membranous **wings** seen in the Maple, Box-Elder, Elm, Ash, etc. Fruits furnished with such an appendage will be readily transported by the wind, often to considerable distances. The fruits of the Thistle, Dandelion, etc. are still better equipped for such transporta-

tion. Their light dissected parachute or fluffy ball is the modified form of the calyx, called the *pappus.* The wing-like bract doubtless renders the fruit cluster of the Basswood more buoyant and transportable by the wind. Many fruits have **barbs, hooks** or **prickles** by which they lay hold of animals or the clothing of man and in this manner are often carried great distances. Such are the fruits of the Beggar-ticks (*Bidens*), Tickseed (*Coreopsis*), Tick-trefoil (*Meibomia*), Bur-grass (*Cenchrus*), etc. In the Burdock the involucral scales are hooked and the whole head of fruit is often carried from the plant on which it grew. The prickly fruit of the Cocklebur also represents an involucre and its assistance in distribution is similar and very effectual.

6. Fleshy and edible fruits are, it is true, often eaten and wholly destroyed; it might therefore seem that the production of an edible part would be a detriment to seed-dispersion. But in very many cases the seeds escape uninjured. Indeed the importance of such fleshy or edible portions in effecting the distribution of the seed is such that we may regard that as their proper and only function. Many seed-coats are so firm as to resist for a long time the action of water. The seeds may therefore germinate after being transported long distances by river and ocean currents. In several cases, for example, Witch Hazel and Touch-me-not, the pods burst in such a way as to throw the seeds some distance.

7. The seeds of pods that break open at maturity are in some cases furnished with appendages that aid in the dissemination. Those of the Trumpet Creeper and Catalpa have conspicuous thin wings. In the former these entirely surround the seed; in the latter they extend mainly from the two ends and terminate in a hairy fringe. In the Milkweed and Epilobium each seed is surmounted by a tuft of long delicate hairs which are very efficient aids to its distribution. The Cotton plant produces in a dehiscent pod, seeds that are completely covered with very long hairs, which constitute the cotton of commerce, and which for the plant are important contrivances for seed distribution. Seeds often lie dormant

for a long time and then finally germinate when favorable conditions obtain. It is estimated that a large Elm produces upward of half a million and a single Tobacco plant and many other weeds ten to forty thousand seeds, numbers which are small in comparison with those of the spores (corresponding functionally to seeds) produced by Puff-balls and other Fungi. This great fecundity should be borne in mind when considering the dispersion of plants. The spores of the lower plants are extremely small, and they can be readily transported by the slighest breeze. They are found literally everywhere, as the universal occurrence of Moulds, Mildews, Blights, etc. testifies.

CHAPTER IX.

THE CELL AND TISSUE.

1. SECTIONS taken from the various parts of the plants are shown by the aid of the microscope to consist of small sac-like bodies (Fig. 93). These structural units are called **Cells.** Those which are isolated, as pollen grains, spores of Smut, etc. are nearly or quite globular; so also are the cells of pith.

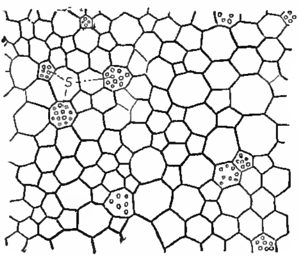


FIG. 93.

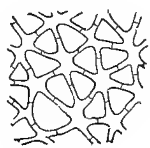


FIG. 94.

But in stems they are usually crowded closely together, and become many-sided by mutual pressure; they are often also much elongated. In leaves the outer layer of cells is compact; in the interior they are sometimes nearly globular, or often quite irregular in shape; there are comparatively large spaces between them. Occasionally cells are star-shaped, as in the tissue of the Rush (Fig. 94). Sometimes they are very irregular and branching, as in the common Moulds.

While a laboratory and compound microscopes are indispensable for a full and satisfactory study of cells and tissue (which, however, belongs to an advanced course in Botany), yet by the aid of figures in the text, and the help of a good pocket lens, the essentials of this portion of the subject may be profitably studied. The work can be made much more valuable, if a compound microscope can be used for the exhibition of prepared mounts that illustrate the parts of the cell, the cell-contents and the various kinds of tissue, etc.

2. The cells in the tissues of common plants are, with few exceptions, microscopic in size. The majority of them are between one-hundredth and one-thousandth of an inch in diameter. In bast tissue they are much larger. Plant hairs often consist of a single cell and are usually large enough to be detected by the unaided eye. Sometimes they are very long, as some Algæ, the milk-vessels in some Spurges, and the cotton, which consists of unicellular hairs from the seeds of the Cotton-plant. Many cells, on the other hand, are extremely small. The unicellular plants called Yeast and Bacteria are examples of such. The transparent, nearly round Yeast-cells are about three ten-thousandths of an inch in diameter. The *Bacterium termo*, or common fungus which causes putrefaction, consists of a cell about nine hundred-thousandths of an inch long and little more than half as wide.

3. The vegetable cell usually consists of four parts which are readily distinguishable, namely, protoplasm, nucleus, cell-wall and cell-sap (Fig. 95). The **Protoplasm** is a nearly

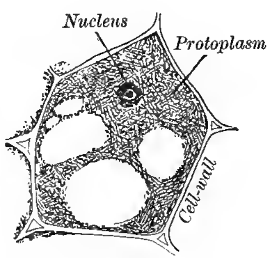


FIG. 95.

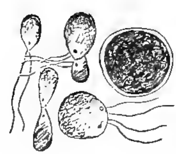


FIG. 96.

transparent, more or less granular, usually semifluid substance. A denser small globular portion within, called the **nucleus**, is usually visible. The protoplasm is the essential part of the cell. In it, all the vital activities are manifest and when it disappears the cell is dead. It is very complex both in structure and composition. Its constituents are albuminoids (containing oxygen, hydrogen, carbon and nitrogen), a variable amount of water, and a small quantity of ash or mineral constituents.

4. The protoplasm secretes the **cell-wall.** This consists of *cellulose*, which is composed of carbon, hydrogen and oxygen (but no nitrogen), also water and ash, or mineral constituents. The **cell-sap** is a watery fluid containing plant food in solution. It fills the apparent vacant spaces, called *vacuoles*, in the cell and also permeates the protoplasm. The cell has no wall or covering in the earlier stage of its existence. In a few cases none is ever formed, at least in the vegetative stage or that preceding the reproductive period. The free protoplasm can in such case swim about, as the so-called Swarm-spores (Fig. 96) are seen to do. Or it may creep about, as do the

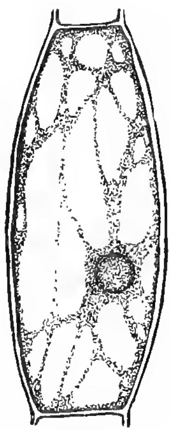


Fig. 97.

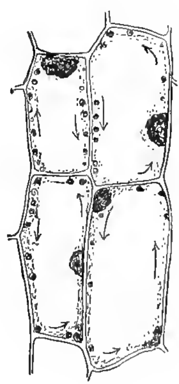


Fig. 98.

Slime-Moulds. When the protoplasm is enclosed in a wall it may yet manifest movements. In some cases there are slender streams moving about in various directions, mostly from the central to the parietal portions and in the reverse direction. This is called the **circulation** (Fig. 97) of the protoplasm. In other cases it moves as a broad stream around the cell-wall. This movement is called the **rotation** (Fig. 98).

5. The cell wall often remains quite thin. In some of the bast-cells, in wood-cells and many others, it becomes very thick; but its growth in thickness is not uniform. Only a spiral band becomes thickened in very many cases; occasionally a thickened ring or annular band is formed. Sometimes the whole wall except small circular areas here and there attains a considerable thickness. Simple pits in the wall result from such growth. Bordered pits are formed in the wood-cells of the Pine family. The sides of the pit arch over as growth in thickness proceeds—the upper margin thus making the inner ring, and the bottom of the pit the outer ring, when

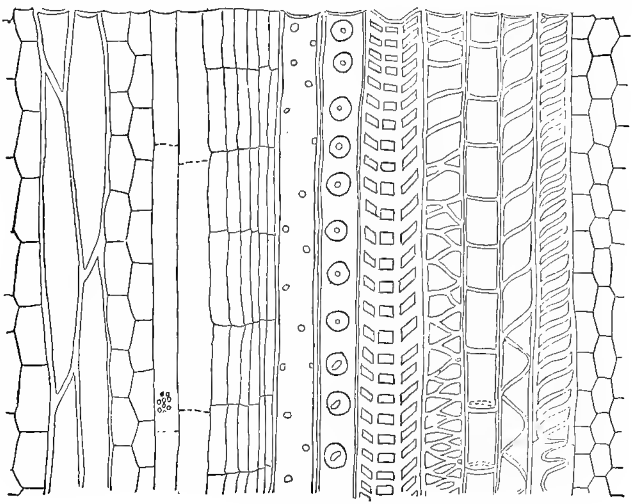


Fig. 99.

viewed on the side of the cell. In some cells the thickened portions are at the angles and extend across at short and regular intervals, being thus scalariform, that is, like a stairway or slightly resembling the rounds of a ladder. Occasionally the

5

thickening has a reticulate or net like form (Fig. 99). In the case of isolated cells, like pollen grains and spores, spines, papillæ, or ridges are occasionally developed.

6. The important substance called leaf-green, or **chlorophyll** (Gr. *chloros*, green ; *phyllon*, leaf), is found in many cells of the common plants. It is a green coloring matter which is soluble in alcohol, ether, chloroform, etc. When it is removed by these solvents a protoplasmic grain remains. Chlorophyll develops in cells exposed to sunlight or electric light. Plants with chlorophyll will gradually lose their color if placed in the dark. The importance of this substance in plant nutrition is evident from the fact that only in cells containing chlorophyll is mineral, or inorganic, matter changed—while exposed to light—to organic, or vegetable material. Those plants which are destitute of chlorophyll, for example the Fungi and a few other plants, as Indian Pipe, Dodder, etc., cannot live on mineral matter but must absorb their digested food from living plants or decaying material. Such plants can grow in the dark.

Put in a vial of alcohol some bits of green leaves and in a day or two note the solution of the chlorophyll. Cover up some green plants with soil or put them in a dark room, or put a board over the grass, and after several days note the bleaching, or disappearance of chlorophyll. Let potatoes sprout in the cellar and the stems will remain white.

7. **Starch** is formed in the chlorophyll-bearing cells. It is always in the form of grains (Fig. 100). These are oval in the potato, elliptical in the bean, elongated and very irregular in *Euphorbia splendens*. They are very small in corn, wheat, rice, etc. The starch grains of the potato are distinctly visible with a good lens. The average or commonest size, as well as the shape, is constant in each species of plant, but they vary exceedingly in both these respects in different species. When

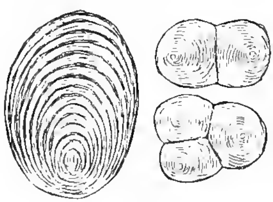


FIG. 100.

starch is examined under the microscope a nucleus is seen in the larger grains and around it are numerous concentric layers. Starch after its formation in the chlorophyll becomes dissolved, and is transported to growing parts and at once consumed in the formation of the vegetable fabric; or it reappears in the form of starch in reservoirs, stored up for future use, as in seeds, tubers, bulbs, roots, stems, etc. Other products are formed in cells, as oils, organic acids, alkaloids, resins, salts, sugars, etc.

Scrape the freshly cut and moist surface of a potato, bean or grain of wheat or corn and a quantity of starch will be obtained. Add to it a drop of dilute iodine solution (made by dissolving a bit of potassium iodide in a little water and adding a very small grain of metallic iodine, till a cherry-red solution is obtained) and note the deep-blue coloration. This is the test for the presence of starch. Examine also with the lens. Make with a sharp blade very thin slices of various tissues, as potato-tuber, bean, twigs, etc., put them under the lens and then add a little of the iodine solution. Sometimes the stem of the Oxalis, Begonia or other plants have also crystals that can be seen with the lens when very thin sections are examined.

8. Though each plant begins its existence as a single cell, or simple mass of protoplasm in the embryo cell, all but the unicellular species very soon become many-celled. This multiplication of cells is brought about by the division of the first cell into two. Each of these after increasing in size divides into two, or four in all. The resultant four divide into eight and so on indefinitely. A microscopic study of the process of division shows it to be very complicated, and its elucidation will not be attempted here. Suffice it to state that the nucleus takes the initiative; after it divides into two portions, the protoplasm becomes separated into two masses, a new cell-wall being formed between them and two distinct cells are the result. The increase in the size of plants is then due to an increase in the number of cells. Countless millions are to be found even in a plant of moderate size. It has been demonstrated that though the protoplasm is surrounded in each case, and apparently isolated, by a cell-wall, yet minute protoplasmic threads reach from each mass through the walls to

adjacent ones. By this *continuity* of protoplasm an intimate union of all parts of the individual plant is established.

9. The cells in the very early development of the plant, and those in simple plants, are nearly or quite alike. Later they may take on different shapes and functions. Several kinds of tissue can then be recognized. In our common herbaceous and woody plants there may be found three distinct systems, namely, the *epidermal*, the *woody strands*, and the *fundamental tissue.* The first of these includes the epidermis, the hairs and scales, and the stomates. The **epidermis** (Fig. 101) is the external compact layer of cells, protecting the more delicate tissue below. Outgrowths of the epidermal cells form **hairs.** These may be one-celled or they may become several-celled; they may be simple or become branched; sometimes they are glandular at the tip. The general function of the hairs is to protect the parts on which they grow, but in special cases they have other duties to perform; for example, the rhizoids (root-hairs) absorb food from the soil. **Scales** are composed of many cells, and like the hairs, they represent modified epidermal cells.

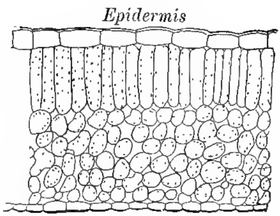


FIG. 101.

10. The **stomates** are very small openings through the epidermis. They are popularly spoken of as "breathing pores," since the oxygen, as well as other gases, passes through them. One of their very important functions is to convey from the interior of the leaf the excessive amount of moisture which the roots absorb in taking up the necessary mineral matter for food. Examination with the microscope shows that the stomate is an opening between two cells, which are called *guard-cells.* These are very different in outline from the other epidermal cells. Each is nearly half-moon shaped, the two joined together being broadly oval or spherical (Fig. 102). They contain chlorophyll, which is not usually present in the other epidermal cells. In section also they appear different from the

other cells (Fig. 103). Immediately below each stomate is an *air-cavity* and from this there is communication with the large spaces between the cells in the interior of the leaf. Though the size is small yet the number of the stomates is enormous.

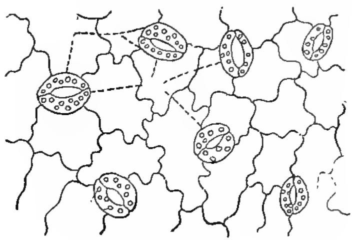


FIG. 102.

For example, in the leaf of the Anemone there are about 43,000 to the square inch on the under side, none on the upper. On the upper side of the leaves of the Indian Corn there are about 60,000 and on the lower surface about 102,000

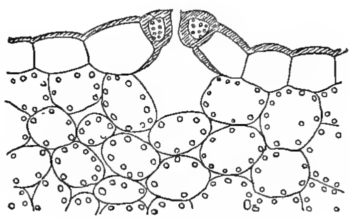


FIG. 103.

to the square inch. In the leaf of the Sunflower there are about 112,000 stomates above and about 209,000 below. In the leaves which float on the water stomates occur only on the upper side. They are wholly wanting in submersed leaves.

11. The **woody strands** (called also *fibro-vascular bundles*) can be easily separated from the other tissue in the stems of Indian Corn, of the Plantain leaf, etc., but microscopic examination is necessary to determine their structure. In one

type of strands, that from the monocotyledonous stems (Fig. 104), there are two kinds of tissue, namely, the *wood* and the *bast.* These are shown in Fig. 105. In the other type, that from the dicotyledonous

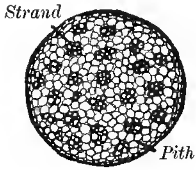


Fig. 104.

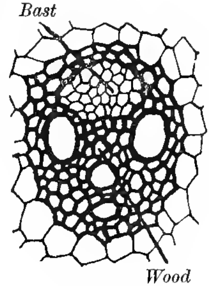


Fig. 105.

stems, the strand consists of *wood*, *cambium*, and *bast* (Figs. 106 and 109). The cambium cells are thin-walled, rich in

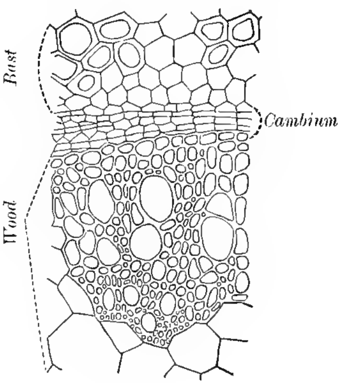


Fig. 106.

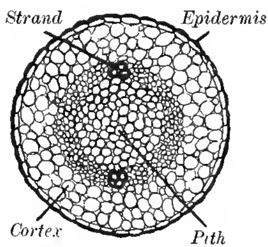


Fig. 107.

protoplasm and capable of division. If microscopic sections are not available, an inspection of the figures given may convey a general idea of the structure of the strands and the development of the woody stems and tissue of the tree trunks.

12. Two of the strands begin development simultaneously on the opposite sides of the pith (Fig. 107), in case of the dicotyledonous stem. Later two others appear (Fig. 108), and

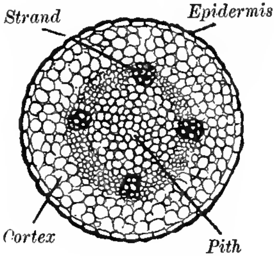


FIG. 108.

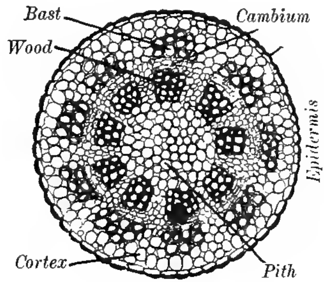


FIG. 109.

very soon numerous strands are present which together form a continuous ring (Fig. 109; other parts of this figure, also of Figs. 107 and 108, are the *pith*, the *cortex*, and the *epidermis*). As the wood in each strand is on the pith side, the fusion of the strands results in the formation of a *ring of wood* adjacent to the pith. It is evident also that a continuous *ring of cambium* would be formed, and outside of this a *ring of bast*. In the following season the cambium renews its growth, the cells are multiplied, and those next to the wood formed the first year are changed to wood cells; on the opposite side some of the cambium cells become bast. The cells of wood formed in the early spring are usually larger than those formed in the latter part of the growing season, and hence the rings or cylinders of growth for each year are distinctly seen in most trees (Fig. 110). The entire portion exterior to the cambium may be designated as *bark*. In the outer portion of the bast, corky plates or corky layers are developed; these and the external lifeless bast cells form the dry, often furrowed, dead bark.

13. The original tissue, or that from which the epidermis and woody strands are developed, is called the **fundamental**

tissue. The pith and cortex belong to this, as do also the cells in the *medullary rays*. The latter are seen as radiating lines in the woody stems (Fig. 111). Some of them extend from the pith. These had their origin in the compressed tis-

Fig. 110.

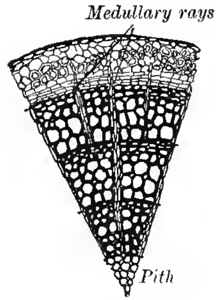


Fig. 111.

sue between the encroaching woody strands. The cells of the medullary rays are longer in the radial direction, whereas the other lignified cells of the trunk have their vertical diameter

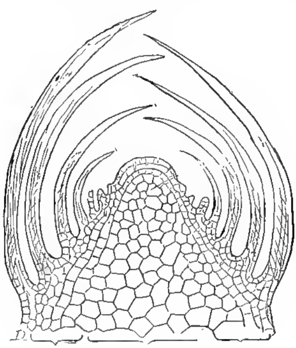


Fig. 112.

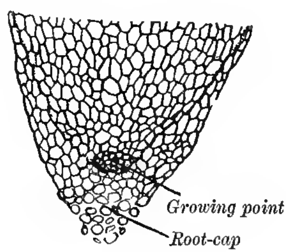


Fig. 113.

much longer than their other dimensions. In lumber where they are especially conspicuous, as in Oak, etc., the medullary rays are called the "silver grain." The milky juice (*latex*) is contained in special elongated cells called the laticiferous vessels. **Cork tissue** is composed of cells whose walls are thin and impermeable to liquids and gases.

14. The **growing point** of stems and roots is composed of delicate cells, thin-walled and rich in protoplasm. By their multiplication the stems and roots are lengthened. The scales (leaves) of the bud cover the growing point of the stem (Fig. 112). A root-cap protects the growing point of the root (Fig. 113). The outermost cells are abraded as the root-tip penetrates the soil, but the cap is constantly renewed by the multiplying cells of the growing point.

CHAPTER X.

THE PHYSIOLOGY OF PLANTS.

1. WATER plays an important part in the nutrition of plants. It not only dissolves the mineral matters of the soil, which constitute an important part of plant food, but it also conveys them into and through the plant. It is a constituent of all vegetable material. In aquatic plants it may constitute as much as ninety-five per cent. of the whole weight. In terrestrial plants it generally averages about seventy-five per cent. In consequence of this quantity of water the cells are rendered turgid, without which growth would be impossible. If green plants be dried in the air at ordinary temperatures, they lose only a portion of their water. Thus Red Clover contains seventy-nine per cent. of water, and when air-dry (as hay) it contains seventeen per cent. Fresh pine-wood contains forty per cent. of water, and the same, dry, contains twenty per cent. The first quantity in each case may be called the *free water of vegetation.* The second represents the *water of organization.* Only a very small portion of the water that is absorbed by the roots is decomposed and consumed in the plant; nearly all of it escapes from the surface of the leaves and tender shoots.

Select parts of various plants—especially succulent plants, and those that contain much water, as growing Corn, Radish, Cucumbers, Watermelous, etc. Cut them into pieces, and after weighing spread out in the sun or put in a warm oven, till *thoroughly* dried. Weigh again and the difference in weight will be the amount of escaped water of vegetation.

2. The **transpiration** (called also exhalation) or escape of watery vapor from the surface of a plant cannot take place

when the air is saturated with moisture. The farther below the point of saturation the amount of moisture falls, the greater the transpiration. From delicate and thin-walled cells the evaporation would be excessive, but considerable hindrance is offered by the epidermis. This in most plants is a layer one cell thick, but in some cases it consists of several layers of cells. The outer wall of each epidermal cell is thickened and besides sometimes covered with a waxy coating, or a thin impervious layer called the cuticle. In such cases there could be no exhalation except through the stomates. In fact the stomates may be considered as the special organs of exhalation. The guard-cells become flaccid or turgid under the varying influences of light and atmospheric conditions, thus closing or dilating the stomates. Moreover the water in plants holds in solution various substances, and the rate of evaporation is thereby decreased.

3. The **rate** of transpiration differs much in different plants and under varying conditions, but it is always slow. A few from the many published examples are as follows: In twelve hours of daylight the amount evaporated from a Vine was equal to a film only 0.005 inch thick, that from a Cabbage in the same time equalled a film 0.012 inch and from an Apple 0.01 inch thick. The amount of water exhaled from a close-topped Oak tree 20 feet high during the growing season of five and a half months was a little over 30,000 gallons. This is equal to a layer about 1.3 inches thick over the whole evaporating surface. The transpiration from leaves is usually given as one-sixth to one-third as much as the evaporation from an equal surface area of water. This would be a much larger loss of water from the plant than the amount of annual rainfall on the ground surface the plant covers.

Fasten a leafy shoot or single leaf with roundish petiole in a closely fitting stopper in one end of a U-tube filled with water and furnished with a small horizontal tube as shown in Fig. 114. The water soon recedes in the horizontal tube, indicating loss by transpiration.

4. In midsummer the transpiration may be so great that the roots cannot furnish the requisite amount of water to sup-

ply the loss. If a hole be bored in the trunk of a vigorous young tree and into it one end of a glass tube be fitted air-tight, while the other end dips down into a vessel of water, the latter will ascend in the tube to a varying height. If the experiment be performed in the spring before the extensive evaporating surface (leaves) appears, an opposite effect would be observed. The flow of sap from Maple trees in spring is referable to the quick alternate contraction and expansion of the contained air, and perhaps other gases, due to the sudden changes of temperature, rather than to influences connected with transpiration.

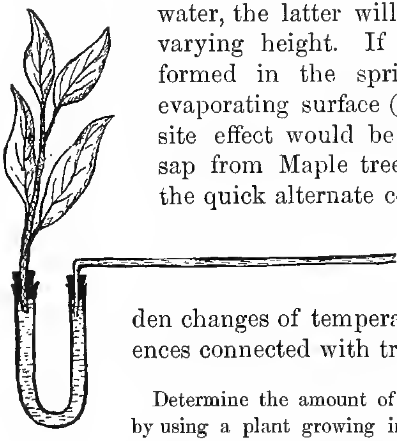


FIG. 114.

Determine the amount of transpiration in a given time by using a plant growing in a small pot. Cover the pot closely and completely with paper to prevent loss of water except through the plant itself, and place it on one of the pans of delicate scales. Balance with weights; after an interval of time (a few hours at least), remove weights necessary to restore the balance. The weights removed will indicate the amount of evaporation.

5. The water lost by transpiration is replaced by a **constant stream** passing from the soil through the roots and stems to the leaves. This current is intercepted when a shoot is cut off and its leaves consequently soon wilt. If the stem be placed in water so as to obtain a partial supply, wilting is much delayed. Or if water is forced into the stem the partially wilted leaves will regain their turgidity. In the common plants the upward stream of water is conducted exclusively through the lignified cell walls. The rapidity of the ascent is dependent on the rate of exhalation—perhaps between five and fifty inches per hour would be the commonest rate.

Use the apparatus described in the experiment under paragraph 3 (the U-tube, with diameter one-half inch or less), as shown in Fig. 114, but discard the horizontal tube and one stopper. In the other stopper closely adjust a shoot of Sunflower after it has become slightly wilted. Pour mercury in the free arm and the pressure will force the water into the shoot causing it to regain its rigidity.

6. If a vigorously growing young plant be cut off near the ground, water (sap) will exude. This "bleeding" is due to what is termed **root pressure.** It is a consequence of the absorbent activity of the root-hairs. The root pressure of perennial plants is greatest in the spring while the extensive leaf surface and high temperature are wanting. In some plants the root pressure is manifest in the exudation of drops of water from the margins and tips of the leaves, especially the younger ones, as in case of some Aroids, Grasses, etc.

Cut off a strong young Grape-vine (or other plant, as Sunflower, Dahlia, Maple, Birch, etc.) in middle spring, a short distance above the ground. To the stem remaining in the ground attach an upright glass tube by means of a short rubber tube. Note the rise of the sap and the variation in the height of the column during the day.

7. Comparatively few of the elements found in nature are concerned in the **nutrition** of plants. Those found by chemical analysis of the tissues are the food elements required. Another method of determining which of the elements are necessary in plant nutrition, is the employment of "water-cultures." These are arranged as follows: A clean flask or wide-mouthed bottle with distilled water is used. Very small quantities of soluble substances which will furnish the elements supposed to be necessary for plant growth are added. A seed is then germinated and fastened in the mouth of the bottle or suspended so that the root will grow downward into the liquid from which it can absorb the food materials needed. The plant can then be grown to maturity—flowers and seed being produced as when grown in soil under ordinary conditions.

Dissolve in two litres (about four pints) of distilled water the following: Two grams potassium nitrate; one gram sodium chloride; one gram calcium phosphate; one gram calcium sulphate; one gram magnesium sulphate; and add a few drops of a solution of ferric chloride or ferrous sulphate. Fill a glass jar of one pint capacity or less, with the nutrient solution. Fasten in the perforated cork, with cotton, a seedling that has a radicle a half inch long or more so that it will grow down into the water. The seed itself should not touch the water. Surround the vessel with a paper jacket to exclude the light in order to prevent the growth of Algæ. Set in the sunlight and replace the fluid from time to time as necessary. The entire solution should be renewed every two weeks. It has also been recommended to place the plant from time to time in a saturated solution of gypsum and to aërate the liquid frequently by an aspirator, but this is not necessary for ordinary demonstration.

8. Both by analysis and by cultures it has been determined that the following elements are *necessary to plant life:* carbon, hydrogen, oxygen, nitrogen, sulphur, phosphorus, potassium, calcium, magnesium, iron and sodium. **Carbon** constitutes usually about one-half of the entire dried substance of the plant. This element is derived mainly from the carbon-dioxide (CO_2) of the air. This gas, ordinarily about four hundredths of one per cent. of the atmosphere, is taken through the stomates of the chlorophyll-bearing plants, and in the presence of sunlight decomposed, the carbon being retained and the oxygen set free or to some extent separately consumed. Plants which do not contain chlorophyll get their carbon from absorbed organic compounds which have this element as one of their constituents. The plants that have chlorophyll—while obtaining nearly all of their carbon from the air—are nevertheless capable of absorbing complex carbon compounds. For example, "insectivorous" plants absorb such substances, and these are known to be important factors in their nutrition.

9. The element **hydrogen** constituting a very much smaller per cent. of the substance of the plant than carbon, is derived mainly from water (H_2O). A portion is derived from ammonia (NH_3) and its compounds and from complex carbon compounds. **Oxygen** forms the largest portion, after carbon, of the weight of the dried vegetable substance. It is taken into the plant both in the free state and in combination. The free oxygen of the air is absorbed (respired) by all plants and is largely concerned in the destructive processes in nutrition. The oxygen that is specially concerned in the constructive

processes of the plants is obtained from water (H_2O), and from various oxygen-containing salts. **Nitrogen,** though small in quantity, is a very important plant constituent. It is derived from ammonia (NH_3) and its salts, from nitrates and from such organic substances as contain nitrogen, which the roots absorb. Nearly four-fifths of the atmosphere is free nitrogen, but it was long ago proven that plants are incapable of taking up this free element. It should be added, however, that recent experiments show that leguminous plants and possibly a few others, *which bear root-tubercles,* are capable of using the free nitrogen of the air. It is in some way connected with the activity of the micro-organisms (Bacteria or other simple plants) that are found in the tubercles.

10. **Sulphur** is obtained by the plant from sulphates—especially the sulphates of ammonia, potassium, magnesium, and calcium. **Phosphorus** is furnished by the phosphates. There are several compounds from which the plants obtain **potassium**—the sulphate, phosphate, chloride and probably the silicate. **Calcium** is supplied by the sulphate, phosphate, nitrate and carbonate. Similarly, **magnesium** is furnished by all its salts, except the chloride. Any of the soluble salts of **iron** furnishes this element—extremely minute quantities being sufficient for the needs of the plant. When iron is withheld in culture solutions, the plants do not become green. **Sodium,** furnished by its several salts, is necessary to plant nutrition, but it is found in very small quantity.

Repeat the experiment with the water-culture as detailed under paragraph 7, but omit the iron and notice the chlorotic effect, *i. e.* the green does not develop. Omit other ingredients and their necessity to plant nutrition will be proven. When all are omitted (the roots growing in pure water), development will cease when all the food stored up in the seed is exhausted.

11. **Chlorine** and **silicon** are always found in the ash of plants, but they do not appear to be essential to plant nutrition. In marine plants **iodine** and **bromine** are present. Several other elements are occasionally found in plants in small quantities when they are abundant in soluble form in the soil. All plants do not have the same proportional

amounts of the several elements. The different species therefore have, at least to some extent, a selective power, and consequently they absorb the different food elements in different amounts. When one kind of crop is grown continuously for years in the same soil the yield usually decreases—due doubtless to the partial exhaustion of some one or more of the food elements or at least of the soluble compounds which furnish the same. But another kind of crop would perhaps draw more heavily on other elements and so by alternating or "by rotation" the soil is less quickly exhausted, time being given in the interim for the accumulation of the various soluble compounds that furnish the needed foods.

12. The mineral or inorganic food taken into the plant must undergo chemical changes to become vegetable fabric. The conditions under which these take place, and the processes are but partially understood. But it is known that the carbon-dioxide and water are decomposed, and the elements are re-combined to form carbon compounds. Starch is the first *visible* product, though it is probable that some other carbohydrate (perhaps glucose) is really the first in the series. The process involving the above changes takes place only in the chlorophyll-body in the presence of sunlight (or electric light). It is called *photo-synthesis.*[1]

Tie a piece of Elodea or other water plant to a glass rod and place it (with the lower cut end of the stem uppermost) in a beaker or vessel of spring water, or water containing carbon dioxide. When placed in strong sunlight a stream of bubbles will escape; fewer will be seen if the light is less intense, and none will appear in the absence of light. To show that this escaping gas is oxygen, have in the vessel of water a number of shoots of the water-plant covered by an inverted funnel over which is placed a test-tube filled with water. The gas (oxygen) which collects in this test-tube can be tested with a glowing splinter.

13. Starch is formed in the leaf or other green parts only during the day. It becomes during the night dissolved

[1] It has until recently been called *assimilation*, but this word can be most advantageously used in the sense in which it is employed in animal physiology.

(chemically changed), in which form it can be transported to all parts of the plant. If a portion of the leaf is covered, preventing exposure to sunlight, in that part no starch is formed.

Cut a cork stopper into layers one quarter of an inch thick. Place one piece on the upper surface of a vigorously growing leaf (for example, *Tropæolum*—"Nasturtium") and another piece on the lower surface directly opposite the first. Thrust two pins through the pieces to keep them in this position. After they have remained twenty-four hours remove them (*in the afternoon*), sever the leaf from the plant, and put it in boiling water for three or four minutes, to kill the protoplasm and to swell the starch grains. Now remove the chlorophyll by immersing the leaf in alcohol for a day or two and finally plunge it into a solution of iodine (made as directed on page 67). After a short time it will become a deep blue, except over the previously darkened area, where consequently no starch was formed.

14. The exact function of the chlorophyll itself is not known, but "it is probable that it absorbs certain rays of light and thus enables the protoplasm with which it is intimately connected to avail itself of the radiant energy of the sun's rays for the construction of organic substances from carbonic dioxide and water." (Vines.) The formation of the nitrogenous materials in the plant is not yet clearly understood. It is not however a photo-synthetic process, that is, it is not dependent on the presence of chlorophyll, and apparently takes place at night as well as day. All the transformations or changes that take place in the food materials after the photo-synthetic process is completed are designated by the term **metabolism.** These metabolic changes may be regarded as the **digestion,** and the final conversion into vegetable fabric (tissues) may be called **assimilation.** These two processes correspond to those in animal physiology which are designated by the same terms.

15. A small number of plants can capture insects, which in part at least they consume as food. Of such insectivorous plants a common example is the Sundew (*Drosera*), which grows in bogs and wet places. The radical leaves are furnished with stalked glands, whose glistening secretion imprisons flies which alight thereon. The flies soon die and are

then digested by the acidulous secretion, which is at such times more copiously poured forth. The nutritive portion is absorbed by the plant and thus furnishes a portion of its (nitrogenous) food. Venus's Fly-trap (Fig. 115), the lobes of whose leaves quickly close and capture insects when the latter touch the slender hairs on the upper side, is likewise capable of digesting animal food. The numerous sessile glands provide the digestive secretion, and also absorb into the plant the digested portions of the insects. Glands, whose viscid secretion is capable of digesting nitrogenous material, are also found on the leaves of the Butterwort (*Pinguicula*), which grows on wet rocks and damp soils. The curious little bladders of the Bladderwort (*Utricularia*) capture small water animals. In the pitcher-leaves of Sarracenia and Nepenthes, insects fall and drown; these animals, by their decay, probably furnish some food to be absorbed by the plants.

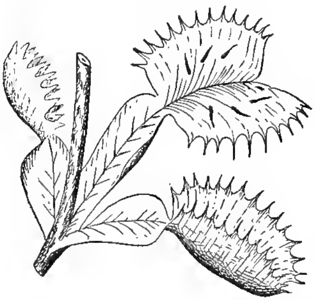


FIG. 115.

16. A portion of the elaborated food, or **plastic material** as it is called, is consumed at once at the points where growth is taking place. In the earlier or vegetative stage of the plant all of it may be consumed immediately. But there is in plants generally an excess which is then stored up for future use. It is called **reserve material.** During the reproductive period in the life of plants a large portion is laid up in the seeds and spores. It also accumulates in roots, tubers, bulbs, rhizomes and stems. In case of the deciduous shrubs and trees the food material passes from the leaves into the twigs at the close of the growing season. Then a **separative layer** of cells is formed at the base of the leaf and the latter consequently severs its connection. The scar that remains is not a wound, since the exposed cells are cutinized and rendered impervious to fluids. In the following spring the growth is

resumed at the expense of the reserve material. From that in the stems and roots the buds develop; from that in the bulb, a stem, leaf or flower-cluster may be formed; from that in the tuber the buds ("eyes") develop into branches; from that in the seed the embryo grows into a self-supporting plant; from that in the spore a germinative tube or other form of growth proceeds.

17. **Respiration** of plants, as of animals, consists in the absorption of atmospheric oxygen and the liberation of carbon dioxide. This cannot readily be detected during the daytime, when photo-synthesis is carried on. Nevertheless, respiration is constantly performed, oxidizing the products resulting from photo-synthesis and producing other chemical changes. "The whole life of the plant consists in complicated movements of the molecules and atoms; and the forces necessary for these movements are set free by respiration." (Sachs.) In the absence of oxygen, the chemical changes connected with growth, the movements of protoplasm and the power of motion in motile and irritable organs cease. The heat generated by oxidation seldom causes a sensible increase in the temperature. But in some cases, for example in a mass of germinating seeds or a heap of unfolding flowers, it can be detected.

Put some Sunflower seeds (after removal of the hulls), in an open vessel of water and they will germinate. Repeat the experiment but use a bottle full of *boiled* (then cooled) water, avoiding any air space below the tightly fitting cork. Since no air (free oxygen) is present no germination will occur. In a glass jar or wide-mouthed bottle place a mass of germinating peas. Into the centre thrust the bulb of a thermometer (preferably graduated to fractions of a degree). Contrast the reading of this thermometer with another (previously compared) outside the vessel. It would be advantageous to cover both with a large bell jar.

18. The limits of **temperature** at which photo-synthesis and growth may take place vary in different plants. Some live in very low temperatures, for example, the Red-snow plant. In polar waters myriads of Diatoms and some of the sea-weeds (Algæ) flourish. The common plants of our region require a comparatively high degree of temperature for the

performance of the life-processes. Tropical plants live in a still higher temperature. Even the thermal springs are inhabited by some of the lower plants. Exposure to a freezing temperature is fatal to many plants. Those containing much water suffer most. When comparatively deficient in water—for example dry seeds and spores and plants during their period of rest from growth—they may endure a very low temperature without injury. When freezing takes place no ice is formed within the cells. The water exudes from the protoplasm and escapes from the cells; the ice crystals form between the cells (in intercellular spaces) or on the surface. When the protoplasm is not killed by the freezing it will regain its former turgidity and activity, provided the thawing is so slow that the water may be reabsorbed by the protoplasm.

19. If all other conditions are constant, the rapidity of growth of most aërial stems is greater in darkness than in light. This is due to the retarding influence of the rays of high refrangibility (blue, etc.). When, therefore, the illumination is greater on one side of the stem than on the other, a curvature arises in consequence of the retarding influence of light. Thus, when plants are grown in windows they curve strongly toward the light. This phenomenon has received the name of **heliotropism** (Gr. *helios*, sun; *trepein*, to turn). It is due to the fact that the growth of the cells on the illuminated side is retarded, while on the opposite side the cells elongate.

20. The stems of most of the common plants grow upward or from the earth, and the roots grow downward or toward the earth; the stems of most Mosses grow upward and their rhizoids downward; the spore-bearing or conidial filaments, or hyphæ, of some Fungi grow upward and the root-like hyphæ downward. To designate these phenomena of growth the term **geotropism** (Gr. *ge*, earth; *trepein*, to turn) has been used. The organ is said to be positively geotropic if it grows downward; and negatively geotropic if it grows upward. That geotropism is due to the influence of gravitation may be demonstrated experimentally by placing germinating seeds

on rapidly rotating wheels. If the rotation is vertical, the centrifugal force is substituted for gravitation, and the roots grow away from the centre of the wheel and the stems grow toward it; if the rotation is horizontal, the centrifugal force and gravitation act at right angles, and the roots will grow in a line coinciding with a diagonal, or resultant of the two forces, outward and downward, and the stems will grow upward and inward.

21. Certain well-known **movements** depend upon other external stimuli. Thus the leaves of many plants assume a position at night ("sleep") different from the ordinary or diurnal position, in consequence of sensitiveness to light. For example, the leaves of Clover, Vicia, Lathyrus, and Honey Locust fold upward at night; those of the Locust and Oxalis downwards. The petals of the Tulip, Oxalis, Portulaca, etc., open and close alternately in the morning and evening, or upon a change of weather. The leaves of various species of Oxalis, Mimosa, etc., are sensitive to contact and concussion. The stamens of the Barberry, in contact with the corolla when at rest, curve inward when lightly touched near the base, bringing the anther in contact with the stigma. The stamens of the Centaurea and other *Compositæ* are sensitive to irritation. When at rest their free filaments, bearing united anthers, curve concavely outward; on contact or concussion they contract and straighten, lengthening again after some minutes, and resuming their curved form. "This phenomenon occurs only while the style is growing through the anther-tube and the pollen is being emptied into the tube. The motion of the filaments effected by insects causes the anther-tube to be drawn downward, and a portion of the pollen thus to escape above it, which is then carried away by insects to other flowers and capitula when the stigmas are already unfolded." (Sachs.)

22. It often happens that growth takes place more rapidly first on one side of an organ and then on the other side. By the alternating rate of elongation of the two sides, a movement of nutation in one plane will take place. Many leaves furnish a good example; in the bud the greater growth is on

the under or outer side of the leaf, the latter bending upward; but on the opening of the bud the greater growth takes place on the upper side. Floral leaves often exhibit such nutations, as do also many stamens and styles. If the points of unequal growth, instead of alternating from side to side, pass regularly around the organ, a revolving nutation will be the consequence. This is illustrated in twining plants and tendrils. When they touch an upright object they continue their rotation and thus twine around a support. Tendrils grow straight until they have attained about three-fourths of their size. They are then sensitive to contact, and are continually revolving; when they touch any object, a curvature takes place and a number of revolutions are performed around the support. That portion between the point of contact and base also coils in a corkscrew manner (in two directions, since both ends are attached), thus bringing the plant nearer the support.

Plant in flower-pots some seeds of twining plants and of those that bear tendrils, as Morning Glory, Pea, etc. Furnish a support around which they may twine or to which the tendrils may cling. Watch these from day to day, recording their development and behavior. Observe also some plants of the native flora that exhibit these motions.

CHAPTER XI.

SYSTEMATIC BOTANY.

1. ALL individual plants which closely resemble each other in every particular, or are so nearly alike that they may be reasonably referred to an immediate common parentage, constitute what botanists call a **species**. Thus all the Red Clover plants are—unless subjected to some abnormal or peculiar influences—so nearly alike that a minute description, or an exact figure of any one would be an accurate account or representation of any other individual; the same may be said of the individual White Oaks, Locusts, Dogwoods, May-apples, Dandelions, or any other kind of plants; each of these groups of similar individuals, therefore, is a separate species. That some species occasionally pass, by a series of intermediate forms, into one another is well known. The large majority of species now existing, however, are well marked; and though usually very closely related to some others, their characters appear constant.

2. The seeds of any species of plants will, when sown, produce individuals quite, or approximately, like the adult. The same is true for all succeeding generations so far as is known by actual experiment or observation. It sometimes happens, however, that certain individuals differ slightly, but evidently, from the typical, *i. e.* the usual form. If the descendants of these individuals differ in the same respect from the typical form; or, in other words, *if their characters are constant*, they form a **variety** of that species. Thus the Cultivated Snowball is a variety of the wild High Cranberry (*Viburnum opulus*). The latter has only the outer flowers of the cluster enlarged and conspicuous (neutral); in the former they are

all thus characterized. The amount of variation, within varietal limits, cannot of course be dogmatically determined; some botanists may, in particular cases, call species what others designate as merely good varieties. In general, varieties may be regarded as incipient species.

3. An individual of any species may occasionally show a conspicuous variation from the typical form; as a Violet without a spur, a Strawberry plant with simple leaves, a regular flower when the flowers of the plant are labiate, and so on. Such characters are not transmitted to descendants: the latter present the typical form. Individuals behaving in this manner are called **sports**. Exaggerations of such tendencies produce monstrosities. These are sometimes very instructive, especially in cases of reversion. Thus in a monstrous flower, the several organs may revert to the form of leaves, of which evidently, therefore, they must be considered modifications; or a flower-bud may develop into a branch, showing that the flower is homologous with the latter. The influence of cultivation in producing monstrosities, sports, races, and "varieties" (in the sense understood by gardeners) is very marked. Thus, there are hosts of forms of the Dahlia in cultivation, all derived since 1802 from Dahlia variabilis; the Pansies, from Viola tricolor, are also numerous; "some Melons are no larger than small plums, others weigh as much as 66 pounds; one variety has scarlet fruit, another is only one inch in diameter, but three feet long; one variety can scarcely be distinguished externally or internally from cucumbers; one Algerian variety suddenly splits up into sections when ripe." (Darwin.)

4. The several species of Willows have a marked resemblance to each other; the same may be said of the various Oaks, the Osiers, the Clovers, the Violets, etc. A group of such nearly-related species is designated by the word **genus**. Thus, there is a genus of Oaks (*Quercus*), a genus of Roses (*Rosa*), a genus of Toad-stools (*Agaricus*), a genus of Rusts (*Puccinia*), and so on. The genera including the Bean (*Phaseolus*), Pea (*Pisum*), Vetch (*Vicia*), and many others have a general re-

semblance in flowers, fruit, etc. They are, therefore, grouped together and constitute a **family** called Leguminosæ. Others, as the Ironweeds (*Vernonia*), Thistles (*Carduus*), Dandelion (*Taraxacum*), Hieracium, Lactuca, etc.—characterized by having the flowers in an involucrate head and united anthers—form the family Compositæ. In like manner, that is by grouping more or less closely related genera, other families, as Ranunculaceæ, Cruciferæ, Labiatæ, Gramineæ, etc. are formed. Larger groups, or Orders, are formed of families and still more comprehensive are the so-called Classes.

5. The system of **nomenclature**, perfected by Linnæus, and used since his time, is binomial; that is, every plant is designated by a double name—the name of the genus followed by the name of the species, both being Latin or Latinized words. Thus the botanical name of Black Walnut is *Juglans nigra* L.; of Sugar Maple, *Acer saccharum* Marsh.; of Burr Oak, *Quercus macrocarpa* Mx. When a variety is to be designated a trinomial is used; thus, a variety of the native Hydrangea is called *Hydrangea arborescens kanawhana* Millsp. The specific name is generally an adjective, as *canadensis* (in Sanguinaria canadensis L.); sometimes it is an old substantive as *stramonium* (in Datura stramonium L.), or the name of a person as *purshii* (in Phacelia purshii Buckley). The generic name is a substantive, and may be the old classical name, as Platanus, Acer, Quercus; a name formed from Latin, Greek or other words, as Trifolium (Lat. *tri*, three; *folium*, leaf), Zea (Gr. *Zao*, to live), Datura (Arabic *Tatorah*); or the name of a person, as Claytonia (after John Clayton, an early botanist of Virginia); Linnæa (after Linnæus, the immortal Swedish botanist, born 1707, died 1778). The abbreviation of the author's name is also added when botanical names are written. Thus, L., Marsh., and Mx. in the names above are for Linnæus, Marshall and Michaux, who described and named the respective species.

6. The two most comprehensive groups in the vegetable kingdom are the **Seed-bearing plants** (*Phenogams*), and the

Spore-bearing plants (*Cryptogams*). The first group includes most of our common plants; they bear flowers, whose function is the production of seeds. Each seed when mature contains an embryo, or rudimentary plantlet. This small organism begins its development as a new individual when the seed germinates. The second group of plants includes the Ferns, Mosses, Lichens, Mushrooms, Mildews, Smuts, Bacteria, Yeast plant, etc. These are generally spoken of as the "lower plants." They do not produce flowers, and their reproductive bodies are *spores* instead of seeds. Spores are simpler in structure than seeds; they do not contain an embryo, but merely protoplasm including the food material, which, when germination takes place, gives rise to the new individual. The divisions and subdivisions of these main groups are shown in the following outline:

Phenogams, or Seed-bearing plants.	Angiosperms .	Dicotyls .	Oak, Pea, etc.
		Monocotyls	Lily, Grasses, etc.
	Gymnosperms	. . .	Pines, Cedars, etc.
Cryptogams, or Spore-bearing plants.	Pteridophytes.	Lycopodiaceæ .	Club Mosses.
		Equisetaceæ .	Horsetails.
		Filices . .	Ferns.
	Bryophytes	Musci . . .	Mosses.
		Hepaticæ .	Liverworts.
	Thallophytes .	Lichens .	Lichens.
		Fungi . .	Mushrooms, Moulds, etc.
		Algæ . . .	Pond-scum, "Sea-moss."
		Schizophytes .	Bacteria, Yeast.
		Myxomycetes .	Slime-moulds.

7. The **Myxomycetes**, or Slime-moulds, are peculiar and interesting plants.[1] During their growing or vegetative stage, they consist of a homogeneous mass of colored (but never green) protoplasm, which has received the name of *plasmodium*. There is no cell-wall; there is a streaming or circulation in the mass of protoplasm, and the latter can, by constant change of form, move slowly around on the damp decaying wood, or vegetable mould, where these plants are often to be met with. In their vegetative state they are so much like the

[1] This group is regarded by many—perhaps by a majority of botanists—as belonging to the animal kingdom.

lower animals (the *Monera*) that many naturalists consider them as belonging to the animal kingdom, rather than to the vegetable kingdom. If they are brought to rest by absence of proper moisture and temperature, they become changed into rounded masses, and secrete a cellulose wall. This is called the *sclerotium* stage. Upon return of suitable conditions the plasmodium form is again assumed. The reproductive stage (Fig. 116) is also one of rest; in most of the species the mass becomes compact, then heaps up into definite shapes, each portion becoming surrounded by cellulose; the protoplasm within becomes separated into multitudes of spores which, in many species, are commingled with an irregular network of (often ornamented) filaments, called the *capillitium*. Under proper conditions the spores burst open, the protoplasm of each escapes as a swarm-spore with one cilium, and undergoes fission (division into two equal parts by constriction). Coalescence of a number of these takes place in a few days to form the new plasmodium.

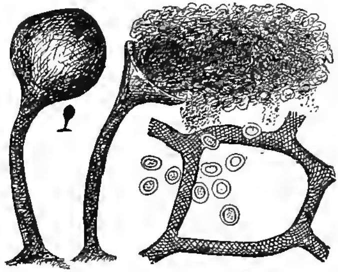


FIG. 116.

Specimens of the vegetative stage (*plasmodium*) of the Slime-moulds are difficult to find except in a few species where the mass is very large, as in "Flowers-of-tan," sometimes seen on spent tan-bark, on piles of rotten sawdust or on rotten stumps in damp woods. But specimens showing the reproductive stage may be found on rotten logs, stumps, etc. in damp shady woods. The pocket lens will reveal some of the characters mentioned in the text, but of course they cannot be exhaustively studied without a compound microscope. Illustrative specimens can be glued to herbarium sheets, or preferably put in paper pockets or small pill-boxes.

8. The **Bacteria** are representatives of the group Schizophytes. They are exceedingly small (in some cases no more than one twenty-thousandth of an inch broad) and simple organisms destitute of chlorophyll (Fig. 117). They occur

isolated or in cell-families, and multiply usually by transverse fission of the cells; most of them have a motile and a motionless stage. The unicellular Bacteria sometimes form a jelly-like mass or colony, and this is called the *zoöglœa* stage. Representatives of the genus *Bacterium* have an oval or cylindric-oblong shape. The common agent of putrefaction is *Bacterium termo*, which consists of very small cylindrical cells. The genus *Micrococcus* consists of spherical cells. *M. prodigiosus* causes the blood-like patches on bread, paste, etc. *M. diphtheriticus* causes diphtheria. *M. nitrificans* decomposes the ammoniacal compounds found in the soil. There are two genera with filiform cells: *Bacillus*, with the filament straight, and *Vibrio*, with the filament curved or undulated. *B. subtilis* is the butyric ferment, *B. anthracis* causes the anthrax or splenic fever, and *B. tuberculosus* causes pulmonary consumption. The genus *Spirillum* has spirally twisted cells. *S. choleræ asiaticæ* produces Asiatic cholera.

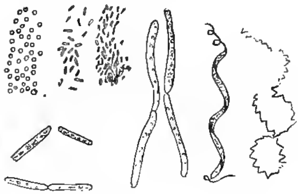


Fig. 117.

The compound microscope with high powers is required for a study of the Bacteria. The results of their work can be seen almost everywhere, although the individual plants themselves are always microscopic.

9. The rôle or part performed by these micro-organisms or Bacteria, in the economy of nature and in our everyday life is very important. Many forms flourish in the soil, and without their agency plant food would not be made available. Numerous species disintegrate organic matter and deliver the elements back to the mineral kingdom. The souring of milk, the maturing of cream, the ripening of cheese, and many operations incident to our civilization are directly dependent on the presence of the Bacteria. Comparatively few species are injurious to man and other animals. Diseases caused by Bacteria are designated as "germ diseases." They are contagious and often epidemic. Most of the fevers belong to this

class, as do also pulmonary consumption, diphtheria, etc. In each of such cases it is a certain species only that invades the human system and causes the disease. The species of Bacteria are not directly injurious, but there are secreted poisonous substances, called *ptomaines.* The organism may survive the attack of the parasites, and in case of several of the diseases immunity (as yet unsatisfactorily explained) is thereafter enjoyed.

10. Another family of plants belonging to the Schizophytes, includes the Yeast plant (*Saccharomyces cerevisiæ*) and other species, which produce fermentation in sugar solutions. The transparent cells are round, oval, or elongated, and multiply by budding (Fig. 118). When the supply of nourishment is less abundant (as when Yeast is grown on slices of potato or carrot), the cells are larger and divide internally into four new cells. These may be called spores; they escape and grow into cells of the ordinary kind capable of multiplication by budding. *Saccharomyces cerevisiæ* produces the alcoholic fermentation; that is, the sugar in the solution is converted into alcohol with the escape of carbonic dioxide. Its agency in bread-making is well known. *S. ellipsoides*, *S. conglomeratæ*, and others live on grapes and find their way into the juice in the manufacture of wine, and cause the fermentation of the latter. *S. mycoderma* is found on the surface of spoiled beer or wine; it does not produce fermentation like the others, but putrefaction instead.

FIG. 118.

A supply of the Yeast plant for study can be found in vigorously growing yeast, but the use of the compound microscope is indispensable for its examination.

11. Very common, abundant, and beautiful fresh-water species belonging to the group of **Algæ** (easily recognized among the lower plants by uniform presence of chlorophyll), are the members of the genus *Spirogyra.* They are many-celled, filamentous, having the chlorophyll in spiral bands, and a conspicuous nucleus in each cell, which is imbedded in the small

central protoplasmic mass, and suspended by extensions to the parietal layer (Fig. 119). The filaments elongate by the growth and transverse division of the cells; the protoplasm divides, a cellulose wall is at the same time secreted, and the

FIG. 119.

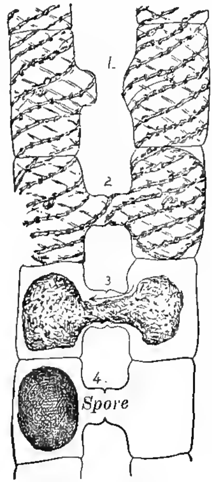


FIG. 120.

two resultant cells then elongate to the normal length. Sometimes the filaments break up spontaneously, and each part gives rise to a new filament. A form of reproduction (which may be denominated *sexual*, the methods mentioned previously being called *vegetative*), takes place by the process called *conjugation* (Fig. 120). From each of the cells of two filaments lying parallel to each other, slight protrusions arise and these grow toward each other until they come in contact and unite. The partition between them becomes absorbed; in the meantime the protoplasm in each of the two cells contracts, rounds itself, and one mass passes gradually through the channel over into the other cell, where the two unite and form the spore. The old cell-walls decay and the spore falls to the bottom of the water, there remaining till the process of germination commences.

Collect representative Algæ from running water where the coarse branching kinds abundantly occur. The fine silky sorts will mostly be found in stagnant water. On the wet ground or often on flower-pots in the greenhouse, the kinds that form a felted mass can be found. The individuals of only the coarser kinds can be clearly seen with a pocket lens. If desired to make herbarium specimens, float a quantity in a basin of water; insert under the mass a piece of writing-paper. Slowly lift the paper, at the same time spread the Algæ evenly over it with a small camel's-hair brush. After the surplus water has drained off, put the paper with the Algæ on it under pressure between blotting-papers, first having laid a piece of muslin over the Algæ. The latter will adhere to the paper but not to the cloth.

12. The **Fungi** include a large number of cryptogamous plants of varied size and character; some are large and complex in structure, others are microscopic and simple. They are destitute of chlorophyll, and either live on decaying matter (*saprophytic*), as Mushrooms, Toadstools, Puff-balls and Moulds, or inhabit and draw their nourishment from living plants, as the Rusts, Smuts, Leaf-Mildews, Black-knot, Ergot, etc. These (the *parasitic* species) cause many of the so-called diseases of plants. Their vegetative portion, or *mycelium*, consists of delicate tubular threads (called *hyphæ*) that penetrate the tissue of the host-plant and absorb nourishment that the host provided for its own use. Some of them, for example the family **Uredineæ** (Red and Black Rusts) are polymorphic; that is, in their life-course they take on at successive periods two or more distinct forms, so unlike each other generally that the different stages were formerly considered as distinct plants. The mycelium penetrates between the cells in the tissue of leaves, sometimes causing abnormal growth or distortion. There then appear, beneath the epidermis, globular masses, having within at their base a compact layer of upright hyphæ, each of which produces a chain of *conidial spores.* The epidermis is ruptured by the growing mass; and the thin layer of cells, or peridium, enclosing the spores breaks open; the yellow spores, hitherto many-sided from mutual pressure, become round and escape. This stage formerly received the generic name of *Æcidium* (Fig. 121). The spores may, therefore, be called the *æcidiospores.* There are often present also

smaller flask-shaped bodies, called *spermogonia* (Fig. 121), containing hair-like filaments, which break up into exceedingly small bodies, called the *spermatia*. The exact function

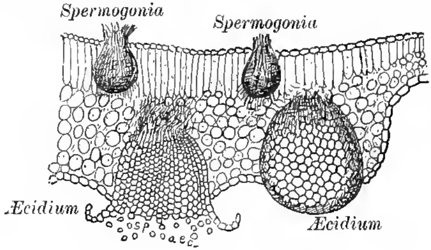


FIG. 121.

of these is not known. The æcidiospores germinate, and when on the proper host-plants the germ-tube grows through the stomates. A dense mycelium is then formed in the parenchyma of the leaf; from this mycelium grow pedicelled spores, called *uredospores*. They form, when they burst through the epidermis, orange-colored spots, called *Red Rust*. This stage was formerly designated as the genus *Uredo* (Fig. 122). The

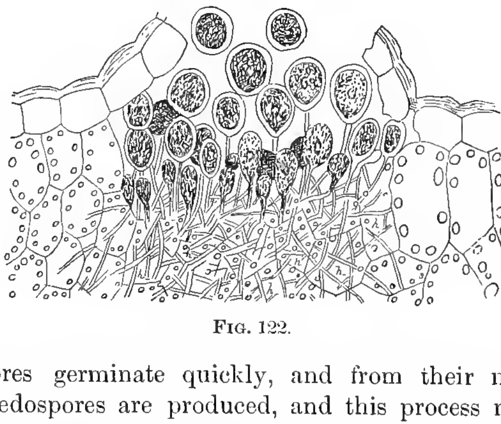


FIG. 122.

uredospores germinate quickly, and from their mycelium other uredospores are produced, and this process may continue a great length of time. Finally, from the same mycelium are produced thick-walled brown or black spores, called *teleutospores* (Gr. *teleuta*, end). These may be one-celled (as in

Fig. 123.

Uromyces and *Melampsora*), two-celled (as in *Puccinia*, or Rusts, Fig. 123, and *Gymnosporangium*, the so-called Cedar apples,

Fig. 124.

Fig. 124), or many-celled (as in *Phragmidium*). They rupture the epidermis and thus become exposed, but generally remain attached to their host-plant during the winter. In the spring they germinate by sending out from each cell a jointed filament, called the *promycelium.* On small branches of the promycelium, small terminal cells, or *sporidia* are formed. These are carried about by the wind, some of which may alight on the proper host-plant. Here germinating, they send their filaments into the parenchyma of the leaf, from which a mycelium proceeds that gives rise to an æcidium, and so on, as before described. In some species all the stages may grow on the same plant; more often the æcidial stage is found on one plant and the other stages on some other one; or, in yet other species, each stage may have a different host-plant. The Wheat Rusts belong to the second group; the æcidial stage of one of the species occurs only on the Barberry leaves and the uredospores and teleutospores are found on Wheat and other Gramineæ.

Collect Mushrooms, Toadstools, Puff-balls, Pore-fungi (*Polypori*), Black-knot, etc. and draw figures to illustrate all that can be seen without the aid of the microscope. Those species which are usually called "microscopic fungi," many of which are parasitic on leaves and other parts of common plants, as Leaf Mildew, Smut, Rust, "Leaf-spot," etc., can scarcely be studied to advantage by the beginner, but the important ones should be recognized as such at sight. Therefore as many as possible should be collected and compared, examined under the lens and notes and drawings made. They can best be preserved (after drying under pressure) by enclosing in paper pockets glued to the herbarium sheets.

13. The **Lichens** constitute a peculiar and very interesting group of plants. They are found on tree trunks, old rails, etc., also occasionally on the ground. They have generally a greenish-gray color, but are in some cases yellow or of other colors. They are rather small plants, usually flattish, but in some cases branching. The tissue of the Lichens consists of jointed, branching, colorless filaments similar to the hyphæ of the Fungi. These are attached to or surround small green bodies called *gonidia*, which are now known to be imprisoned Algæ. The latter furnish food for the Lichens and are protected by them in return for this service. Such a mode of

life—advantageous to both organisms—is called *symbiosis*. In most of the common species the spore-bearing disks or cups (called *apothecia*), are readily seen. The spores in their origin and structure resemble those of many of the Fungi. In fact the Lichens may be regarded merely as a group of the Fungi.

Collect, examine and figure representatives of the forms of Lichens mentioned in the text—taking care to get those that have *apothecia*, *i. e.* those that have visible fruit-cups. This can be done more satisfactorily immediately after prolonged rain. Remove them from their substratum and put under moderate pressure till dry, when they can be enclosed in pockets as in the case of Fungi, or glued directly to herbarium sheets.

14. The **Bryophytes** (Mosses and Liverworts) constitute the next higher division of the vegetable kingdom. In this group there is a well-marked alternation of sexual and non-sexual generations. The first, or that proceeding from the spore, bears the reproductive organs called *archeyonia* and *antheridia*. It is the sexual generation (*gametophyte*). After fecundation there grows a sporocarp or fruit (called *sporangium*), in which spores arise non-sexually ; *i. e.* not the result of the fusion of two cells. This may be called the non-sexual generation (*sporophyte*). The **archegonium** is flask-shaped, in the bottom of which is a naked mass of protoplasm, the germ-cell, which is the essential part of the female organ. The **antheridium** is generally club-shaped or subspherical, supported by a pedicel, and filled with many sperm-cells, each of which contains a single, spirally coiled spermatozoid. The neck of the archegonium is open at the time for fecundation and into it pass the free spermatozoids, which fuse with the protoplasm in the germ-cell. Thereupon a thick wall or covering is formed. Cell-division now takes place, and the result of this development is the formation of a spore-case (*sporangium*), and a supporting pedicel, or *seta*. The spore-case with its seta remains attached to the plant that produced it, is nourished by it, yet has no organic connection. This, the second, is called the non-sexual generation. Within the sporangium the spores are formed, and contain, besides colorless protoplasm, starch and drops of oil, also chlorophyll grains. When ripe, the spore-case, as

for example, in Hypnum, opens by a more or less beaked lid, called the *operculum* (Fig. 125), which in many species

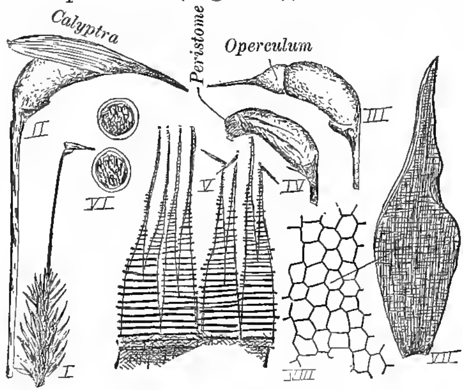


Fig. 125.

is surmounted by a hood, called the *calyptra* (Fig. 125); surrounding the orifice is a single or double row of teeth (Fig. 125), called the **peristome** (Gr. *peri*, around; *stoma*, mouth); the teeth number four, eight, sixteen, thirty-two, or sixty-four. The spores germinate by the rupture of the firm outer coat or exospore and the tube-like protrusion of the delicate inner coat or endospore. This continues to grow and gives rise to the filamentous pro-embryo, called the *protonema;* from the protonema numerous buds arise, which give origin to the upright, leafy, sexual plants.

15. No true roots are produced by the Bryophytes; organs functionally, but not structurally, corresponding to them, are the rhizoids or root-hairs, which grow from the under surface of the thallus, or from the sides of the stem. They serve to fix the plant in its place, and also to absorb nourishment for its growth. The tissues of the Bryophytes are more highly differentiated than in previous groups. The epidermis is often quite well defined; and true stomates, absent in the lower groups, here appear. The tissue is mainly parenchymous; but in the axial portions of the stem, and in the veins of the leaf, there is, by the elongated bundles of cells, slight

indication of a fibro-vascular system. The two classes, into which the Bryophytes are divided, are the Liverworts (*Hepaticæ*, Fig. 126), and the Mosses (*Musci*, Fig. 125).

Collect as many kinds of Mosses as can be found in fruit, *i. e.* with the (usually long) pedicels surmounted by the *capsules*. Sketch the entire plant, natural size. Then use the lens and make magnified figures of leaves, also of the capsule and all that can be seen in connection with it. Liverworts are less common, but specimens may be found on damp shaded rocks. For herbarium specimens (which should, especially in case of the Mosses, show the *fruit*), dry between sheets of soft paper; then put in pockets or glue direct to the herbarium sheets.

16. The next division, **Pteridophytes,** includes the Vascular Cryptogams, namely the Ferns and their allies. Here as in the previous division there is an alternation of sexual and non-sexual generations. But while the conspicuous generation (the Moss) in the Bryophytes is sexual and the inconspicuous, namely the sporangium, non-sexual, the reverse is the case in the Pteridophytes. That is, the conspicuous generation (the Fern, etc.) is non-sexual; and the sexual generation or stage (the *prothallium*), that bearing the sexual reproductive organs, is very much reduced and short-lived. This prothallium is a small, flattened, thallus-like growth from the spore, composed of chlorophyll-bearing parenchymous cells, in one or a few layers; on its under surface are produced rhizoids, by which it is fixed to the ground. On the prothallia are developed the archegonia and antheridia, which are essentially similar to those in the higher plants of the preceding division. The spirally-coiled spermatozoids escape from the antheridium, enter the tube or neck of the archegonium, and fecundate the germ-cell therein contained. The protoplasm thus fecundated begins a course of development resulting in the formation of a young plantlet, which

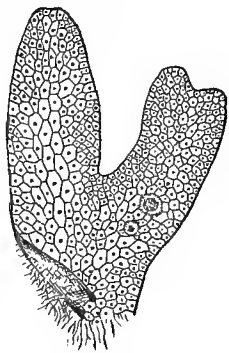


FIG. 126.

develops into a leafy plant of considerable size, with marked differentiation of tissue, and capable of producing non-sexual spores.

17. **True roots** first make their appearance in the Pteridophytes. They, like the stem, develop from a triangular apical cell (Fig. 127, *Ap.*). This gives rise behind to the tissue of the root, and in front to the root-cap (Fig. 127). The three systems of tissue—epidermal, fibro-vascular, and fundamental—are well developed. The epidermis contains stomates of the ordinary kind. Trichomes or hairs are often abundantly developed, especially on young leaves when they take the form of scurfy hairs or scales. The Pteridophytes are divided into three classes: the Ferns (*Filices*), the Horsetails, or Scouring Rushes (*Equisetaceæ*), and the Club-mosses (*Lycopodiaceæ*).

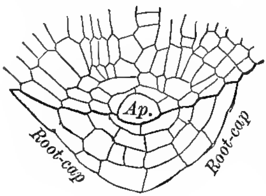


FIG. 127.

18. The **Ferns** have a solid stem, with roots and broadly expanded leaves. They are mostly terrestrial, and all richly supplied with chlorophyll. The spores are developed in sporangia on the surface or margins of the ordinary or modified leaves. The leaves, usually called *fronds*, are circinate in their unfolding, and often divided and several times compound. On their under surface are the *sori*, or clusters of sporangia (Fig. 128). Each sorus may be naked, or it may be covered by a membrane, called the *indusium* (Fig. 128). This is of various shapes, and has various modes of attachment in the different genera. The sporangia are generally roundish and pedicelled bodies. Each sporangium, in

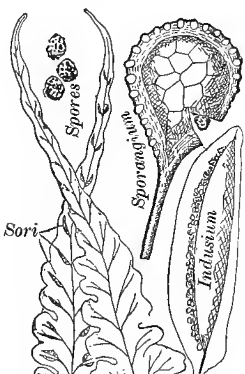


FIG. 128.

the family *Filices*, is surrounded by an elastic ring (*annulus*). This contracts and ruptures the sporangium, thus setting the spores free at maturity. The stems are mostly short or creeping (rhizomes), but in the Tropics they are often of considerable thickness and height. They contain flat fibro-vascular bundles, usually arranged in a circle. When the stems become thick with increase of growth, a network of anastomosing bundles is formed in place of the central bundle. Ferns appeared in the Devonian Age, represented by twelve genera, belonging to extinct families. In the Carboniferous Age they were much more numerous, but have decreased up to the present time. These plants are very ornamental, but otherwise of comparatively little economic value. The largest and commonest genera are Asplenium, Dryopteris, Botrychium, Cystopteris, etc.

Collect specimens of the different species of Ferns showing various forms of fruit, which may be found in late spring and summer. Make an outline sketch of a small portion of the frond (leaf). The figure should be large enough to show plainly the venation and the fruit. Both vary much in different genera and serve to characterize the latter. Specimens of the small prothallia with young fern-plants developing may often be found on the soil of pots in green-houses. For making herbarium specimens, follow the directions given on p. 105 for collecting and preserving flowering plants.

19. The **Horsetails** or **Scouring Rushes** have hollow, jointed grooved stems, in the epidermis of which there is a large amount of silica. The leaves are borne at each node in the form of a sheath. The branches are verticillate. The spores are produced in sporangia forming a cone-like spike at the end of the stems. The stems of the **Club-mosses** are solid, leafy, and mostly erect. The leaves are simple, small, sessile, imbricated, and resemble those of the Mosses. The spores are produced in sporangia, situated in the axils, and are appendages of the leaves. In some of the genera (*Lycopodium*, etc.) the spores are all alike; in others (*Selaginella*, etc.) there are two kinds—large spores (*macrospores*) and small spores (*microspores*). The plants of this class, now generally terrestrial, and only a few inches high, were numerous in the

Devonian and Carboniferous Ages. Some of them (Lepidodendron, etc., Fig. 131), were of gigantic size, but the group to which they belonged became extinct in the Permian Period. Several species of Lycopodium occur in the United States. Many species of Selaginella, which are mostly tropical, are cultivated for ornament.

The Equiseta and Club-mosses may be found in wet, sandy places and in damp, rocky woods. Take a single specimen of each, and after close examination make notes and figures illustrating the general structure. The spores and the minute anatomy cannot be examined without the aid of the microscope. Herbarium specimens of the species can be made as in case of the flowering plants (p. 105).

20. The lower group of the Phenogamous plants includes the **Gymnosperms** (Gr. *gymnos*, naked; *sperma*, seed), as Cycads, Pines, Firs, etc. They rank above the Cryptogamous plants but are closely allied to them. They are characterized by having (as the name indicates) naked ovules, that is, ovules not enclosed in an ovary. The seeds have in many cases several cotyledons. The species are terrestrial, chlorophyll-bearing, and with some exceptions trees, often very large. Bordered pits are found in their woody tissue and are peculiar to this group. Many of the representatives produce turpentine containing dissolved resin. The family *Pinaceæ* (including the Pines, Firs, Balsams, Larches, Cedars, Big Trees of California, etc.) is of great economic importance, furnishing, besides turpentine and resin, a large quantity of lumber suitable for a great variety of uses.

21. The other group of flowering plants, namely the **Angiosperms** (Gr. *angios*, vessel), is distinguished from the preceding by having the ovules enclosed in seed-vessels or ovaries. It is to this group that the outline of Organography and much of the practical work suggested in preceding pages in the main applies. The two divisions, *Monocotyls* and *Dicotyls*, have been frequently mentioned and contrasted. The morphological and physiological development is higher than that of the preceding groups. They are also of greater economic importance, furnishing an exceedingly large variety of useful products.

Directions for Collecting and Mounting Botanical Specimens.—It is often desirable to examine or study specimens of the native plants at times when it would be impossible to obtain the living or fresh material; exotic plants or those of other regions would also be desired. To make such study possible, plants are collected in their proper season and in the regions where they grow; they are properly dried and then attached to sheets of paper and finally arranged in systematic order. Such a collection is called a **Herbarium.** Herbaria are indispensable to the botanist. Some suggestions are here given to guide the beginner in work of this kind.

It must be remembered that no subsequent manipulation, however skilful, will make good specimens out of poor material; therefore, the first requisite is to get **perfect specimens** of the plants to be preserved. Such specimens include leaves, flowers, fruit, and a portion or the whole of the stem and root.

In the great majority of cases a single properly selected plant will furnish all these parts, since ripe fruit is not always essential. But if the flowers precede the leaves, specimens of each must be collected separately and at different dates. Usually the second collecting in such cases will exhibit the mature fruit on the same branches with the leaves. Fully developed fruits or seeds are essential in case of several families of plants, particularly the Parsley family, the Mustard family, the Sunflower family and the Sedge family. The specimens selected for the herbarium should be average representatives of the species, neither above nor below the usual size, and should show the usual characteristics in every respect. Besides these, any unusual or aberrant forms that occur should be collected. If a monstrosity or an individual differing much from the typical species is found, it should, of course, be preserved. Often such a specimen is of the greatest interest and value.

The **Size of the herbarium sheets** on which specimens are to be mounted is eleven and one-half inches wide and sixteen and one-half inches long. Therefore all plants that are not over fifteen or sixteen inches high can be taken entire. Bulbs or tubers, if present, should be secured—sliced when thick in order to dry more quickly and to be in more convenient shape at mounting time. Only a small portion of the root, however, is needed; but it would not be allowable to cut off the plant however near the root, since it would not be evident how much of the plant had been discarded.

Usually a specimen can be bent sharply (broken, but not severed) in case the plant is more than sixteen and a half inches high. In this way the entire plant may be shown. Slender stems, as in case of some grasses, can be bent (broken, but not severed) at two or even more points if necessary. The specimens may be held in position till dry by slipping over the bent portions narrow strips of paper in which longitudinal slits have been cut.

Very large herbs, as the Sunflower, Hemp, or Poke-weed, as well as shrubs and trees, cannot be laid entire in the herbarium. Therefore, from each take portions sixteen inches long. Select two or more specimens when necessary to show variation in leaves, etc. This precaution should be especially observed when the root-leaves differ from those of the stem. When the flowers are not perfect, or when the staminate and pistillate flowers are not on the same plant, two separate plants must be secured to make the complete herbarium specimen.

If a long excursion is to be made a **Collecting box** will be needed. In fact, delicate plants often wilt in a few minutes unless placed under cover to prevent evaporation. A plant press can be taken into the field, but it is perhaps preferable not to be encumbered by anything more than a light collecting box. The latter should have a close-fitting lid, and be convenient to handle. A tin box fifteen to twenty inches long, oval in transverse section, with the lid occupying the major portion of one side, is perhaps the most serviceable and a comparatively cheap vasculum. A handle can be soldered on the middle above, or rings attached at the ends for fastening a strap to be thrown over the shoulder. But expense may be avoided altogether by using a pasteboard box, like a long envelope-box.

Having the fresh plants at home, they should be prepared at once for **pressing and drying.** Papers for dryers should be cut a half-inch or an inch larger each way than the species sheets, perhaps twelve by seventeen or eighteen inches. Old newspapers may be utilized, but the soft felt paper used by builders is preferable, and costs only a few cents per pound. Do not lay the specimens directly on the dryers, but put them in folded sheets of thin paper. These folded specimen-holders should be cut eleven and a half by sixteen and a half inches, the size of the sheets on which the specimens are ultimately to be mounted.

A little attention should be given to the **appearance** of the specimen when laid in press, the object being to show the several parts to the best advantage, and above all, to have a specimen when finished that will look as life-like as possible. Large leaves should be straightened, if necessary, and other parts disposed so as to give the best result. With each specimen never fail to lay in a temporary label, giving the following items: the locality, the date, the collector's name, and, if known, also the name of the plant. When all the specimens are placed on top of each other with one to three dryers (or more if the specimens are succulent or contain much moisture) intervening throughout, the pile is to be subjected to moderate and continuous pressure. After twelve or twenty-four hours the dryers will have absorbed considerable moisture and therefore should be exchanged for dry ones. This changing of dryers should be attended to daily until the specimens are thoroughly dry, when they may be removed (still lying in the specimen-holders) from the press and are ready for mounting.

A satisfactory **Press** will be a matter of considerable moment. Two plans are recommended, each having advantages peculiar to itself. The simplest plan is to procure boards twelve by seventeen or eighteen inches, one to be placed at the bottom and the other at the top of the pile of specimens, and one, two or three at intervals between the dryers according to the size of the pile and the character of the material in reference to moisture contained. For weight, use a good-sized stone or two or three smaller ones. A shallow box with sand or pebbles is perhaps still more convenient. A press of this kind secures uniform and continuous pressure, and is not expensive. Under no circumstances use a screw press; many specimens would probably be ruined by too much pressure, and besides, the pressure becomes less as the pile of specimens gradually loses moisture.

For ease of handling, convenience at home and in the field, neatness of appearance combined with efficiency, a **Slat-press** is to be recommended. This can be made of wooden strips seventeen or eighteen inches long, seven-eighths inch wide, and one-eighth inch thick, with cross pieces fourteen inches long, five-eighths inch wide, and three-fourths inch thick. Seven of the slats placed equally distant from each other should be nailed to four of the cleats or cross pieces, an inch of each end of the latter projecting beyond the outermost slat on either side; the press will therefore be twelve inches wide exclusive of the projecting ends of the cleats. Two of the cleats should be at the two ends of the set of slats and the other two placed equidistantly between. Seven slats and four cleats similarly nailed together would form the other side or half of the press. To secure the necessary pressure on the specimens pass strong cords, one on each side, attached to a cleat-end, continuously over the upper and lower projecting ends of all the cross pieces. In each a shallow groove should be cut or filed to receive the continuous cord; a belaying pin, a groove sawed in the end of a cleat, or other device should be added to secure the free end of the same. To make the press still more efficient, "ventilators" should be inserted, one, two or more according to amount in the press and the quantity of moisture in the specimens. The ventilators, seventeen or eighteen inches long and twelve inches wide, can be made of slats of same dimensions as those used in making the press; use fourteen of them in two equal series one above the other, between which place four cross pieces one-half inch square and twelve inches long, disposed to correspond in position with the four cleats on each half of the press. Such ventilators can, of course, be used advantageously in any kind of press.

For Mosses, Lichens and Fungi much less pressure generally is required. Otherwise their manipulation would be in general as indicated above. They should be collected only *when in fruit*.

At the end of the collecting season the specimens should be **permanently mounted.** The species-sheets should be of a good quality of white calendered paper, cut eleven and one-half by sixteen and one-half inches. On these the specimens are to be fastened with glue; a good quality of liquid glue should be used. Thick ends of twigs, etc., should be further anchored with very narrow, short slips of gummed paper or white court plaster. A label written in ink, giving the scientific name of the plant, the date, locality and name of the collector, should be fastened to the lower right-hand corner of the species-sheet. All the sheets holding species of one and the same genus should be put in a folded genus-cover made of heavy manila paper. Outside on the lower left-hand corner of this—which would be opposite to the free edges—the name of the genus is to be written. The arrangement of the genera in proper sequence completes the herbarium.

CHAPTER XII.

GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF PLANTS.

1. THE forces now operating in producing changes of the surface of the earth were acting—and of course with similar results—during a preceding (geological) period, which continued a very great length of time. The denudations of the elevated portions of the earth's surface, and deposition of the transported material, caused a succession of layers of mud to be formed. Occasionally remains of any plants (and animals) that may then have been living, especially the harder parts in their structure, became incased in this mud. These layers of mud became converted into rock, in the layers of which the organic remains or their imprints, called *fossils*, are contained. They afford to-day the record—as yet but partially examined—whose reading gives the past, or geological, history of our earth. For convenience of study, this period of development is divided by geologists into Times, called, beginning with the earliest, **Archæan** (Gr. *archein*, to be first); **Paleozoic** (Gr. *palaios*, ancient; *zoös*, living), including the Cambrian, Lower Silurian, Upper Silurian, Devonian, and Carboniferous eras; **Mesozoic** (Gr. *mesos*, middle), formerly called the Reptilian Age, including the Triassic, Jurassic, and Cretaceous eras; and **Cenozoic** (Gr. *kainos*, recent), including the Mammalian Era (divided into the Tertiary and Quaternary periods). No fossil plants have as yet been found in the Archæan rocks, though there is reason to believe that a flora existed at that time. One proof of this is found in the extensive deposits of iron ore. The compounds of iron, widely deposited in the soil, are decomposed in the presence of organic matter and then dissolved

by percolating waters, which convey them to points where vast deposits accumulate. Another proof of an Archæan flora is the occurrence of graphite. This is formed by metamorphism of coal, which in turn had its origin in the plants that previously grew in that region. Carbonaceous shales and beds of limestone also indicate the existence of aquatic life in Archæan time.

2. In the **Cambrian** and **Silurian Eras** the lower animals were very abundant; this is conclusive proof that plants must have existed at the time in great quantity; probably, too, in great variety. For animals depend on the vegetable kingdom for their sustenance, each animal consuming many times its own weight of vegetable food. That fossil animals are in every age found more abundantly than fossil plants is not to be taken as proof that there were fewer of the latter; it must be borne in mind that the hard parts of the animals are much less destructible than most vegetable tissue, and

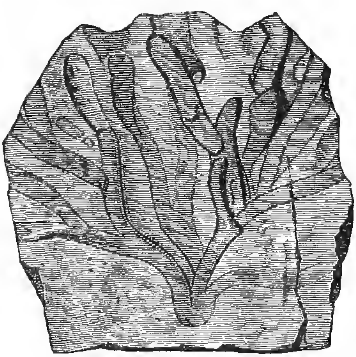


FIG. 129.

FIG. 130.

are, therefore, oftener preserved in the fossil state. The plants of the Cambrian and Silurian eras which have been found and described up to the present time are a number of cellular, and a few vascular, cryptogams. Many of them were marine plants, apparently related to the genus Fucus; a branching form has received the generic name of Buthotrephis (Fig. 129). In the Upper Silurian, besides many marine species, there were a number of true land-plants, among which may be mentioned the genus Psilophyton, which is a representative of the Club-mosses or Lycopods.

3. A very marked advance is exhibited in the vegetation of the **Devonian Era.** The fucoidal plants of the Silurian continue in this age, but they were accompanied with a multitude of Vascular Cryptogams, and even some Phenogams (Gymnosperms). For the first time there was a true forest vegetation; and the great size and number of the plants thus early foreshadowed the remarkable development that took place in the next age. The groups existing were as follows:

(*a*) The Equisetaceæ were represented by Calamites and Asterophyllites (Fig. 130). The Calamites had long, slender, tapering, and jointed stems, sometimes two feet in diameter and thirty feet high. The surface was finely striated, or fluted, and at all the joints were situated whorls of scale-like or thread-like leaves. They were, except as regards size, like our living Equiseta, which grow generally less than three feet high and no thicker than the finger. The Asterophyllites were herbaceous, flexible species, with leaves arranged in whorls at the joints as the name indicates.

(*b*) The Ferns were represented by such genera as Cyclopteris and Neuropteris. In these the leaflets or pinnæ have no midrib.

(*c*) The Lycopods were Psilophyton, already introduced in the Upper Silurian, Lepidodendron and Sigillaria. The Lepidodendra were gigantic plants, the surface of whose trunks and branches was regularly marked in rhomboidal patterns, or quincuncially, representing the leaf arrangement (Fig. 131); the branches were clothed with squamous, spinous or acicular leaves, and terminated by scale-cones, which bore spores like the Club-mosses. The Sigillariæ were likewise arboreous, but their trunks exhibited longitudinal ribbing or fluting, and vertical rows of seal-like impressions representing the leaf arrangement; they were but little, if at all, branched, and clothed with numerous long, tapering leaves.

(*d*) The Conifers were represented by the genus Protaxites, allied to the Yew (*Taxus*).

4. The flora of the **Carboniferous Era,** or the vegetation of the Coal-measures, is of peculiar interest, both because of its abundance and its diversity of forms. About one-fourth of all known fossil plants are from the Coal-measures. There were also many marine plants, among which may be mentioned the curious Spiral-plant, or *Spirophyton*. Fungi ex-

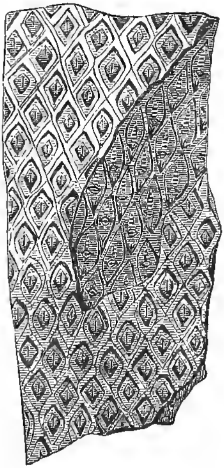


FIG. 131.

FIG. 132.

isted at that time. But the great majority of plants may be referred to the following groups:

(*a*) *Equisetaceæ*.—Besides plants of the genus Calamites, which has already been described, there were representatives of other closely-related genera, as Asterophyllites, Sphenophyllum, etc., all of which became extinct in the last period of the Carboniferous era.

(*b*) *Filices*.—The Ferns were abundantly represented—nearly one-half of all the plants of the Coal-measures belong to this group. Some of them had creeping stems like our common Ferns, and others were Tree-ferns, such as are to-day found growing only in warm latitudes. A Tree-fern of the Coal-measures, called *Megaphyton*, had its large fronds in two vertical ranks; other common genera were Cyclopteris, Odontopteris, Neuropteris, etc., whose leaflets, or pinnæ, were destitute of a midrib; Sphenopteris, Hymenophyllites, etc., whose pinnæ had a midrib discernible only toward the base, and from which the veins did not branch; Alethopteris, Pecopteris, Asplenites, etc., whose pinnæ presented a distinct midrib, from which the nerves branched more or less obliquely (Fig. 132).

(*c*) *Lycopodiaceæ.*—The Lycopods were represented by huge Lepidodendra (Fig. 131) and other nearly-related genera, as well as by the gigantic *Sigillariæ.* The roots of these plants are often found fossil, and are distinguished by scattered, rounded depressions or elevations. These were formerly believed to be the leaf-scars on stems and branches; and the genus *Stigmaria* was formed to include them. They are yet designated by this name, but they have in many cases been found attached as roots to the Lepidodendra and Sigillariæ. Fruits have also been found, generally isolated, but they are believed to be the fruits of the preceding plants.

(*d*) *Coniferæ.*—Fossil Conifers are found in the form of stumps, logs, leaves and fruits. They were very unlike the present Conifers of the temperate climates. They resembled more or less the tropical *Araucaria*, the broad-leaved Chinese *Salisburia* (Maiden-hair tree), or the curious two-leaved African Welwitschia. A very interesting genus is that of Cordaites. It had a straight trunk, sometimes sixty to seventy feet long, and was clothed with long strap-shaped leaves.

5. In the early part of the **Reptilian Age** (during the *Triassic* and *Jurassic* eras), the flora differed from the preceding age mainly in the enormous development of the Gymnosperms. These, the Cycads (appearing for the first time) and Conifers, together with the Tree-ferns, constituted the forest vegetation. There were also new species of Ferns and Equiseta. Diatoms and Desmids were abundant. But it is in the latter part of this age (during the *Cretaceous* era)

that the greatest change took place. The **Angiosperms** for the first time made their appearance, and field and forest began to assume a somewhat modern aspect. Such genera as the Oaks, Maples, Willows, Sassafras (Fig. 133), Dogwood, Hickory, Beech, Poplar, Liriodendron, Walnut, Sycamore, Laurel, etc., were each represented by one or more species.

FIG. 133.

FIG. 134.

The groups to which the Angiosperms belonged are as follows:

(*a*) *Monocotyls.*—Gramineæ, Cyperaceæ, Liliaceæ, Naiadaceæ, Scitamineæ, Dioscoreaceæ, and Palmaceæ.

(*b*) *Dicotyls.*—Salicaceæ, Fagaceæ, Lauraceæ, Urticaceæ, Ericaceæ, Ebenaceæ, Platanaceæ, Araliaceæ, Rosaceæ, Sapotaceæ and Magnoliaceæ.

6. In the **Cenozoic** time, which includes the *Tertiary* and *Quaternary* periods, the vegetation was decidedly more modern than in the preceding. In the Tertiary period nearly all the genera of the Palms, Grasses, and Dicotyls (Fig. 134) were the same as now, though most of the species are extinct. The Diatoms, too, existed in great abundance; and immense deposits consisting wholly of their siliceous shells or valves (frustules), are found in the Tertiary period. The celebrated Bohemian deposit in Europe is fourteen feet thick, and Ehrenberg estimated that every cubic inch of the material contains forty billion shells. The Richmond deposit in Virginia is

thirty feet thick, and many miles in extent. Still more extensive deposits are found in the West. In the Quaternary period the plants were almost wholly identical with those now living.

7. The present time exhibits a vegetation of higher morphological and physiological development than in the preceding ages; besides, the species are exceedingly numerous. All countries are not yet fully explored and there is no means, therefore, of knowing the number of species of plants which exist. Even in countries long known new species, especially of the lower plants, are constantly being found. It is certain that there are at least nearly three hundred thousand species. The great majority are limited to a more or less restricted area of the globe, yet each species manifests a disposition to spread itself as widely as possible. This may, in fact, be regarded as a further expression of the fundamental instinct of race-perpetuation, which naturally follows the primary instinct of self-preservation; that is, as in the earlier stages of the individual the struggle is for existence, necessitated by the environment; so later the effort, equally imperative, is to perpetuate the kind. The adaptations for migration of the species are seen plainly in the contrivances for wide dispersion of the seed, an account of which has been given in the latter part of Chapter IX.

8. The barriers to indefinite **migration** of the species are high mountain ranges, great bodies of water, character of the soil, amount and distribution of rain-fall, variation in temperature, and in case of parasites, absence of the proper host-plants. Some species are able to migrate over considerable elevations of land, a few travel over wide areas of water, but these are impassable barriers to the great majority of plants. Some species thrive only on calcareous soils, others are confined to arenaceous or other kinds. Aquatic and terrestrial plants each demand and cannot transcend their proper habitat. Some terrestrial species are limited to sheltered and moist regions, others grow only in exposed situations. Many are peculiar to prairie regions, others inhabit deserts. The limits

determined by temperature are manifest. The tropics, the temperate and frigid zones, and the mountain sides having corresponding temperatures, have their peculiar species. The numerous Rusts, Smuts, Leaf-mildews, Blights, and other parasitic Fungi are necessarily limited to the regions in which their hosts grow.

9. In widely separated regions, but whose soil, climate and other conditions are similar, different species of plants generally occur. Exceptionally it may be found, however, that a given species occurs in two or more such regions, between which now are great distances and impassable barriers. The floras of the two regions must therefore have had a common origin. Recognizing that the geologic or past distribution of species has been an important factor in determining the geographical or present distribution, the area of the globe may be separated into four botanical divisions, namely: (1) North Extra-tropical, (2) Paleotropical, (3) Neotropical, and (4) Southern or Antarctic. Each of these divisions has been separated into regions; each region is divided into provinces and each province into zones.

10. The **North Extra-tropical** division coincides with the area of glacial action. Its southern limit is bounded by a line running through the northern part of Africa, crossing Arabia, passing along the shores of the Persian Gulf, thence extending northward above Afghanistan and India, following the south range of the Himalaya Mountains, passing through China and Japan (including most of the latter), then continuing north of Mexico and south of the Southern States, emerging between Florida and Cuba. Throughout this region in both the eastern and western hemispheres fossil plants have been found identical with those now living, for example Bald Cypress (*Taxodium distichum*). Several have received different names but cannot be separated from living species; for example *Sequoia langsdorfii* (fossil) is not separable from *Sequoia sempervirens* (the Redwood). And while such fossil species as *Carpinus grandis*, *Corylus mac-quarrii*, *Alnus kefersteinii*, do not wholly coincide with the living Water Beech (*Carpinus ameri-*

cana), Hazelnut (*Corylus avellana*), and Alder (*Alnus glutinosa*), the former nevertheless must be regarded as the immediate ancestors of the latter respectively.

11. The **regions** into which this division (North Extra-tropical) have been separated are as follows: (*a*) Arctic; (*b*) Subarctic or Coniferous; (*c*) Middle European and Ural-Caspian; (*d*) Central Asiatic; (*e*) Mediterranean; (*f*) Manchurian-Japanese; (*g*) Pacific North American; (*h*) Atlantic North American. These regions are divided into **provinces**; those for the Atlantic North American being the *Appalachian* and the *Prairie*. The first lies east of the Mississippi. It is pre-eminently a forest region, having numerous representatives of such genera as *Quercus*, *Juglans*, *Hicoria*, *Magnolia*, *Pinus*, *Juniperus*, etc. The other province (the Prairie) lying west of the Mississippi is covered with many species of grasses. The low characteristic ones belong to the genera *Bouteloua* (Mesquite grass), *Bulbilis* (Buffalo grass), etc. Farther westward and southward are found various species of Cactus, Yucca, Agave, etc.

12. The **Paleotropical** division includes Central and Southern Africa (except a part of Cape Colony), southern Asia, the northern and eastern coast-region of Australia, and all of the islands lying immediately northward. It is composed of the following regions: (*a*) West African; (*b*) Africo-Arabian; (*c*) Madagascar and Islands; (*d*) Indian; (*e*) Tropical Himalayan (a narrow area extending southward from the point where the Brahmaputra cuts through the Himalayas); (*f*) East Asiatic; (*g*) Malay; (*h*) Araucarian (eastern border of Australia), New Caledonian and the northern island of New Zealand; (*i*) Polynesian; (*j*) Sandwich Islands.

13. The **Neotropical** division includes Mexico, Central America and the greater part of South America—excluding the Chilian coast south of latitude 35 degrees, and Terra del Fuego. The regions into which it is divided are: (*a*) Mexican tablelands; (*b*) Tropical American (including the Provinces: West Indian, Sub-Andean or Panama with parts of Colombia and Venezuela, North Brazil-Guianan and South Brazilian),

(*c*) Andean. The **Southern or Antarctic** division includes the following: (*a*) Antarctic forest region (of South America); (*b*) New Zealand region; (*c*) Australian region; (*d*) Cape Colony region; (*e*) The Islands of Tristan d'Acunha, St. Helena, and Ascension.

CHAPTER XIII.

ECONOMIC BOTANY.

1. THE useful products furnished by the vegetable kingdom are extremely numerous. Only the more prominent can be briefly mentioned. Perhaps none occur more widely than the **Resins.** They are found in nearly all groups of plants, even in the mycelium of Fungi. Their occurrence is mostly in the cortical portions of plants, yet they have been found in all tissues except the cambium. The resins are hydrocarbons, being rich in carbon, containing but little oxygen and no nitrogen. They contain resinous acids, volatile oils, gums, carbonaceous substances, cellulose, tannin, etc. The color is usually between yellow and brown, but may be red, white or black. Resins arise by a metamorphosis of tissue, etc., or they are a product of secreting cells. **Gamboge** used extensively for coloring varnishes, etc., is a resin furnished by *Garcinia morella*, a small tree belonging to the Gamboge family (*Guttiferæ*). It occurs in Ceylon, Siam, Cambodia (or Cambogia, whence the name). The resin is obtained by making incisions in the stem, out of which it flows. **Asafœtida** is an exudation from the stems of two plants of the Parsley family (*Umbelliferæ*). These grow in Southwestern Asia.

Specimens of most of the vegetable products mentioned in this chapter can be obtained. They should not be used merely as illustrations (though highly desirable for such purpose), but careful examination of them accompanied by notes and drawings should be a part of the regular class-work.

2. The **Turpentines** of commerce come mainly from Europe and North America. In the former country the Firs (*Abies*) and Larch (*Larix europæa*) yield this oleo-resinous substance.

In North America it is obtained from the Balsam Fir (*Abies balsamea*), White Pine (*Pinus strobus*), Red Pine (*Pinus resinosa*), Loblolly or Old Field Pine (*Pinus tæda*), and Broom Pine (*Pinus palustris*). Turpentine is found both in the cortex and wood. The better kinds are thin and clear; those of poorer quality are thick and cloudy. They find extensive use in the manufacture of varnish, sealing-wax, soaps, etc. The finer kinds are used in medicine. That called Venetian turpentine is obtained from the European Larch. The finest of all turpentines is the **Canada Balsam,** from the Balsam Fir. Common resin (or *rosin*) is the mass remaining after the natural escape or removal by distillation, of the volatile oil from the turpentine. Wood after yielding resin is often used in the manufacture of tar, illuminating gas, creosote, paraffine and aniline. Other important resins are Balm of Gilead, Mastic, Sandarac, Damar, Gum Lac, Copal, etc.

3. **Gums** occur very commonly. They are homogeneous exudations from many trees, arising by a metamorphosis of tissue, or rarely by a chemical change of the starch. They are soluble (or soften) in water and are insoluble in alcohol. The color may be yellowish, brownish, reddish, seldom white or black. The powder is always white. Gums are carbo-hydrates, containing carbon, hydrogen and oxygen, but no nitrogen. They are of little or no dietetic value. For mucilage their use is very general, but the largest quantity is consumed in stiffening fabrics and producing a glazed surface upon them. Gums are often added to fluids to increase their density, so they will hold in suspension pigments or other added substances. The most important gum is that obtained from the species of *Acacia* (Bean family). The plants are generally small, spiny trees or shrubs, growing in Africa, Arabia and other countries, often forming vast forests. The gums from the different countries usually have different names, as Gum Arabic, Cape Gum, Gum Senegal, Australian Gum, etc. From plants belonging to the genus *Astragalus* (Bean family) of Greece, Asia Minor and Persia, Gum Tragacanth is obtained. It is softer than Gum Arabic, swells up in water, but is only partially soluble.

4. **Caoutchouc** has become, since the invention of the process of vulcanizing (impregnating with sulphur) a very important article, and is now used for a great variety of purposes. It occurs in the form of granules in the milky juice of many plants, as *Siphonia* (Spurge family), in Brazil; *Urceola* (Dogbane family), in East India; *Vahea* (Dogbane family), in Madagascar. Caoutchouc is a "non-conductor" of electricity, insoluble in water, not attacked by acids at ordinary temperatures, swells up in alcohol, oil of turpentine, carbon bisulphide, ether and benzine. Ebonite is harder, containing more sulphur. **Gutta percha** is not so widely distributed as Caoutchouc. It occurs in the milky juice of plants only of the family *Sapotaceæ*. Most of it is furnished by *Isonandra gutta*, a tree of India and the Sandwich Islands. It is not so elastic as Caoutchouc, but much like the latter, though more complex in composition. Gutta percha is used in immense quantities to cover submarine cables.

5. **Opium** is the dried milky juice from the sliced pods of the White Poppy (*Papaver somniferum*). The plant is cultivated extensively in Egypt, Asia Minor, Persia and India. Opium contains several alkaloids, the most important being *morphine*, *papaverine*, and *narcotine*. The inspissated juice from the leaves of several species of the genus **Aloe** (Iris family), especially *A. vulgaris* and *A. socotrina*, constitute the drug **Aloes**, used in medicine and dyeing. The plants grow in Africa; they have thick fleshy leaves and tall flowering spikes. **Palm oil** is expressed from the fruits of *Elæis guineensis* (Palm family) a small tree growing in Africa, the West Indies and Brazil. It is extensively used in the manufacture of candles and soap, and in lubricating machinery. The natives of the countries where this Palm grows use the oil for food. The Olive, *Olea europæa*, a small evergreen tree of the Ash family, cultivated extensively in the Mediterranean region, produces dark violet or black drupes from which **Olive oil** is obtained. Another important oil is expressed from flaxseed, usually called **Linseed oil**. It is a drying oil, used in the manufacture of printers' ink, varnishes, soaps, etc.

6. The Camphor tree, *Laurus camphora*, is an evergreen of Eastern Asia. It resembles the Linden tree, but is evergreen, and belongs to the Laurel family. The **Camphor** is obtained from the twigs by sublimation. It is used in pyrotechnics and in medicine. The **Starch** of commerce is derived from bulbs, tubers, seeds, etc. The most important starch-producing plants are the Potato, Wheat, Rice, Corn, the East Indian Arrow-root, and the West Indian Arrow-root. A plant, *Manihot utilissima* (Spurge family.), indigenous to tropical America, but cultivated in many tropical lands, furnishes the Brazilan Arrow-root, Cassava and Tapioca. The large fleshy parsnip-like root is poisonous in the natural state. It is peeled and washed carefully, thus removing the poisonous material; the ground mass is called **Cassava.** The starch is moistened, granulated by means of sieves and heated on metal plates to make **Tapioca.** The quantity of **Sugar** used annually is enormous; the largest portion is obtained from Sugar-cane and from the Sugar-beet. The Maple tree and Sorghum also furnish a considerable quantity.

7. The various vegetable **Fibres** used in the manufacture of fabrics, cordage, paper, etc., constitute a class of products of great importance. They may be vegetable *hairs*, as cotton, silk cotton, etc.; *woody strands* (fibro-vascular bundles) from Monocotyls, as New Zealand flax, Manila hemp, etc.; or they may be parts (the bast) of fibro-vascular bundles from Dicotyls, as Hemp, Flax, Jute, etc. Most fibres are white or whitish in color; others may be gray or yellowish. They are composed almost exclusively of cellulose; occasionally they are partially lignified, and then are brittle. For *cordage* (ropes, cables, strings) the fibres may be coarse but they must be strong and not break when bent at a sharp angle. Those for *cables* must, besides, be capable of absorbing tar. The fibres for *yarns* must be of considerable length, fineness and strength. They must be glossy, or possess the "spinning quality." For *paper* they must be thin and strong, and suitable for felting together when wet. A curly disposition so as to catch each other and become entangled, gives tenacity to the paper; this

is increased if the ends of the fibres are lacerated into numerous fibrils.

8. The most important of all fibres used in spinning is **Cotton.** It was cultivated in Egypt five hundred years before the Christian era, but was not known to the ancient Egyptians. In India it has been known from time immemorial. Now it is cultivated in nearly all warm regions of the globe. Cotton consists of hairs on the seeds of several species of *Gossypium*, Mallow family. The most important are *G. herbaceum*, *G. arboreum* and *G. hirsutum*. The climate, soil, mode of culture, etc. have an influence on the fibre (cotton), as well as on the habit of the plant. Each fibre is a single cell, sometimes an inch long, which is at first cylindrical but more or less flattened when dry. The cell-wall is thicker than in most hairs. The **silk-cotton** is from seeds of several species of *Bombax*, also of the Mallow family. The hairs have a lustrous appearance but are not very strong or durable. It is sometimes mixed with cotton but most commonly used in stuffing cushions, etc.

9. The fibre longest used in spinning, namely **Flax,** is the bast of *Linum usitatissimum*, a species of the Flax family (*Linaceæ*). It is a slender annual, growing from two to five feet high, and has small alternate, lanceolate leaves and blue flowers. "The use of flax reaches back to the very earliest periods of civilization, and it was most extensively and variously applied in the prehistoric lake dwellings of Switzerland, even in those of the Stone period. Flax was the material for making lines and nets for fishing and catching wild animals, cords for carrying the earthenware vessels and other heavy objects; in fact one can hardly imagine how navigation could be carried on, or the lake dwellings themselves be erected, without the use of the ropes and cords." (Keller.) Flax is extensively cultivated in many lands; other species are found in cultivation, but to a limited extent. In warm regions more seed and less fibre, and in colder regions more fibre and less seed are produced. The flax is harvested before the seeds are ripe, when the bast at the base

of the stem begins to turn yellow; later, lignification sets in, to the detriment of the fibre. The unripe seeds may be used for oil, but not for planting. The plants are pulled out of the ground and subjected to a process of retting, either by dew, cold or warm water, or steam, by means of which the bast is loosened from the stem, and more or less decomposed into fibres. The best flax is very lustrous. That which is lustreless is contaminated with cortical parenchyma. The bast cells of which it is composed have the walls so thick that the cavity is nearly closed.

10. The very important textile fibre, **Hemp**, consists of the bast of *Cannabis sativa*, a diœcious species of the Nettle family (*Urticaceæ*), growing six to ten feet high, having long pedate leaves, with five narrow leaflets, and inconspicuous flowers. It is supposed to be a native of the warm parts of Asia, and is found in cultivation in Africa, North America, Australia, and elsewhere. It has been used in Europe several hundred years. It must be harvested for the fibre before the maturity of the seed; the latter can then be used in obtaining oil. The pistillate plants when grown for the seed must be allowed to ripen. The process of retting is similar to that employed in the case of flax. The color is often white, but the gray is the best. It is lustrous. The cavity of the cell is about one-third of its diameter. The Hemp plant is used as an intoxicant for chewing and smoking by over three hundred millions of people. Its narcotic effect is due to a gum-resin existing in the leaves and flowers; it is called "hasheesh." The seeds of Hemp contain thirty-four per cent. of oil, most of which may be extracted by pressure. It is a drying oil, greenish at first, then becoming yellow, and is used in mixing paints, making soap, etc. China Grass, *Bœhmeria nivea* and *B. tenacissima*, perennial herbs, belonging to the Nettle family (*Urticaceæ*), have been cultivated in India since very early times, for their excellent fibre called **Ramie**. It cannot be readily separated from the epidermis and surrounding tissue. The bast-cells have a very large diameter. They are dirty green, whitish, yellowish or light brown, and are very tough and

strong. Ramie is used for cordage; in India it is extensively used for fishing-nets. The finest fibre, even rivalling flax in fineness and durability, is woven into cloth. Bœhmeria nivea is now cultivated in the Southern States and in California.

11. One of the most important vegetable fibres, namely **Jute**, is the bast of *Corchorus capsularis*, and other species, of the Linden family (*Tiliaceæ*). It is an annual herb, growing to a height of eight to twelve feet, bearing simple jagged leaves and small yellow flowers, extensively cultivated in India, China, Egypt, Guinea, etc. For the best growth there must be a hot, moist climate, with abundant rain-fall, and a rich alluvial soil. The plant is harvested while in flower, for if it is allowed to stand till in fruit, the quality of the bast is not good; as in the case of hemp, flax, etc., so here also the strength and flexibility decreases from the time of the appearance of the flowers till the ripening of the fruit, in consequence probably of lignification of the cells, which takes place during this time. The fibre is separated from the plant by retting (maceration). It is easily distinguished from flax and hemp by its silky lustre; it is also much more intensely colored by aniline. Fresh jute has but little color; it varies from whitish to yellowish; exposed to the atmosphere, and especially to dampness, it becomes deeply colored, as seen in that used for coffee-sacks, wool-sacks, etc. The walls of the jute cells vary much in thickness; and when examined in longitudinal sections, it is found that each individual cell has at one place thin, and at another place thick walls. Jute has been used since olden times, in those countries where it is indigenous, in the preparation of robes and fabrics. Only within the last half-century, however, has it come into extended use. From it is manufactured coarse cloth in great quantity, used for packing and transporting all manner of goods. Even carpets and cloth of considerable fineness are now made from it. It is sometimes woven with silk.

12. *Musa textilis* (family *Musaceæ*), a Monocotyl, is much like the Banana-tree in appearance, being fifteen to twenty feet high, and having dark-green leaves. It is cultivated on the

Moluccas, the Philippine Islands, etc. From it and other species of the same genus the **Manila hemp,** called also Siam hemp, Plantain fibre, and White rope, is obtained. The leaves contain fibres but they are not very strong, and are not used. Those of the stem or the trunk are obtained as follows: The tree when five or six inches in diameter is felled and subjected to a process of retting and then passed through iron combs. Manila hemp is used extensively for cordage; it is very useful for cables for ships on account of its durability in water. The old worn ropes are then used in the manufacture of paper.

13. Fibres from which **Paper** is manufactured must be obtainable in immense quantities; they must also be soft, fine, and readily bleached. Those most used are cotton, linen, hemp, jute, straw, wood, young Bamboo-trees, bast of Paper-mulberry, Esparto Grass, etc. The textile fibres are not used generally until the cloth into which they have been woven is worn out. The oldest paper made from straw is Chinese paper, made from rice-straw. Now, straw of all kinds (Wheat, Rye, Barley, Oats) is used. Wood must be a white, soft, fibrous kind. That from the Paper-mulberry, *Broussonetia papyrifera* (family *Urticaceæ*), a native of the islands of the Southern Ocean, is now extensively used in paper-making. The bast is removed from the tree in large, white, flexible pieces, and then separated into long, fine fibres, from which, in Japan, paper, flexible like cloth, is made; this is used for handkerchiefs, napkins, etc. The plant is now cultivated in many countries. The Alfa or Esparto Grass is also much used in paper-making. There are two species, *Stipa tenacissima* and *Lygeum spartum* (family *Gramineæ*). They grow wild on the high grounds of North Africa. The cells are remarkably firm and short, and manifest a tendency to curl. They have the merit over wood-pulp of absorbing printing-ink more rapidly.

14. The **Cork Oak,** *Quercus suber* (family *Fagaceæ*), is found in the southern part of Europe and the northern part of Africa. It has oval, dentate, evergreen leaves. The thick mass of cork

which it develops is removed periodically, and constitutes the cork of commerce. A corky layer or periderm begins to be developed when the tree is two or three years old. The first cork that is produced is very inferior, but after its removal good cork is yielded. When the tree is five years old, the worthless layer can be removed without injury to the *phellogen*, or cork-producing cambium. This is done by making vertical and horizontal incisions, reaching almost to the generating layer of cells, or phellogen, within; the bark is then carefully pried off. This process cannot be performed with safety during the active renewal of growth in the spring; it can be done, however, between May and October without in the least harming the phellogen, provided the latter is not exposed to rain. The layers become two-thirds to one inch (or more) thick, and are removed every eight or ten years. When the trees are fifteen years old, a valuable layer may be removed. Cork continues to be produced till the trees are one hundred or one hundred and fifty years old; that is best, however, which is removed from trees between fifty to one hundred years old. The cork that grows in warm regions is better than that produced in cold climates; and that from trees on the mountains is better than that from trees in swamps.

15. Of the various **Tanning barks** used in different countries none compare with those from several species of Oak (*Quercus*). The most valuable species in Europe are *Q. pedunculata* and *Q. sessiliflora*. These have for centuries supplied the tanners with bark, by the use of which leather of the best kind is made. The inner bark of the Cork Oak (*Q. suber*) contains much tannin and is used in Spain for tanning. The Oran or African Oak (*Q. coccifera*) yields considerable tannin and is extensively exported for tanners' use. In Russia one of the most important tanning materials is furnished by the Willows. In this country most of the bark used in tannery comes from the Oaks—especially the White, Red, Scarlet, Black, Burr and Chestnut Oaks; the Hemlock (Pine family), and Wattles, or species of *Acacia* (Bean family) growing in Australia, are now extensively used.

16. The bark of *Cinnamomum zeylonicum*, of the Laurel family, is the **Cinnamon** of commerce. The plant is cultivated in India, Ceylon, Sunda Islands, West Indies, and South America. It is a small tree, twenty to thirty feet high, with oblong-lanceolate leaves. The trees are topped, every one or two years, like Basket-willows, and thus from the main stem many shoots are produced; from these the bark is easily removed in the spring, after a rainy period, when the activity of the cells in the cambium zone is greatest. Circular incisions are made at considerable distances from each other, and connected by a longitudinal incision. The bark is then removed by the help of the knife-blade. When partially dry the outer bark is scraped off; the bark or bast is then whitish, but as soon as dry presents the peculiar cinnamon color. If vigorous growth takes place in November and December, the bark can be again removed, but it is inferior. The refuse parts, together with the leaves, are used in the manufacture of oil of cinnamon, of which the bark contains 0.5 to 1 per cent. This is used in perfumery. Cinnamon finds extensive use as a spice; it is also used in medicine.

17. Several arboreous species of the South American genus *Cinchona*, as *C. calisaya*, *C. lutea*, *C. micrantha* (Madder family), furnish the **Cinchona bark** of commerce, the most important febrifuge known. It is also called Peruvian or Jesuits' bark. The outer part of the bark of old trees is removed as worthless; the entire bark of young trees or stems is used. The taste of Cinchona bark is intensely bitter, but the odor is weak. Among the numerous constituents are found cellulose, gum, sugar, starch, mineral constituents (mostly calcic and sodic carbonate) and many alkaloids. Of the latter, *quinia* is the most important; it is crystallizable, slightly soluble in water, soluble in alcohol, ether and chloroform; forms crystallizable salts with several acids. The sulphate of quinia, or Quinine, fine, white, silky, is the form most used in medicine. The next most important alkaloid constituent is *cinchonia*, which is about one-half less powerful than quinia. Various

preparations of the bark and alkaloids are made, and used medicinally as tonics and febrifuges.

18. **Wood**, the lignified stems, trunks, and branches of Gymnosperms (as Pines, etc.) and of Dicotyls, is used in architecture, ship-building, manufacture of vehicles, machines, implements, tools, furniture, ornaments, in the construction of bridges, fences, for fuel, etc. A great variety as regards color, strength, hardness, weight, porosity, durability, flexibility, are offered by the numerous species of woody plants. Some of our most important kinds of wood or indigenous timber trees are the Pines, Cedars, Redwood, Larch, Cypress, the Maples, Yellow Poplar, Honey Locust, Ash, Elm, Walnut, Chestnut, Hickories, Oaks, etc. Of foreign woods very important kinds found in commerce are Mahogany, Teak, Logwood, Brazil-wood, Red Sandal-wood, Boxwood, Ebony, etc.

19. *Curcuma longa*, a member of the Ginger family (*Zingiberaceæ*), is a native of Southern Asia, and is cultivated in India, Ceylon, Java, the West Indies, etc. Many different varieties have arisen under cultivation. They furnish the dye **Turmeric** in varying qualities. Turmeric (the yellow rhizome) is used in dyeing paper, wood and leather, and in coloring varnishes. It is much used in cookery, also in medicine. Turmeric paper, or unsized paper colored with a decoction of turmeric, is used in the chemical laboratory as a test for free alkali and acid. The Ginger plant, *Zingiber officinale* (family *Zingiberaceæ*), has been cultivated from time immemorial in India, in which country it is probably indigenous. It has recently come into cultivation in the West Indies and other tropical lands. It is an annual plant, with stems two or three feet high and leaves two or three inches long. The flowers are yellowish, and have an aromatic odor. The rhizome, powdered or otherwise, constitutes the **Ginger** of commerce. It contains volatile oil, starch, resin, etc. The sweet flag (*Acorus calamus*) has a fleshy aromatic rhizome called **Calamus**, well known and extensively used in Europe, Asia and North America. It grows in marshy or wet places.

20. The **Tea** plant, *Camellia chinensis* (family *Turnstrœmi-*

aceæ), has been cultivated for ages, and its native country is now no longer known. It is an evergreen shrub or very small tree, generally kept dwarf by pruning. The branches are very numerous, bearing elliptical or lanceolate leaves, which are two or three inches in length. The plants yield a small picking when three years old, but the maximum yield is in the eighth or tenth year. The processes of heating, airing, pressing, rolling, and drying are continued alternately till the desired changes take place in the leaves. The rapidity of this operation and the age of the leaves when picked determine the quality of the tea; young leaves, quickly prepared, give the best green teas. Old leaves subjected to a less rapid operation yield the black teas. Among the many constituents found by analysis, may be mentioned carbo-hydrates, albuminoids, tannin, caffein, aromatic oil, and mineral substances. Tea (an infusion of the leaves) has been used by the Chinese as an exhilarating beverage for centuries. Recently it has found its way into nearly all countries, and is used almost universally now by rich and poor.

21. **Tobacco,** *Nicotiana tabacum* (Nightshade family) was used by the Indians long before America was discovered by Columbus. In old Indian mounds smoking utensils have been found. It was taken to Spain by De Oviedo in the early part of the sixteenth century, later to France by Nicot, and to Germany by Gessler. Although sometimes prohibited by edicts, smoking soon became general all over Europe, passed into other countries, and finally found its way into Australia; and tobacco unfortunately is now "used by all civilized nations of the globe." It is a native of South America, but cultivated in many countries, being easily acclimated. The plant grows from three to six feet high, and bears long, broad, soft, hairy leaves. The flowers are terminal, rose-color, and showy. The culture, soil and climate affect the quality of the tobacco very much.

22. "The most beautiful, the most elegant, the most precious of all trees" is the *Caryophyllus aromaticus*, which produces the **Cloves** of commerce. It is a member of the Pink family, and grows to the height of forty feet. The trunk is

straight; the bark is smooth, and of a light olive color; the crown of the tree forms a perfect cone. The Clove-tree is a native of the Moluccas and New Guinea, and cultivated in many tropical lands. The cloves are the unexpanded flowers or flower buds; these, attached to their pedicels, are collected when they contain the most and best oil, which amounts to from sixteen to twenty-five per cent. They also contain a large amount of tannin. When dry, the stems are broken off, and from them about four per cent. of oil is obtained by distillation. The oil is slightly yellowish or brownish. It is found in drops in intercellular spaces, in all the tissues. Cloves are extensively used as a spice and also in medicine. The oil is used in perfumery and in flavoring liquors.

23. The **Coffee** plant, *Coffea arabica* (family *Rubiaceæ*), is indigenous to Abyssinia, and within a few hundred years has come into cultivation in many other countries. It is an evergreen tree, eighteen to twenty feet high; it has white, papery bark, and slender horizontal branches. The leaves are smooth and shining, six inches long, and nearly one-half as wide. The evanescent flowers are in axillary clusters; they are pure white and have a rich, fragrant odor. The fruit is a cherry-like berry becoming a dark-red color as it ripens; the pulp within is yellow and encloses two plano-convex seeds, the Coffee of commerce. The use of coffee was prohibited by the Koran, it being regarded as an intoxicant. Coffee-houses were opened in Constantinople in the sixteenth century, and were met with violent hostility on the part of ecclesiastics. The first coffee-house was opened in London in 1652; the use of coffee met with opposition here also. At about the same time cocoa and tea were introduced. Coffee is now used in immense quantities.

24. The **Chocolate-tree** of Tropical America, *Theobroma cacao* (family *Sterculiaceæ*), is a small tree sixteen to twenty feet high, having large oblong leaves, thin and papery. The small flowers are followed by the elongated, ribbed fruits, each containing fifty or more oily seeds, arranged in five vertical rows. The tree blooms almost constantly; the fruits are collected twice a year. The almost colorless seeds when dried become

reddish-brown. The constituents of the seeds are cocoa-butter thirty-four to fifty-six per cent; the alkaloid *theobromine* (which imparts the bitter taste), sugar, cellulose, starch, and albuminoids. The seeds are used in the manufacture of butter of cocoa (used in perfumery) and of chocolate and cocoa. The seeds are roasted, then ground into a paste; to this are added vanilla, sugar, etc., forming chocolate, or without these various ingredients it is cocoa. The Vanilla plant (*Vanilla planifolia*) is a member of the Orchid family. It is an epiphyte, growing on trees in tropical America, now cultivated in India, East Indies, and elsewhere. It has thick, laurel-like leaves and inconspicuous flowers. The fruit is a fleshy capsule five or ten inches long; it is gathered before maturity, wrapped in wool, heated, and then exposed. This process is repeated till the fruit is dry; the odor and the brown color in the meantime become fully developed. Upon analysis the following constituents have been found: tannic acid, resin, fat, wax, gum, sugar, and an aromatic substance, namely, *vanillin*. The flowers of the Vanilla plant when cultivated out of its native country must be artificially pollinated. It is propagated by attaching scions to trees, which produce fruit after three years, and continue to bear thirty to forty years. Its culture is carried on in connection with the culture of the Chocolate tree, on which the Vanilla plant grows.

25. The various plants furnishing important and indispensable foods and medicines are extremely numerous. The **Cereals** belong to the Grass family (*Gramineæ*). As furnishing food for man and animals and other useful products, this large family of plants ranks first in importance. The Palm family ranks second for the importance of its products. In the countries in which the various species grow, the fruits (and the other products) are extensively used. Many kinds are exported, as dates, cocoanuts, etc. A large number of our commonest fruits are furnished by the Rose family; many also are obtained from the Bean family, the Mustard family, the Parsley family, the Nightshade family, the Orange family, the Banana family, and many others.

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