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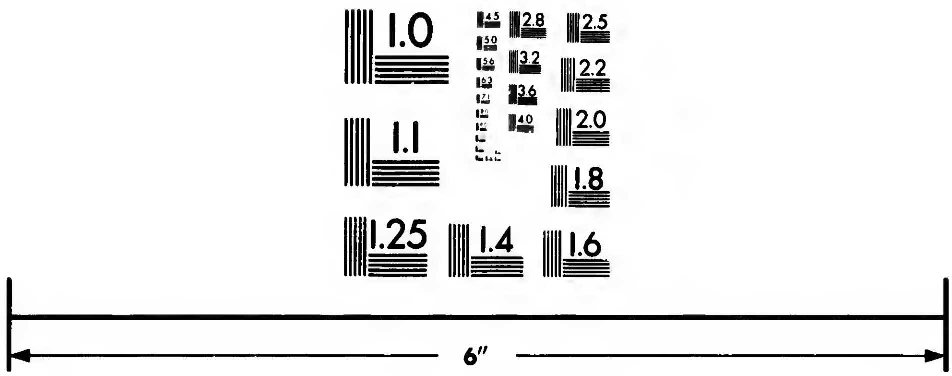

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W. J. Gage & Co.'s Educational Series.

THE ELEMENTS

OF

STRUCTURAL BOTANY

WITH SPECIAL REFERENCE TO THE STUDY

OF

CANADIAN PLANTS;

TO WHICH IS ADDED

A SELECTION OF EXAMINATION PAPERS.

BY

H. B. SPOTTON, M.A., F.L.S.,
HEAD MASTER OF BARRIE COLLEGIATE INSTITUTE.

REVISED EDITION.

With many Illustrations by the Author and others.

W. J. GAGE AND COMPANY,
TORONTO.

PREFACE TO FIRST EDITION.

The work, of which the present little volume forms the first part, has been undertaken, at the suggestion of several eminent educationists, to supply a palpable want. The works on Botany, many of them of great excellence, which have found their way into this country, have been prepared with reference to climates differing, in some cases, very widely from our own. They consequently contain accounts of many plants which are entirely foreign to Canada, thus obstructing the search for descriptions of those which happen to be common to our own and other countries ; and, on the other hand, many of our Canadian species are not mentioned at all in some of the Classifications which have been in use. It is believed that the Classification which is to form the second part of this work will be found to contain all the commonly occurring species of the Provinces whose floras it is designed to illustrate, without being burdened with those which are either extremely rare or which do not occur in Canada at all.

The present part is designed to teach the Elements of Structural Botany in accordance with a method which is believed to be more rational than that commonly adopted; and it will be found to supply all that is requisite for passing the examinations for Teachers' Certificates of all grades, as well as any others demanding an elementary knowledge of the subject. It contains familiar descriptions of common plants, illustrating the chief variations in plant-structure, with a view to laying a foundation for the intelligent study of Systematic Botany with the aid of the second part ; then follow a few lessons on Morphology ; and the Elements of

Vegetable Histology are treated of in as simple and brief a manner as was thought to be consistent with the nature of the subject.

The Schedules, the use of which is very strongly recommended, were devised by the late Professor Henslow, of Cambridge University, to fix the attention of pupils upon the salient points of structure. They will be found invaluable to the teacher as tests of the accuracy of his pupils' knowledge. The cost of striking off a few hundred blanks of each sort would be very trifling, and not worth considering in view of the resulting advantages.

The wood-cuts are from drawings from living specimens, except in two or three instances where assistance was derived from cuts of well-known excellence in standard works on Botany. It need hardly be said that the engravings are not in any sense intended to take the place of the living plants. They are designed chiefly to assist in the examination of the latter; and whilst it is hoped that they may be of service to those who may desire to read the book in the winter season, it is strongly urged upon teachers and students not to be satisfied with them as long as the plants themselves are available.

The works most frequently consulted in the preparation of the text are those of Hooker, Gray, Bentley, and Oliver.

Finally, the Author looks for indulgence at the hands of his fellow-teachers, and will be glad to receive suggestions tending to increase the usefulness of the work, and to extend a taste for what must ever be regarded as one of the most refining as well as one of the most practically useful of studies.

September, 1879.

PREFACE TO REVISED EDITION.

The re-arrangement of the course of study in Botany for Teachers' Certificates and for Junior Matriculation has afforded an opportunity for revising and, it is hoped, improving the present text-book, to which so kind a reception was accorded on its first appearance some years ago.

The principal feature of the new curriculum is the addition of certain Cryptogamous types. These are necessarily somewhat more difficult of study than the Phanerogams, because their characteristics cannot be satisfactorily made out without employing high powers of the microscope; but it is hoped that the numerous illustrations which accompany the text, and which have been gathered from various sources, will materially assist the student in this part of the work.

The chapter relating to minute structure has been rewritten, and, as will be seen, considerably extended. Though it is still but a sketch, it is hoped that it will serve a useful purpose in paving the way for the fuller study of the anatomy and physiology of plants with the aid of advanced works.

Other changes and additions have also been made, chiefly in the chapter on Morphology.

The writer need hardly add that in preparing this revision he has laid under contribution the various text-books of recognized merit which have come within his reach, and that beyond the mere presentation of the subject he lays no claim to originality.

Barrie, August, 1887.

TABLE OF COMMON PLANTS EXAMINED.

PHANEROGAMS.

Buttercup, Hepatica, Marsh-Marigold	representing	Ranunculaceæ.
Shepherd's Purse	"	Cruciferæ.
Round-leaved Mallow	"	Malvaceæ.
Garden Pea.	"	Leguminosæ.
Great Willow-herb............	"	Onagraceæ.
Sweet Brier, Strawberry, Crab-Apple, Cherry, Raspberry	"	Rosaceæ.
Water-Parsnip.................	"	Umbelliferæ.
Dandelion	"	Compositæ.
Catnip.........................	"	Labiatæ.
Cucumber......................	"	Cucurbitaceæ.
Oak............................	"	Cupuliferæ.
Willow........................	"	Salicaceæ.
Maple	"	Sapindaceæ.
Dog's-tooth Violet	"	Liliaceæ.
Iris	"	Iridaceæ.
Orchis.........................	"	Orchidaceæ.
Indian Turnip, Calla..........	"	Araceæ.
Timothy, Red-top, Meadow-Grass, Chess, Couch Grass, Old-witch Grass, Barnyard Grass, Foxtail	"	Gramineæ.
White Pine, Ground Hemlock	"	Coniferæ.

CRYPTOGAMS.

Polypody......................	representing	Ferns.
Common Club-Moss............	"	Lycopods.
Common Horsetail	"	Horsetails.
Hair-Moss.....................	"	Mosses.
Marchantia polymorpha........	"	Liverworts.
Parmelia parietina............	"	Lichens.
Common Mushroom............	"	Mushrooms.
Chara fragilis.................	"	The Charas.

CONTENTS.

THE ELEMENTS

OF

STRUCTURAL BOTANY.

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1. The study of Botany is commonly rendered unattractive to the beginner by the order in which the parts of the subject are presented to him. His patience becomes exhausted by the long interval which must necessarily elapse before he is in a position to do any practical work for himself. In accordance with the usual plan, some months are spent in committing to memory a mass of terms descriptive of the various modifications which the organs of plants undergo; and not until the student has mastered these, and perhaps been initiated into the mysteries of the fibro-vascular system, is he permitted to examine a plant as a whole. In this little work, we purpose, following the example of some recent writers, to reverse this order of things, and at the outset to put into the learner's hands some common plants, and to lead him, by his own examination of these, to a knowledge of their various organs—to cultivate, in short, not merely his memory, but also, and chiefly, his powers of observation.

It is desirable that the beginner should provide himself with a magnifying glass of moderate power for examining the more minute parts of specimens; a sharp penknife for dissecting; and a couple of fine needles, which he can himself insert in convenient handles, and which will be found of great service in separating delicate parts, and in impaling fine portions for examination with the aid of the lens.

CHAPTER I.

EXAMINATION OF A BUTTERCUP.

2. To begin with, there is no plant quite so suitable as our common Buttercup. This plant, which has conspicuous yellow flowers, may be found growing in almost every moist meadow. Having found one, take up the whole plant, loosening the soil a little, so as to obtain as much of the Root as possible. Wash away the earth adhering to the latter part, and then proceed to examine your specimen. Beginning with the **Root** (Fig. 1), the first noticeable thing is that it is not of the same colour as the rest of the plant. It is

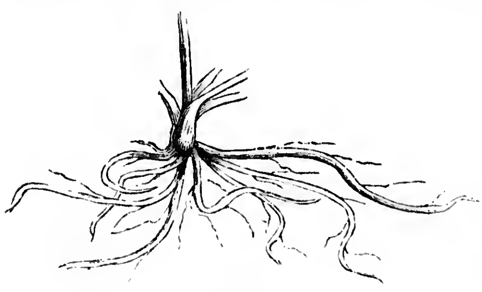

Fig. 1

Fig. 1.—Fibrous Root of Buttercup.

nearly white. Then it is not of the same *form* as the part of the plant above ground. It is made up of a number of thread-like parts which spread out in all directions, and if you examine one of these threads through your magnifying glass, you will find that from its surface are given off many finer threads, called *rootlets.* These latter are of great importance to the plant; it is largely by means of their tender extremities, and the parts adjacent to these, that it imbibes the nutritious fluids contained in the soil.

Whilst you are looking at these delicate rootlets, you may perhaps wonder that they should be able to make their way through the soil, but how they do this will be apparent to you if you examine the tip of one of them with a microscope of considerable power. Fig. 2 represents such a tip highly magnified. It is to be observed that the growth of the rootlet does not take place at the very extremity, but immediately behind it. The extreme tip consists of harder and firmer matter than that behind, and is in fact a sort of cap or thimble to protect the growing part underneath. As the rootlets grow, this little thimble is pushed on first through the crevices of the soil, and, as you may suppose, is soon worn away on the outside, but it is as rapidly renewed by the rootlet itself on the inside.

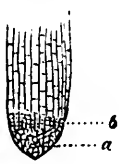

Fig. 2.

Another difference between the root and the part above ground you will scarcely have failed to discover: the root has no leaves, nor has it any buds.

You may describe the root of the Buttercup as *fibrous.*

Fig. 2.—Extremity of rootlet; *a*, the harder tip; *b*, the growing portion behind the tip.

Fig. 3.

3. Let us now look at the **Stem** (Fig. 3). It is upright, pretty firm, coloured green, and leaves spring from it at intervals. As there is scarcely any appearance of wood in it, we may describe it as *herbaceous.* At several points along the main stem branches are given off, and you will observe that immediately below the point from which every branch springs there is a leaf on the stem. The angle between the leaf and the stem, on the upper side is called the *axil* of the leaf (*axilla*, an armpit), and it is a rule to which there are scarcely any exceptions, that branches can only spring from the axils of leaves.

The stem and all the branches of our plant terminate, at their upper extremities, either in flowers or in flower-buds.

4. Let us now consider the **Leaves.** A glance will show you that the leaves of this plant are not all alike. Those at the lower end of the stem have long stalks (Fig. 4), which we shall henceforward speak of as *petioles.* Those a little higher up have petioles too, but they are not

Fig. 3.—Stem of Buttercup.

quite so long as the lower ones, and the highest leaves have no petioles at all. They appear to be sitting on the stem, and hence are said to be *sessile*. The lowest leaves of all, as they seem to spring from the root, may be described as *radical*, whilst the higher ones may be called *cauline* (*caulis*, a stem). The broad part of a leaf is its *blade*. In the plant we are now examining, the blades of the leaves are almost divided into distinct pieces, which are called *lobes*, and each of these again is more or less deeply *cut*. Both petioles and blades of our leaves are covered with minute hairs, and so are said to be *hairy*.

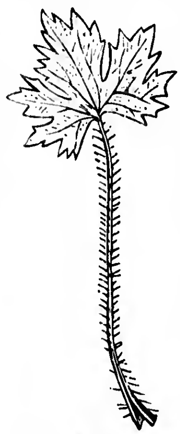

Fig. 4.

Hold up one of these leaves to the light, and you will observe that the veins run through it in all directions, forming a sort of net-work. The leaves are therefore *net-veined*.

The points along the stem from which the leaves arise are called *nodes*, and the portions of stem between the nodes are called *internodes*.

5. Let us next examine the **Flowers**. Each flower in our plant is at the end either of the stem or of a branch of the stem. The upper portions of the stem and its branches, upon which the flowers are raised, are called the *peduncles* of the flowers.

Fig. 5.

Take now a flower which has just opened. Beginning at the outside, you will find five little spreading leaves, somewhat yellowish

Fig. 4.—Radical leaf of Buttercup.
Fig. 5.—Flower of Buttercup, from the back.

in colour. Each of these is called a *sepal*, and the five together form the **calyx** of the flower. If you look at a flower which is a little older, you will probably not find any sepals. They will have fallen off, and for this reason they are said to be *deciduous*. So, in like manner, the leaves of most of our trees are deciduous, because they fall at the approach of winter. You will find that you can pull off the sepals one at a time, without disturbing those that remain. This shows that they are not connected together. They are therefore said to be *free*, and the calyx is described as *polysepalous*.

Inside the circle of sepals there is another circle of leaves, usually five in number, bright yellow in colour, and much larger than the sepals. Each of them is called a *petal*, and the five together form the **corolla** of the flower. Observe carefully that each petal is not inserted in front of a sepal, but in front of the space between two sepals. The petals can be removed one at a time like the sepals. They, too, are free, and the corolla is *polypetalous*. If you compare the petals with one another, you will see that they are, as nearly as possible, alike in size and shape. The corolla is therefore *regular*.

6. We have now examined, minutely enough for our present purpose, the calyx and corolla. Though their divisions are not coloured green, like the ordinary leaves of the plant, still, from their general form, you will have no difficulty in accepting the statement that the sepals and petals are in reality *leaves*. It will not be quite so apparent that the parts of the flower which still remain are also only modifications of the same structure. But there is good evidence that this is the case. Let us, however, examine these parts that remain. There is

first a large number of little yellow bodies, each at the top of a little thread-like stalk. Each of these bodies, with its stalk, is called a **stamen**. The little body itself is the *anther*, and the stalk is its *filament*. Your magnifying glass will show you that each anther consists of two oblong sacs, united lengthwise, the filament being a continuation of the line of union (Fig. 7).

Fig. 6.

If you look at a stamen of a flower which has been open some time, you will find that each anther-cell has split open along its outer edge, and has thus allowed a fine yellowish dust to escape from it (Fig. 8). This dust is called *pollen*. A powerful magnifier will show this pollen to consist of grains having a distinct form.

Fig. 7.

Fig. 8.

As the stamens are many in number, and free from each other, they are said to be *polyandrous*.

7. On removing the stamens there is still left a little raised mass (Fig. 9), which, with the aid of your needle, you will be able to separate into a number of distinct pieces, all exactly alike, and looking something like unripe seeds. Fig. 10 shows one of them very much magnified, and cut through lengthwise. These little bodies, taken separately, are called *carpels*. Taken together, they form the **pistil**. They are hollow, and each of them contains, as the figure shows, a

Fig. 9.

Fig. 10.

Fig. 6.—Section of a flower of Buttercup.
Fig. 7.—Stamen of Buttercup.
Fig. 8.—The same, showing longitudinal opening of the anther.
Fig. 9.—Head of carpels of Buttercup.
Fig. 10.—A single carpel cut through lengthwise to show the ovule.

little grain-like substance attached to the lower end of its cavity. This substance, in its present condition, is the *ovule*, and later on becomes the *seed*.

You will notice that the carpel ends, at the top, in a little bent point, and that the convex edge is more or less rough and moist, so that in flowers whose anthers have burst open, a quantity of pollen will be found sticking there. This rough upper part of the carpel is called the *stigma*. Fig. 11 shows a stigma greatly magnified. In many plants the stigma is raised on a stalk above the ovary. Such a stalk is called a *style*. In the Buttercup the style is so short as to be almost suppressed. When the style is entirely absent, the stigma is said to be sessile. The hollow part of the carpel is the *ovary*.

Fig. 11.

In our plant the pistil is not connected in any way with the calyx, and is consequently said to be *free* or *superior*, and, as the carpels are not united together, the pistil is said to be *apocarpous*.

8. Remove now all the carpels, and there remains nothing but the swollen top of the peduncle. This swollen top is the *receptacle* of the flower. To it, in the case of the Buttercup, all four parts, calyx, corolla, stamens, and pistil, are attached. When a flower has all four of these parts it is said to be *complete*.

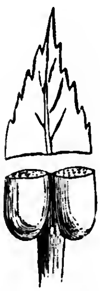

Fig. 12.

9. Let us now return to our statement that the structure of stamens and pistils is only a modification of leaf-structure generally. The stamen

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Fig. 11.—Stigma of Buttercup with adhering pollen-grains; highly magnified.
Fig. 12.—Diagram to show leaf-structure of a stamen.

looks less like a leaf than any other part of the flower. Fig. 12 will, however, serve to show us the plan upon which the botanist considers a stamen to be formed. The anther corresponds to the leaf-blade, and the filament to the petiole. The two cells of the anther correspond to the two halves of the leaf, and the cells burst open along what answers to the margin of the leaf.

10. In the case of apocarpous pistils, as that of the Buttercup, the botanist considers each carpel to be formed by a leaf-blade doubled lengthwise until the edges meet and unite, thus forming the ovary. Fig. 13 will make this clear.

11. There are many facts which support this theory as to the nature of the different parts of the flower. Suffice it to mention here, that in the white Water-Lily,

Fig. 13.

in which there are several circles of sepals and petals, it is difficult to say where the sepals end and the petals begin, on account of the gradual change from one set to the other. And not only is there a gradual transition from sepals to petals, but there is likewise a similar transition from petals to stamens, some parts occurring which are neither altogether petals, nor altogether stamens, but a mixture of both, being imperfect petals with imperfect anthers at their summits. We can thus trace ordinary leaf-forms, by gradual changes, to stamens.

We shall then distinguish the leaves of plants as *foliage-leaves* and *flower-leaves*, giving the latter name exclusively to the parts which make up the flower, and the former to the ordinary leaves which grow upon the stem and its branches.

Fig. 13.—Diagram to illustrate the leaf-structure of the carpel.

12. You are now to try and procure a Buttercup whose flowers, or some of them, have withered away, leaving

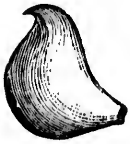


Fig. 14.

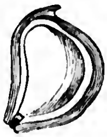


Fig. 15.

only the head of carpels on the receptacle. The carpels will have swollen considerably, and will now show themselves much more distinctly than in the flower which we have been examining. This is owing to the growth of the ovules, which have now become seeds. Remove one of the carpels, and carefully cut it through the middle lengthwise. You will find that the seed almost entirely fills the cavity. (Figs. 14 and 15.)


Fig. 16.

This seed consists mainly of a hard substance called *albumen*, enclosed in a thin covering. At the lower end of the albumen is situated a very small body, which is the *embyro*. It is this which developes into a new plant when the seed germinates.

13. We have seen, then, that our plant consists of several parts:

(1). **The Root.** This penetrates the soil, avoiding the light. It is nearly white, is made up of fibres, from which numbers of much finer fibres are given off, and is entirely destitute of buds and leaves.

(2). **The Stem.** This grows upward, is coloured, bears foliage-leaves at intervals, gives off branches from the axils of these, and bears flowers at its upper end.

(3). **The Leaves.** These are of two sorts: *Foliage-leaves* and *Flower-leaves*. The former are sub-divided

Fig. 14.—Ripe carpel of Buttercup.
Fig. 15.—Section of same.
Fig. 16.—Section of seed showing the small embryo. All much magnified.

into *radical* and *cauline*, and the latter make up the flower, the parts of which are four in number, viz.: **calyx, corolla, stamens,** and **pistil.**

It is of great importance that you should make yourselves thoroughly familiar with the different parts of the plant, as just described, before going further, and to that end it will be desirable for you to review the present chapter carefully, giving special attention to those parts which were not perfectly plain to you on your first reading.

In the next chapter, we shall give a very brief account of the *uses* of the different parts of the flower. If found too difficult, the study of it may be deferred until further progress has been made in plant-examination.

CHAPTER II.

FUNCTIONS OF THE ORGANS OF THE FLOWER.

14. The chief use of the calyx and corolla, or *floral envelopes*, as they are collectively called, is *to protect the other parts of the flower*. They enclose the stamens and pistil in the bud, and they usually wither away and disappear shortly after the anthers have shed their pollen, that is, as we shall presently see, as soon as their services as protectors are no longer required.

15. The corollas of flowers are usually bright-coloured, and frequently sweet-scented. There is little doubt that these qualities serve to attract insects, which, in search

of honey, visit blossom after blossom, and, bringing their hairy limbs and bodies into contact with the open cells of the anthers, detach and carry away quantities of pollen, some of which is sure to be rubbed off upon the stigmas of other flowers of the same kind, subsequently visited.

16. The essential part of the stamen is the anther, and the purpose of this organ is to produce the pollen, which, as you have already learned, consists of minute *grains*, having a definite structure. These little grains are usually alike in plants of the same kind. They are furnished with two coats, the inner one extremely thin, and the outer one much thicker by comparison. The interior of the pollen-grain is filled with liquid matter. When a pollen-grain falls upon the moist stigma it *begins to grow* in a curious manner (Fig. 17). The inner coat pushes its way through the outer one, at some weak point in the latter, thus forming the beginning of a slender tube. This slowly penetrates the stigma, and then extends itself downwards through the style, until it comes to the cavity of the ovary. The liquid contents of the pollen-grain are carried down through this tube, which remains closed at its lower end, and the body of the grain on the stigma withers away.

Fig. 17.

The ovary contains an ovule, which is attached by one end to the wall of the ovary. The ovule consists of a kernel, called the *nucleus*, which is usually surrounded by two coats, through both of which there is a minute opening to the nucleus. This opening is called the *micropyle*, and is

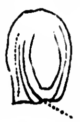


Fig 18.

Fig. 17.—Pollen-grain developing a tube.
Fig. 18 —Section of an ovule, showing central nucleus coats, and micropyle.

always to be found at that end of the ovule which is not attached to the ovary. (Fig. 18, *m.*)

About the time the anthers discharge their pollen, a little cavity, called the *embryo-sac*, appears inside the nucleus, near the micropyle. The pollen-tube, with its liquid contents, enters the ovary, passes through the micropyle, penetrates the nucleus, and attaches itself to the outer surface of the embryo-sac. Presently the tube becomes empty, and then withers away, and, in the meanwhile, a minute body, which in time developes into the embryo, makes its appearance in the embryo-sac, and from that time the ovule may properly be called a seed.

17. In order that ovules may become seeds, it is always essential that they should be *fertilized* in the manner just described. If we prevent pollen from reaching the stigma —by destroying the stamens, for instance—the ovules simply shrivel up and come to nothing.

Now it is the business of the flower to produce seed, and we have seen that the production of seed depends mainly upon the stamens and the pistil. These organs may consequently be called the *essential organs* of the flower. As the calyx and corolla do not play any *direct* part in the production of seed, but only protect the essential organs, and perhaps attract insects, we can understand how it is that they, as a rule, disappear early. Their work is done when fertilization has been accomplished.

Having noticed thus briefly the part played by each set of floral organs, we shall now proceed to the examination of two other plants, with a view to comparing their structure with that of the Buttercup.

CHAPTER III.

EXAMINATION OF HEPATICA AND MARSH-MARIGOLD—RESEMBLANCES BETWEEN THEIR FLOWERS AND THAT OF BUTTERCUP.

18. **Hepatica.** You may procure specimens of the Hepatica almost anywhere in rich dry woods, but you will not find it in flower except in spring and early summer. It is very desirable that you should have the

Fig. 19.

plant itself, but for those who are unable to obtain specimens, the annexed engravings may serve as a substitute.

Fig. 19.—Anemone Hepatica.

Beginning, then, at the root of our new plant, you see that it does not differ in any great measure from that of the Buttercup. It may, in like manner, be described as *fibrous.*

The next point is the stem. You will remember that in the Buttercup the stem is that part of the plant from which the leaves spring. Examining our Hepatica in the light of this fact, and following the petioles of the leaves down to their insertion, we find that they and the roots appear to spring from the same place—that there is, apparently, *no stem.* Plants of this kind are therefore called *acaulescent,* that is, *stemless,* but it must be carefully borne in mind that the absence of the stem is only apparent. In reality there is a stem, but it is so short as to be almost indistinguishable.

The leaves of the Hepatica are, of course, all *radical.* They will also be found to be *net-veined.*

19. The **Flowers** of the Hepatica are all upon long peduncles, which, like the leaves, appear to spring from the root. Naked peduncles of this kind, rising from the ground or near it, are called *scapes.* The flower-stalks of the Tulip and the Dandelion furnish other familiar examples.

Let us now proceed to examine the flower itself. Just beneath the coloured leaves there are three leaflets, which you will be almost certain to regard, at first sight, as sepals, forming a calyx. It will not be difficult, however, to convince you that this conclusion would be incorrect. If, with the aid of your needle, you turn back these leaflets, you will readily discover, between them and the coloured portion of the flower, *a very short bit of stem* (Fig. 20), the upper end of which is the *receptacle.* As these leaflets, then, are on the peduncle, *below* the receptacle, they cannot be sepals. They are simply small foliage leaves, to which, as they are found beside the flower, the name *bracts* is given. Our flower, then, is apparently without a calyx, and in this respect is different from the Buttercup. The whole four parts of the flower not being present, it is said to be *incomplete*.

Fig. 20.

20. It may be explained here that there is an understanding among botanists, that if the calyx and corolla are not both present it is always the corolla which is wanting, and so it happens that the coloured part of the flower under consideration, though resembling a corolla, must be regarded as a calyx, and the flower itself, therefore, as *apetalous*.

21. Remove now these coloured sepals, and what is left of the flower very much resembles what was left of our Buttercup, after the removal of the calyx and corolla. The stamens are very numerous, and are inserted on the receptacle. The carpels are also numerous (Fig. 21), are inserted on the receptacle, and are free from each other (*apocarpous*). And if you examine one of the carpels (Fig. 22) you will find that it contains a single ovule. The flower, in short, so much resembles that of the Buttercup that you will be prepared to learn that the two belong to the same Order or Family of plants, and you will do well to observe and remember such resemblances as have just been brought to your notice, when you set out to examine plants for your

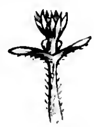


Fig. 21.

Fig. 22.

Fig. 20.—Flower of Hepatica, with bracts below.

Fig. 21.—Carpels of Hepatica. Fig. 22.—Single carpel, enlarged.

selves, because it is only in this way, and by slow steps, that you can acquire a satisfactory knowledge of the reasons which lie at the foundation of the classification of plants.

22. **Marsh-Marigold.** This plant grows in wet places almost everywhere, and is in flower in early summer.

Note the entire absence of hairs on the surface of the plant. It is therefore *glabrous.*

The root, like that of the Buttercup and of the Hepatica, is *fibrous.*

The stem is hollow and furrowed.

The foliage-leaves are of two kinds, as in the Buttercup. The radical leaves spring from the base of the stem, whilst the higher ones are cauline. The leaves are not lobed, as in the other two plants, but are indented on the edge. They are also net-veined.

23. Coming to the flower (Fig. 23) we find a circle, or whorl, of bright yellow leaves, looking a good deal like the petals of the Buttercup, but you will look in vain for the corresponding sepals. In this case there is no whorl of bracts to mislead you. Are we to say, then, that there is no calyx? If we adhere to the understanding mentioned when describing the Hepatica, we must suppose the *corolla* to be wanting, and then the bright yellow leaves of our plant will be the *sepals*, and will together constitute the calyx. As to the number of the sepals, you will find, as in the

Fig. 23.

Fig. 23.—Flower and leaf of Marsh-Marigold.

Hepatica, some variation. Whilst the normal number is five, some flowers will be found to have as many as nine.

24. The stamens are next to be examined, but you should first satisfy yourselves as to whether the calyx is polysepalous or otherwise, and whether it is free from the other floral leaves or not. If your examination be properly made, it will show you that the calyx is free and polysepalous.

The stamens are very much like those of the Buttercup and Hepatica. They are numerous, they have both anthers and filaments, and they shed their pollen through slits on the outer edges of the anthers. They are all separate from each other (polyandrous), and are all inserted on the receptacle. On this latter account they are said to *hypogynous* (below the pistil).

25. Remove the stamens, and you have left, as before, a head of carpels (Fig. 24). Examine one: there is the lower broad part, which you recognize as the *ovary*, the very short style, and the sticky stigma. To all appearance the carpels are pretty much the same as those of the two plants already examined. It will not do, however, to trust altogether to appearances in this case. Cut open a carpel and you find that, instead of a single ovule at the bottom of the ovary, there are several ovules in a row along that edge of the ovary which is turned towards the centre of the flower. The ovary is, in fact, a *pod*, and, when the seeds ripen, splits open along its inner edge. If you can find one which has split in this way, you can hardly fail to be struck with the resemblance which it bears to a common leaf. (Fig. 25.)


Fig. 24.


Fig. 25.

Fig. 24.—Head of carpels of Marsh-Marigold.

Fig. 25.—Single carpel, opened to show the two rows of seeds.

On the whole the resemblance between the structure of the Marsh-Marigold and that of the Hepatica and Buttercup is sufficiently great to justify us in placing it in the same family with them.

26. Having now made yourselves familiar with the different parts of these three plants, you are to write out a tabular description of them according to the following form; and, in like manner, whenever you examine a new plant, do not consider your work done until you have written out such a description of it.

BUTTERCUP.

ORGAN OR PART OF FLOWER.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Polysepalous.	Inferior.	
Corolla. *Petals.*	5	Polypetalous.	Hypogynous	Each Petal with a pit at the base inside
Stamens. *Filaments.* *Anthers.*	∞	Polyandrous.	Hypogynous.	
Pistil. *Carpels.* *Ovary.*	∞	Apocarpous.	Superior.	Carpels 1-seeded.

In the form the term *cohesion* relates to the union of *like* parts; for example, of sepals with sepals, or petals with petals; while the term *adhesion* relates to the union of *unlike* parts; for example, of stamens with corolla, or ovary with calyx. Neither cohesion nor adhesion takes place in any of the three flowers we have examined, and accordingly, under these headings in our schedule we write down the terms polysepalous, polypetalous, &c., to indicate this fact.

HEPATICA.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx.		Polysepalous.	Inferior.	Coloured like a corolla.
Sepals.	7-12			
Corolla.				Wanting.
Petals.				
Stamens.	∞	Polyandrous.	Hypogynous.	
Filaments.				
Anthers.				
Pistil.		Apocarpous.		
Carpels.	∞			Carpels 1-seeded.
Ovary.			Superior.	

MARSH-MARIGOLD.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx.		Polysepalous.	Inferior.	Coloured like a corolla.
Sepals.	5-9			
Corolla.				Wanting.
Petals.				
Stamens.	∞	Polyandrous.	Hypogynous.	
Filaments.				
Anthers.				
Pistil.		Apocarpous.		Carpels contain several seeds.
Carpels.	∞			
Ovary.			Superior.	

The symbol ∞ means "indefinite," or "numerous," and may be used when the parts of any organ exceed ten in number.

Under the head "Remarks" you may describe anything worthy of notice, for which provision is not made elsewhere in the schedule.

If you use the exercise-book which has been prepared to accompany the text-book, you will find also space for *drawing* such parts as are not easy to describe in words.

27. The three plants upon which we have been engaged up to this point are representatives or *types* of a very large group, called by botanists *Ranunculaceæ*, that is, *Ranunculaceous plants.* All the members of it, whilst they may differ in certain minor characteristics, agree in all the more important respects. The minor differences, such as we have observed in our examination of the specimens, lead to the sub-division of the group into several smaller groups, but any plant exhibiting the peculiarities common to all three may be regarded as typical of the *Order*, which is the name given to the group as a whole. These common peculiarities may be summed up with sufficient accuracy for our present purpose, as follows :

1. *The circles of flower-leaves, that is to say, the sepals, petals, stamens, and carpels, are entirely distinct, and unconnected with each other.*
2. *The several members of each circle are also entirely separate from each other.*
3. *It may be added that the stamens are almost invariably numerous, and that the plants are acrid to the taste*

CHAPTER IV.

EXAMINATION OF OTHER COMMON PLANTS WITH HYPOGYNOUS STAMENS—SHEPHERD'S PURSE—ROUND-LEAVED MALLOW.

28. We shall now proceed to examine some plants, the flowers of which exhibit, in their structure, important variations from the Buttercup, Hepatica, and Marsh-Marigold.

Shepherd's Purse. This plant (Fig. 26) is one of the commonest of weeds. As in the Buttercup, the foliage-leaves are of two kinds, radical and cauline, the former being in a cluster around the base of the stem. The cauline leaves are all sessile, and each of them, at its base, projects backward on each side of the stem, so that the leaf somewhat resembles the head of an arrow. Such leaves are, in fact, said to be *sagittate*, or arrow-shaped. The flowers grow in a cluster at the top of the stem, and, as the season advances, the peduncle gradually elongates, until, at the close of the summer, it forms perhaps half of the entire length of the stem. You will observe in this plant, that each separate flower is raised on a little stalk of its own. Each of these little stalks is a *pedicel*, and when pedicels are present, the term peduncle is applied to the portion of stem which supports the whole cluster.

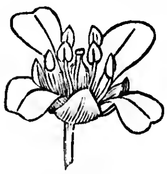


Fig. 27.

29. The flowers (Fig. 27) are rather small, and so will require more than ordinary care in their examination. The calyx is polysepalous, and of

Fig. 27.—Flower of Shepherd's Purse, enlarged.

Fig. 26.—Shepherd's Purse.

four sepals. The corolla is polypetalous, and of four petals. The stamens (Fig. 28) are six in number, and if you examine them attentively, you will see that two of them are shorter than the other four The stamens are consequently said to be *tetradynamous.* But if there had been only *four* stamens, in two sets of two each, they would have been called *didynamous.* The stamens are inserted on the receptacle (hypogynous). The pistil is separate from the other parts of the flower (superior).


Fig. 28.

30. To examine the ovary, it will be better to select a ripening pistil from the lower part of the peduncle. It is a flat body, shaped something like a heart (Fig. 29), and having the short style in the notch. A ridge divides it lengthwise on each side. Carefully cut or pull away the lobes, and this ridge will remain, presenting now the appearance of a narrow loop, with a very thin membranous partition stretched across it. Around the edge, on both sides of the partition, seeds are suspended from slender stalks (Fig. 30). There are, then, *two carpels united together,* and the pistil is, therefore, *syncarpous.*


Fig. 29.


Fig. 30.

31. Shepherd's Purse is a type of a large and important Order, the *Cruciferæ,* or Cress Family. Other common examples, which should be studied and compared with Shepherd's Purse, are the garden Stock (*single* flowers are best for examination), Water-Cress, the yellow Mustard

Fig. 28.—The same, with calyx and corolla removed.
Fig. 29.—Ripened pistil of Shepherd's Purse.
Fig. 30.—The same, with one side removed to show the seeds.

of the wheat-fields, Radish, Sweet Alyssum of the gardens, &c. All these plants, while differing in unimportant particulars, such as the colour and size of the petals and the shape of the pod, agree in presenting the following characters:

1. *The sepals and petals are each four in number.*
2. *The stamens are tetradynamous (and hypogynous).*
3. *The fruit is syncarpous, and is 2-celled by reason of a thin partition stretched between the carpels.*
4. *It may be added that the plants are generally pungent to the taste, and the flowers are almost invariably in terminal clusters, like that of Shepherd's Purse.*

SHEPHERD'S PURSE.

Organ.	No.	Cohesion.	Adhesion.	Remarks.
Calyx. *Sepals.*	4	Polysepalous.	Inferior.	
Corolla. *Petals.*	4	Polypetalous.	Hypogynous.	
Stamens. *Filaments.* *Anthers.*	6	Tetradynamous.	Hypogynous.	Two sepals with a pair of long stamens opposite each; the other two with one short stamen opp. each.
Pistil. *Carpels.* *Ovary.*	2	Syncarpous.	Superior.	The two cells of the ovary separated by a thin partition.

32. **Mallow.** The round-leaved Mallow (Fig. 31) grows along every wayside, and is a very common weed in cultivated grounds. Procure, if possible, a plant which has ripened its seeds, as well as one in flower. The root of this plant is of of a different kind from those of the three plants first examined. It consists of a stout tapering part, descending deep into the soil, from the surface of which fibres are given off irregularly. A stout root of this kind is called a *tap-root*. The carrot is another example.

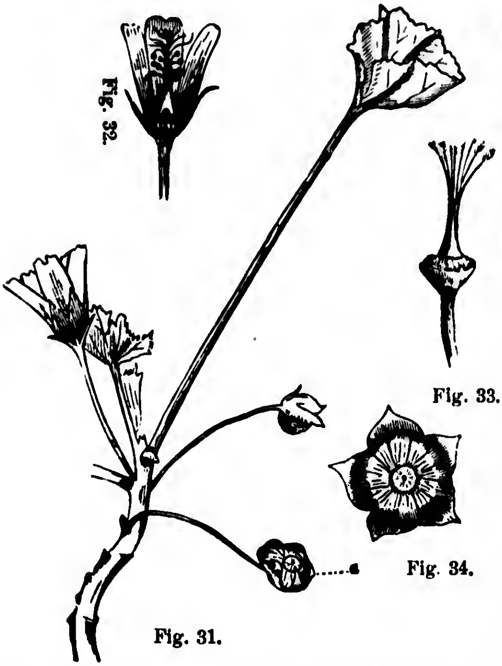


Fig. 32.

Fig. 33.

Fig. 34.

Fig. 31.

33. The leaves are long-petioled, net-veined, and indented on the edges. On each side of the petiole, at its junction with the stem, you will observe a little leaf-like attachment, to which the name *stipule* is given. The presence or absence of stipules is a point of some importance in plant-structure, and you will do well to notice it in your examinations. You have now made yourselves

Fig. 31.—Round-leaved Mallow. Fig. 32.--Section of the flower.
Fig. 33.—Flower with calyx and corolla removed.
Fig. 34.—A ripened pistil with the persistent calyx.

acquainted with all the parts that any leaf has, viz., *blade*, *petiole*, and *stipules*.

34. Coming to the flower, observe first that the parts of the calyx are not entirely separate, as in the flowers you have already examined. For about half their length they are united together so as to form a cup. The upper half of each sepal, however, is perfectly distinct, and forms a *tooth* of the calyx; and the fact that there are five of these teeth shows us unmistakably that the calyx is made up of five sepals. We therefore speak of it as a *gamosepalous* calyx, to indicate that the parts of it are coherent.

As the calyx does not fall away when the other parts of the flower disappear, it is said to be *persistent*. Fig. 31, *a*, shows a persistent calyx.

35. At the base of the calyx there are three minute leaf-like teeth, looking almost like an outer calyx. A circle of bracts of this kind is called an *involucre*. The three bracts under the flower of the Hepatica also constitute an involucre. As the bracts in the Mallow grow on the calyx, some botanists speak of them as an *epicalyx*.

The corolla consists of five petals, separate from each other, but united with the stamens at their base.

36. The stamens are numerous, and as their filaments are united to form a tube, they are said to be *monadelphous*. This tube *springs from the receptacle*, and the stamens are therefore *hypogynous*. Fig. 32 will help you to an understanding of the relation between the petals and stamens.

Having removed the petals, split the tube of the stamens with the point of your needle. A little care will then enable you to remove the stamens without injuring the pistil. The latter organ will then be found to consist of a ring of coherent carpels, a rather stout style, and numerous long stigmas (Fig. 33). If you take the trouble to count the carpels and the stigmas, you will find the numbers to correspond. As the seeds ripen, the carpels separate from each other (Fig. 34).

MALLOW.

ORGAN.	NO.	COHESION.	ADESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous.	Inferior.	Three bracts growing on the calyx.
Corolla. *Petals.*	5	Polypetalous.	Hypogynous.	
Stamens. *Filaments.* *Anthers.*	∞	Monadelphous One-celled.	Hypogynous.	
Pistil. *Carpels.* *Ovary.*	∞	Syncarpous.	Superior.	Carpels as many as the stigmas.

37. Compare now the structure of the Hollyhock (single flowers should be selected) with that of the Mallow, and write out a description. Musk-Mallow and Abutilon (a common green-house plant) may also be examined with advantage.

38. The Order *(Malvaceæ)* of which Mallow is a type is very distinctly marked by the following characteristics:

1. *The sepals are always placed edge to edge (valvate) in the bud, while the petals overlap and are rolled together (convolute).*

2. *The stamens are numerous and monadelphous, and their anthers are 1-celled. Although united at the*

base with the claws of the petals, they are nevertheless inserted on the receptacle (hypogynous).

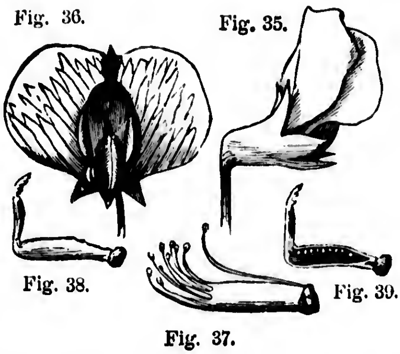
3. *The carpels are almost always united in a ring, which breaks up at maturity.*

4. *It may be added that the leaves are furnished with stipules, and the juice of the plants is mucilaginous.*

CHAPTER V.

EXAMINATION OF COMMON PLANTS WITH PERIGYNOUS STAMENS—GARDEN PEA—GREAT WILLOW-HERB.

39. **Garden Pea.** In the flower of this plant, the calyx is constructed on the same plan as in the Mallow. There are five sepals, coherent below, and spreading out into distinct teeth above (Fig. 35). The calyx is therefore gamosepalous.



Examine next the form of the corolla (Fig. 36). One difference between the corolla and those of the previous plants will strike you at once. In the flowers of the latter you will remember that each petal was precisely like its fellows in size and shape, and we therefore spoke of the corolla as *regular*. In the Pea, on the other hand,

Fig. 35.—Flower of Garden Pea. Fig. 36.—Front view of the same.
Fig. 37.—Diadelphous stamens of the same.
Fig. 38.—The pistil. Fig. 39.—The same cut through lengthwise.

one of the petals is large, broad, and open, whilst two smaller ones, in the front of the flower, are united into a kind of hood. We shall speak of this corolla, then, and all others in which the petals are unlike each other in size or shape, as *irregular*.

As the Pea blossom bears some resemblance to a butterfly, it is said to be *papilionaceous*.

40. Remove now the calyx-teeth and the petals, being very careful not to injure the stamens and the pistil, enveloped by those two which form the hood. Count the stamens, and notice their form (Fig. 37). You will find ten, one by itself, and the other nine with the lower halves of their filaments joined together, or coherent. When stamens occur in this way, in two distinct groups, they are said to be *diadelphous*; if in three groups, they would be *triadelphous*; if in several groups, *polyadelphous*. In the Mallow, you will remember, they are united into *one* group, and therefore we described them as *monadelphous*.

You will, perhaps, be a little puzzled in trying to determine to what part of the flower the stamens are attached. If you look closely, however, you will see that the attachment, or *insertion*, is not quite the same as in the Buttercup and the other flowers examined. In the present instance they are inserted upon the lower part of the calyx, and so they are described as *perigynous*, a term meaning "around the pistil."

41. But the pistil (Figs. 38, 39) is not attached to the calyx. It is *free*, or *superior*. If you cut the ovary across, you will observe there is but one cell, and if you examine the stigma, you will find that it shows no sign of division. You may therefore be certain that the pistil is a single carpel.

You are now prepared to fill up the schedule descriptive of this flower.

GARDEN PEA.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous	Inferior.	
Corolla. *Petals.*	5	Papilionaceous. Irregular.	Perigynous.	The two front petals united.
Stamens. *Filaments. Anthers.*	10	Diadelphous.	Perigynous.	
Pistil. *Carpels. Ovary.*	1	Apocarpous.	Superior.	

42. The beginner will be very likely to think, from its appearance, that the largest of the petals is made up of two coherent ones, but the following considerations show clearly that this is not the case. In the Buttercup, and other flowers in which the number of sepals and petals is the same, the petals do not stand before the sepals, but before the spaces between them. In the Pea-blossom this rule holds good if the large petal is considered as one, but not otherwise. Again, the veining of this petal is similar to that of a common leaf, there being a central rib from which the veins spring on each side; and lastly, there are some flowers of the Pea kind—Cassia, for example—in which this particular petal is of nearly the same size and shape as the other four.

43. The Pea is a type of a highly important group of plants—the Order *Leguminosæ*. To it belong many plants

differing very widely in external appearance—the Locust-Tree and the Clover, for example—but exhibiting in the structure of their flowers so marked a similarity that their relationship is beyond question. The characters by which the Order is distinguished are chiefly these:

1. *The corolla is more or less papilionaceous, and is inserted on the base of the calyx (perigynous).*
2. *The stamens, almost invariably ten in number, are also perigynous, and nearly always diadelphous.*
3. *The pistil is nearly always a legume, that is to say, it is a single carpel which splits into two pieces at maturity, like the pod of the Pea or Bean.*
4. *The leaves have stipules, and are nearly always compound, that is, of several distinct leaflets.*

Plants which may be compared with the Pea are Red Clover, White Clover, Sweet Clover, Medick, Locust-Tree, Bean, Vetch, Lupine, Sweet Pea, &c.

44. **Great Willow-herb.** This plant is extremely common in low grounds and newly-cleared land, and you may easily recognize it by its tall stem and bright purple flowers.


Fig. 40.

Observe the position of the flowers. In the three plants first examined we found the flowers at the end of the stem. In the Willow-herb, as in the Mallow, they spring from the sides of the stem, and immediately below the point from which each flower springs you will find a small leaf or bract (Fig. 40). Flowers

Fig. 40.—Flower of Great Willow-herb.

which arise from the axils of bracts are said to be *axillary*, whilst those which are at the ends of stems are called *terminal*, and you may remember that flowers can only be produced in the axils of leaves and at the ends of stems and branches.

45. Coming to the flower itself, direct your attention, first of all, to the position of the ovary. You will find it apparently under the flower, in the form of a tube tinged with purple. It is not in reality under the flower, because its purplish covering is the calyx, or, more accurately, the *calyx-tube*, which adheres to the whole surface of the ovary, and expands above into four long teeth. The ovary, therefore, is *inferior*, and the calyx, of course, *superior*, in this flower. As the sepals unite below to form the tube the calyx is gamosepalous.

The corolla consists of four petals, free from each other, and is consequently polypetalous. It is also regular, the petals being alike in size and shape. Each petal is narrowed at the base into what is called the *claw* of the petal, the broad part, as in the ordinary foliage-leaf, being the *blade*. The stamens are eight in number (octandrous), four short and four long, and are attached to the calyx (perigynous).

Fig. 42.

Fig. 41.

46. The pistil has its three parts—ovary, style, and stigma—very distinctly marked. The stigma consists of four long lobes, which curl outwards after the flower opens. The

Fig. 41.—Ripened pistil of Willow-herb. Fig. 42.—Cross section of the same.

style is long and slender. The examination of the ovary requires much care; you will get the best idea of its structure by taking one which has just burst open and begun to discharge its seeds (Fig. 41). The outside will then be seen to consist of four pieces (*valves*), whilst the centre is occupied by a slender four-winged column (Fig. 42), in the grooves of which the seeds are compactly arranged. The pistil thus consists of four carpels united together, and is therefore *syncarpous.* Every seed is furnished with a tuft of silky hairs, which greatly facilitates its transportation by the wind.

47. The Willow-herb furnishes an excellent example of what is called *symmetry.* We have seen that the calyx and corolla are each made up of four parts; the stamens are in two sets of four each; the stigma is four-lobed, and the ovary has four seed-cells. A flower is *symmetrical* when each set of floral leaves contains either the same number of parts or a *multiple* of the same number.

Observe that the leaves of our plant are net-veined.

The schedule will be filled up as follows:

GREAT WILLOW-HERB.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	4	Gamosepalous	Superior.	
Corolla. *Petals.*	4	Polypetalous.	Perigynous.	
Stamens. *Filaments.* *Anthers.*	8	Octandrous.	Perigynous.	Four short and four long.
Pistil. *Carpels.* *Ovary.*	4	Syncarpous.	Inferior.	Seeds provided with tufts of hair.

Flowers to compare with Great Willow-herb are Fuchsia and Evening Primrose. Either of these will serve as the type if Willow-herb cannot be obtained.

CHAPTER VI.

EXAMINATION OF COMMON ROSACEOUS PLANTS—SWEET BRIER —STRAWBERRY—CHERRY—CRAB-APPLE—RASPBERRY.

48. **Sweet Brier.** As in the flowers examined in the last chapter, the sepals of Sweet Brier are not entirely distinct; their lower halves cohere to form a tube, and the calyx is therefore gamosepalous.

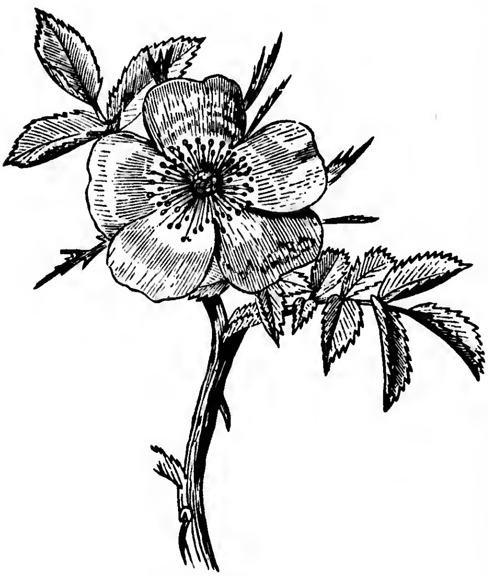


Fig. 43.

The corolla consists of five separate petals of the same size and shape, and is therefore both regular and polypetalous. The stamens are very numerous, and separate from each other. As in the Pea and the Willow-herb, so in this flower they will be

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Fig. 43.—Flower and leaves of Sweet Brier.

found to be attached to the calyx. They are, therefore, *perigynous*.

49. To understand the construction of the pistil, you must make a vertical section through the roundish green mass which you will find on the under side of the flower. You will then have presented to you some such appearance as that in Fig. 44. The green mass, you will observe, is hollow. Its outer covering is simply the continuation of the calyx-tube. *The lining of this calyx-tube is the receptacle of the flower;* to it are attached the separate carpels which together constitute the pistil (Fig. 45), just as the carpels of the Buttercup are attached to the *raised* receptacle of that flower.

Fig. 44.

We must remind you again that whenever the ovary is enclosed in the calyx-tube, and the calyx appears to spring from the summit of the ovary, the latter is said to be *inferior*, and the former *superior*.

In the case of Sweet Brier and similar forms, where the pistil is strictly apocarpous, and the other parts cohere at their base so as to form a tube enclosing the really free carpels, the pistil may be described as *half-inferior*, and the calyx consequently as *half-superior*.

Fig. 45.

50. **Strawberry.** So far as calyx, corolla, and stamens are concerned, the flower of Strawberry very nearly resembles that of Sweet Brier. Alternating with the five calyx-lobes, however, will be found five bractlets,

Fig. 44.—Vertical section through the pistil.
Fig. 45.—Vertical section through ripe fruit of Sweet Brier.

which constitute, as in Mallow, an *epicalyx.* The pistil must be carefully examined. In this case there will be found a conical elevation in the centre of the flower, on the surface of which are inserted many separate carpels, much in the same way as in Buttercup. At maturity this elevated receptacle will have become greatly enlarged and pulpy, with the real fruit, the ripened carpels, dotted over its surface (Fig. 46).

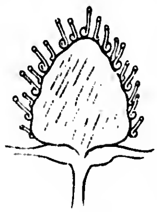


Fig. 46.

51. **Cherry** or **Plum.** Here also the calyx, corolla, and stamens are all adherent, and a hollow cup is formed, in the bottom of which (but entirely free from these parts) the pistil is developed (Fig. 47). It consists of a single carpel, in which there are at first two ovules, though generally but one seed is ripened. The fruit is called a *drupe*, the seed being surrounded by three distinct layers: (1) a hard shell (the *putamen*), (2) a mass of soft pulp, and (3) the outer skin.

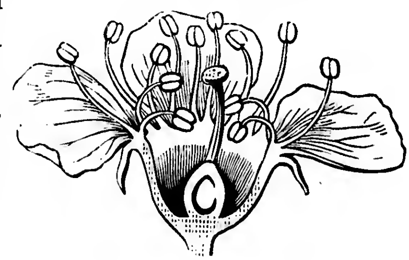


Fig. 47.

52. **Crab-Apple.** Here, as before, we have a gamosepalous calyx, the lower part forming a tube. The five petals are separate and inserted on the calyx, as are also the numerous stamens. To understand the structure of the pistil, make a vertical section through the centre of the flower, and also a cross section. The cross section

Fig. 46.—Vertical section of Strawberry.
Fig. 47.—Vertical section through flower of Cherry. (Gray.)

(Fig. 50) will show you that in this case we have a syncarpous pistil of five carpels, and the vertical section (Fig. 49) shows that the ovary is here truly *inferior*, the calyx-tube being completely adherent or *adnate* to it. The style is divided into five parts, corresponding to the five carpels.

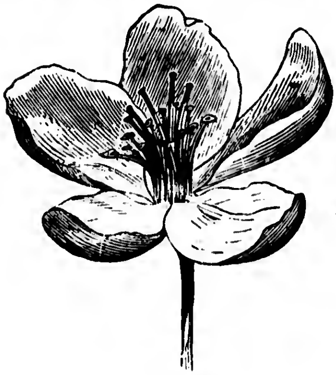


Fig. 48.

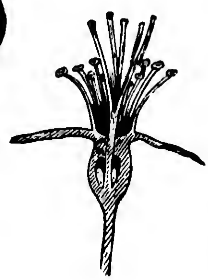


Fig. 49.

53. At maturity, whilst the pistil or central organ has enlarged considerably, it will be found that the calyx-tube, which is adherent to it, has also grown very much. It is, in fact, the largely developed calyx-tube which constitutes the edible part of the apple, the true pistil forming the core. It is not very easy to distinguish the line which separates these two parts of the ripe fruit, but if a cross-section be made through the apple a circle of greenish dots may generally be made out at the outer limit of the core. A fruit of this sort is called a *pome*. The withered calyx-teeth may be found in the hollow at the end opposite the stem, as also, generally, the remains of the five styles.

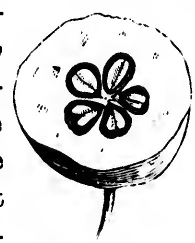


Fig. 50.

Fig. 48.—Flower of Crab-Apple. Fig 49.—Vertical section of ovary.
Fig. 50.—Cross section of fruit of Crab-Apple.

54. **Raspberry**. Calyx, corolla, and stamens have the same arrangement as in Strawberry, and the pistil is likewise apocarpous, the numerous carpels covering the surface of a raised receptacle. But here the carpels do not produce *achenes.* Each of them at maturity forms a fruit resembling a drupe, so that the raspberry is a mass of drupes heaped upon a common receptacle.

55. Let us now sum up our observations upon the representatives of the great Order of Rosaceous plants. We have found them to possess the following characters in common:

1. *The petals and the numerous stamens are inserted on the calyx (perigynous).*
2. *The pistil, except in the Apple, is apocarpous and free from the calyx.*
3. *It may be added that the leaves are furnished with stipules.*

56. The differences (which lead to the sub-division of the Order into subordinate groups) are chiefly in the fruit. In Sweet Brier, with which may be compared any wild Rose, the achenes are enclosed in the calyx-tube. In Strawberry the receptacle is conical; so also in Raspberry. In the Cherry the carpel is single, forming a drupe. In the Apple the ovary is syncarpous and combined with the fleshy calyx. Compare with the Apple the Hawthorn and the Mountain Ash or Rowan Tree.

57. The following are the schedules descriptive of Sweet Brier and Crab-Apple. Those relating to Cherry, Strawberry, and Raspberry should be carefully filled up by the pupil.

SWEET BRIER.

Organ.	No.	Cohesion.	Adhesion.	Remarks.
Calyx. *Sepals.*	5	Gamosepalous	Half-superior.	
Corolla. *Petals.*	5	Polypetalous.	Perigynous.	
Stamens.	∞	Polyandrous.	Perigynous.	
Pistil. *Carpels.*	∞	Apocarpous.	Half-inferior.	The hollow receptacle lines the calyx-tube

CRAB-APPLE.

Organ.	No.	Cohesion.	Adhesion.	Remarks.
Calyx. *Sepals.*	5	Gamosepalous.	Superior.	
Corolla. *Petals.*	5	Polypetalous.	Perigynous.	
Stamens.	∞	Polyandrous.	Perigynous.	
Pistil. *Carpels.*	5	Syncarpous.	Inferior.	Fruit consists chiefly of a fleshy enlargement of the calyx-tube.

CHAPTER VII.

EXAMINATION OF A PLANT WITH EPIGYNOUS STAMENS—WATER-PARSNIP.

58. **Water-Parsnip.** This is a common swamp plant in Canada; but if any difficulty be experienced in procuring specimens, the flower of the common Carrot or Parsnip or of Parsley may be substituted for it, all these plants being closely related, and differing but slightly in the structure of their flowers.

Fig. 53.

Fig. 52. Fig. 51.

Notice first the peculiar appearance of the flower cluster (Fig. 51). There are several pedicels, nearly of the same length, radiating from the end of the peduncle, and from the end of each pedicel radiate in like manner a number of smaller ones, each with a flower at its extremity. Such a cluster is known as an *umbel*. If, as in the present case, there are groups of secondary pedicels, the umbel is *compound*. As the flowers are very small we shall be obliged to use the lens all through the examination. Even with its aid you will have a little difficulty in making out the calyx, the tube of which, in this flower, adheres to the surface of the ovary, as in Willow-herb, and is reduced above to a mere rim or border of five minute teeth. The petals are five in number, and free from each other. Observe that each of them is *incurved* at its extremity

Fig. 51.—Compound umbel of Water-Parsnip.
Fig. 52.—Single flower of same. Fig. 53.—Vertical section of the ovary.

(Fig. 52). They are inserted *on a disk which crowns the ovary*, as are also the five stamens, which are hence said to be *epigynous*. In the centre of the flower are two short styles projecting above the disk, and a vertical section through the ovary (Fig. 53) shows it to be two-celled, with a single seed suspended from the top of each cell.

WATER-PARSNIP.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous	Superior.	Calyx-teeth almost obsolete.
Corolla. *Petals.*	5	Polysepalous.	Epigynous.	Petals incurved.
Stamens.	5	Pentandrous.	Epigynous.	
Pistil. *Carpels.*	2	Syncarpous.	Inferior.	

59. The Water-Parsnip is a type of the large Order *Umbelliferæ*, which is well marked by the following characters :

1. *The flowers are clustered in umbels, and these are generally compound.*
2. *The calyx is perfectly adherent to the ovary, so that almost none of it projects above.*
3. *The petals and stamens (five each) are epigynous.*
4. *The ovary is two-celled, and is surmounted by two styles. At maturity the pistil separates into two dry carpels.*

CHAPTER VIII.

EXAMINATION OF COMMON PLANTS WITH EPIPETALOUS STAMENS—DANDELION—CATNIP.

60. **Dandelion.** The examination of this flower will be somewhat more difficult than that of any we have yet undertaken.


Fig. 54.

Provide yourselves with specimens in flower and in seed.

The root of the plant, like that of the Mallow, is a tap-root.

The stem is almost suppressed, and, as in the case of the Hepatica, the leaves are all radical. They are also net-veined.

The flowers are raised on scapes, which are hollow. At first sight the flower appears to have a calyx of many sepals, and a corolla of many petals. Both of these appearances, however, are contrary to facts. With a sharp knife cut the flower through the middle from top to bottom (Fig. 54). It will then appear that the flower, or rather *flower-head*, is made up of a large number of distinct pieces. With the point of your needle detach one of these pieces. At the lower end of it you have a small body resembling an unripe seed (Fig. 55). It is, in fact, an ovary. Just above this there is a short bit of stalk, surmounted by a circle of silky hairs, and above this a yellow tube with one side greatly prolonged. This yellow tube is a corolla, and a close examination of the extremity of


Fig. 55.

Fig. 54.—Vertical section of Dandelion flower.
Fig. 55—Single floret.

its long side will show the existence of five minute points, or teeth, from which we infer that the tube is made up of five coherent petals. As the corolla is on the ovary, it is said to be *Epigynous*.

Fig. 56.

Out of the corolla protrudes the long style, divided at its summit into two stigmas.

To discern the stamens will require the greatest nicety of observation. Fig. 56 will help you in your task. The stamens are five in number. They are inserted on the tube of the corolla (*epipetalous*) and their anthers cohere (Fig. 57), and form a ring about the style. When the anthers are united in this way, the stamens are said to be *syngenesious*.

61. It appears, then, that the Dandelion, instead of being a single flower, is in reality a compound of a great many flowers upon a common receptacle, and what seemed at first to be a calyx is, in reality, an *involucre*, made up of many bracts.

Fig. 57.

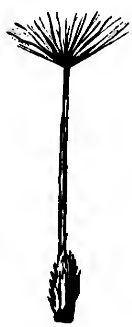


Fig. 58.

But have the single flowers, or *florets*, as they are properly called, no calyx? The theory is that they have one, but that it is adherent to the surface of the ovary, and that the tuft of silky hairs which we noticed is a prolongation of it.

Now turn to your specimen having the seeds ready to blow away. The seeds are all single; the little bit of stalk at the top has grown into a long slender thread, and the tuft of hairs has spread out like the rays of an umbrella (Fig. 58). But though the seeds are

Fig. 56.—Corolla laid open to show epipetalous stamens.
Fig. 57.—Syngenesious anthers of Dandelion. Fig. 58.—Fruit of Dandelion.

invariably single, it is inferred from the two-lobed stigma that there are *two carpels*. The following is the schedule:

DANDELION.

ORGAN.	No.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous	Superior.	The number of sepals is *inferred from analogy* to be five.
Corolla. *Petals.*	5	Gamopetalous	Epigynous.	
Stamens.	5	Syngenesious.	Epipetalous.	
Pistil. *Carpels.*	2	Syncarpous.	Inferior.	Number of carpels inferred from number of stigmas.

62. Flowers constructed on the plan of the Dandelion are called *Composite* flowers. The Order (Compositæ) comprises an immense number of common plants, in some of which all the corollas in the head are, as in the Dandelion, of one sort, namely, with one side prolonged into a strap, and hence called strap-shaped or *ligulate*. In most cases, however, the ligulate corollas form a circle round the margin of the head only, as in Sunflower, while the central *disk* is filled up with small regular gamopetalous corollas with a five-toothed border. Or it may happen, as in Thistle, that all the flowers are regular, ligulate corollas being absent. These, however, are minor points, and, while serving to distinguish subordinate groups, do not interfere with the great and salient characters which mark the Order as a whole. So, also,

instead of the tuft of silky hairs (technically called the *pappus*) which surmounts the ovary, there may be, as in Sunflower, a few teeth-like projections, or scales, or a mere rim hardly to be distinguished at all.

63. The Order is easily recognized by the following characters:

1. *The flowers, or florets, are in heads on a common receptacle, and surrounded by an involucre.*
2. *The stamens are inserted on the corolla, and are united by their anthers (syngenesious).*
3. *The style is 2-lobed at the apex.*

64. Representatives of this Family are so numerous that it is needless to give a list. Specimens exhibiting all the variations in regard to the corollas, pappus, &c., should be gathered and notes made of their structure. In Part II. will be found a very full account of all the species likely to be met with, and the exercise book has a number of blank schedules specially arranged for Composites.

65. **Catnip.** Note carefully the appearance of the stem. It is *square.*

The flowers are in axillary clusters. The calyx is a tube (Fig. 59), terminating in five sharp teeth, and you may observe that the tube is a little longer on the upper side (that is, the side *towards* the stem) than on the lower. The corolla is somewhat peculiar. It has somewhat the appearance of a wide-open mouth, and is known as a *labiate* or two-lipped corolla. The upper lip is erect and notched at the apex.

Fig. 59.

Fig. 59.—Flower of Catnip.

The lower lip spreads outward, and consists of a large central lobe and two small lateral ones. Altogether, therefore, there are *five* lobes constituting the gamopetalous corolla. Pull out the corolla, and with the point of your needle split its tube in front. On laying it open, the stamens will be found to be inserted upon it (epipetalous). They are four in number, two of them longer than the other two. Hence they are described as *didynamous.* The anthers are peculiar in not having their lobes parallel (Fig. 60), these being wide apart at the base, in consequence of the expansion of the *connective*, the name given to that part of the anther which unites its two lobes or cells.

Fig. 60.

The pistil consists of a two-lobed stigma, a long style, and an ovary, which seems at first as if made up of four distinct carpels (Fig. 61). But the two-lobed stigma will warn you against this supposition. The ovary really consists of *two* carpels, each of two deep lobes, and, as the seeds ripen, these lobes form four little nutlets (Fig. 62), each containing a single seed.

Fig. 62.

Fig. 61.

66. The Catnip is a type of the Order *Labiatæ* (Mint Family), so called because the corollas are usually labiate. It is marked by the following characters:

1. *The stem is square, and the leaves are opposite and generally aromatic.*
2. *The corolla is more or less labiate.*
3. *The stamens are mostly didynamous.*

Fig. 60.—Front view of the same. Fig. 61.—Pistil of Catnip.
Fig. 62.—Ripe ovary of four separate nutlets.

4. The ovary is four-lobed, and at maturity breaks up into four nutlets.

Other types are the various Mints, Sage, Thyme, Summer Savory, Pennyroyal, Bergamot, Self-heal, Horehound, &c., many of which are of very common occurrence.

CATNIP.

ORGAN.	No.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous	Inferior.	Calyx-tube nerved.
Corolla. *Petals.*	5	Gamopetalous	Hypogynous.	Two-lipped. Upper lip of two, and lower of three, lobes.
Stamens. *Anthers.*	4	Didynamous.	Epipetalous.	Lobes of anthers not parallel.
Pistil. *Carpels.*	2	Syncarpous.	Superior.	The ripe ovary of four nutlets.

CHAPTER IX.

EXAMINATION OF PLANTS WITH MONŒCIOUS FLOWERS—CUCUMBER—OAK.

67. **Cucumber.** You can hardly have failed to notice that only a small proportion of the blossoms on a Cucumber vine produce cucumbers. A great many

wither away and are apparently of no use. An attentive inspection will show that some of the blossoms have oblong fleshy protuberances beneath them, whilst others are destitute of these attachments. Select a flower of each kind, and examine first the one with the protuberance (Fig. 63), which latter, from its appearance, you will probably have rightly guessed to be the ovary. The situation of the ovary here, indeed, is the same as in the Willow-herb. The calyx-tube adheres to its surface, and is prolonged to some little distance above it, expanding finally into five teeth. The corolla is gamopetalous, and is adherent to the calyx. Remove now the calyx and the adherent corolla, and there is left in the centre of the flower a short column, terminating in three stigmas, each two-lobed.

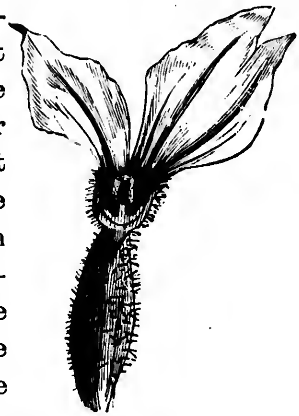


Fig. 63.

There are no stamens.

68. Now examine the other blossom (Fig. 64). Calyx and corolla have almost exactly the same appearance as before. Remove them, and you have left three stamens growing on the calyx-tube, and slightly united by their anthers (syngenesious). *There is no pistil.*

Fig. 64.

Fig. 63.—Pistillate flower of Cucumber.
Fig. 64.—Staminate flower of Cucumber.

You see now why some blossoms produce cucumbers and others do not. Most of the blossoms have no pistil, and are termed *staminate* or *sterile* flowers, whilst the others are *pistillate* or *fertile.* Flowers in which either stamens or pistils are wanting are also called *imperfect.* When staminate and pistillate flowers grow on the same plant, as they do in the case of the Cucumber, they are said to be *monœcious.*

69. In plants of this kind the pollen of one kind of blossom is conveyed to the stigmas of the other kind, chiefly by insects, which visit the flowers indiscriminately in search of honey. The pollen dust clings to their hairy legs and bodies, and is presently rubbed off upon the stigma of some fertile flower.

70. In order to describe monœcious flowers, our schedule will require a slight modification. As given below, the symbol ♂ stands for "staminate flower," and the symbol ♀ for "pistillate flower."

CUCUMBER.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Calyx. *Sepals.*	5	Gamosepalous	Superior.	
Corolla. *Petals.*	5	Gamopetalous	Perigynous.	
♂ Stamens.	3	Syngenesious.	Perigynous.	Two anthers are 2-celled and one 1-celled.
♂ Pistil. *Carpels.*	0			
♀ Stamens.	0			
♀ Pistil. *Carpels.*	3	Syncarpous.	Inferior.	

71. Oak. The Oaks are among our finest and most valuable forest-trees, and while everyone is familiar with

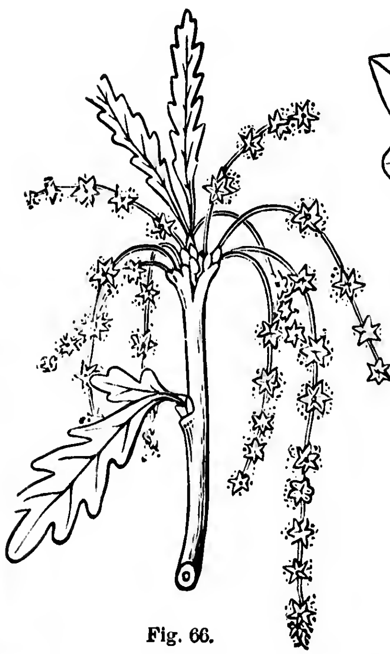


Fig. 66.

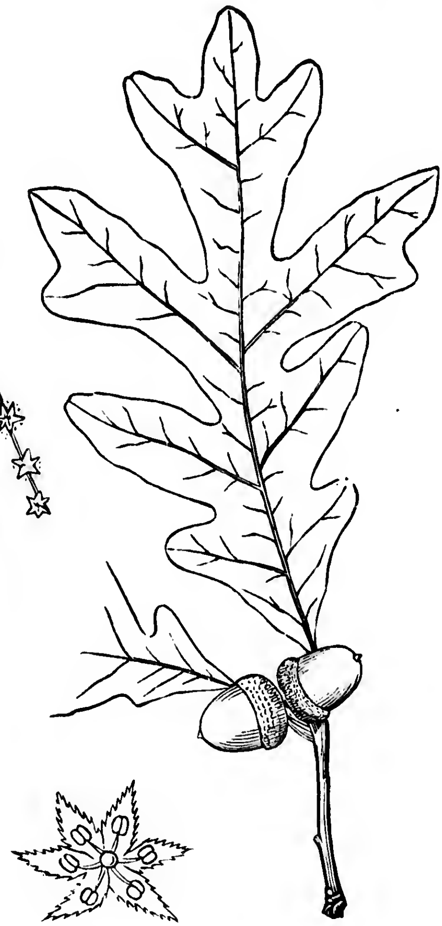


Fig. 67. Fig. 65.

the appearance of the *acorn*, as the fruit of the Oak is

Fig. 66.—Twig of White Oak with sterile catkins.
Fig. 67.—Single staminate flower.
Fig. 68.—Fruit and leaf of Oak. (Wood and Steele.)

called, the fact that the flowers are not to be obtained without effort on account of their distance from the ground, as well as the circumstance of their being rather inconspicuous, may lead to their being overlooked unless special attention is directed to them. The White Oak is perhaps the best known species with us. It may be pretty well distinguished from other species by its leaves, the lobes of which (Fig. 65) are *rounded.* However, for the purposes of this lesson, any other species may be used, if the White Oak is not at hand. The flowers are monœcious, the sterile ones forming long and slender drooping catkins, which are either single or, more generally, several in a cluster, from the same lateral bud (Fig. 66). Each sterile flower (Fig. 67) consists of a perianth or calyx of a variable number of sepals, mostly from four to six, and generally eight stamens. The fertile flowers spring mostly from the axils of the leaves of new shoots, and they occur either singly or two or three in a cluster. Each flower consists of a syncarpous pistil of three carpels. The ovary is three-celled, or nearly so, and two ovules are formed in each cell. The flower is surrounded at the base by a scaly involucre, which, at maturity, has become quite woody, and forms in fact the *cup* in which the acorn rests. If you dissect an acorn you will observe that *there is but one seed in it.* Although the ovary contains six ovules at starting, it always happens that all but one disappear before the fruit is matured.

The White Oak ripens its acorns the first year. The Red Oak, on the other hand, does not ripen its fruit till the autumn of the second year.

72. It will be a valuable exercise to compare flowers of the Beech with those just described. They will be found

to be monœcious also; the sterile ones in small drooping heads, with stamens and sepals variable in number, and the fertile ones from the axils of new leaves, usually two together, surrounded by an involucre of many bristle-pointed scales. These develope into the familiar bristly four-valved involucre which encloses the pair of three-cornered nuts at maturity. Each nut is the product of one flower, and contains but one seed, although at first the ovary was (like that of the Oak) three-celled, with two ovules in each cell.

These resemblances lead us to the conclusion that the Oak and the Beech are nearly related plants. They belong to the same Order (*Cupuliferæ*), as do also the Ironwood, the Chestnut, and the Hazelnut, all of which should be examined and compared, if within reach.

73. The following are the distinguishing characters of the Order:

1. *The flowers are monœcious, the sterile ones being in catkins (or, in Beech, in close heads), the fertile single or in small clusters, with an involucre forming at maturity a cup or covering for the 1-seeded nut.*
2. *The ovary is at first several-celled, but at maturity is 1-celled and 1-seeded.*

The pupil will write out descriptions of one or more representatives of the Order, taking the description of Cucumber for his model.

CHAPTER X.

EXAMINATION OF PLANTS WITH DIŒCIOUS FLOWERS—WILLOW—MAPLE.

74. **Willow.** The flowers of most kinds of Willow appear in spring or early summer before the leaves. They grow from the axils in long, close clusters called *catkins* or *aments*. Collect a few of these *from the same tree or shrub.* You will find them to be exactly alike. If the first one you examine is covered with yellow stamens (Fig. 68), all the rest will likewise consist of stamens, and you will search in vain for any appearance of a pistil. If, on the other hand, one of your catkins is evidently destitute of stamens, and consists of oblong pistils (Fig. 69), then all the others will in like manner be found to be without stamens. Unlike our Cucumber plant, the staminate and pistillate flowers of the Willow are borne on *different* plants. These flowers are therefore said to be *diœcious.* As a general thing, staminate and pistillate catkins will be found upon trees not far apart. Procure one of each kind, and examine first the staminate one. You will probably find the stamens in pairs. Follow any pair of filaments down to

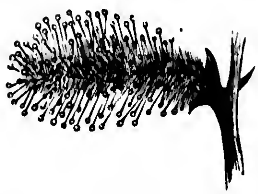


Fig. 68.

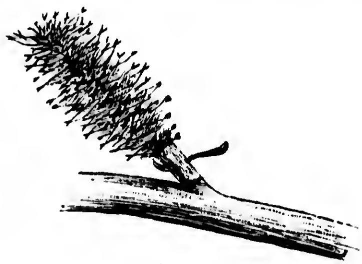


Fig. 69.

Fig. 70.

Fig. 68.—Staminate catkin of Willow. Fig. 69.—Fertile catkin.
Fig. 70.—Single staminate flower.

their insertion, and observe that they spring from the axil of a minute bract (Fig. 70). These bracts are the *scales* of the catkin. There is no appearance of either calyx or corolla, and the flowers are therefore said to be

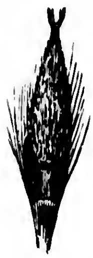


Fig. 71.

achlamydeous, that is, without a covering. Now look at the fertile catkin. Each pistil will, like the stamens, be found to spring from the axil of a scale (Fig. 71). The stigma is two-lobed, and, on carefully opening the ovary, you observe that though there is but one cell yet there are *two rows of seeds*. We therefore infer that the pistil consists of two carpels. The pistillate flowers, like the staminate, are achlamydeous. In diœcious plants

HEART-LEAVED WILLOW.

ORGAN.	No.	COHESION.	ADHESION.	REMARKS.
Calyx.	0			
Corolla.	0			
♂ Stamens.	2	Diandrous.	0	
♂ Pistil.	0			
♀ Stamens.	0			
♀ Pistil. *Carpels.*	2	Syncarpous.	0	

the process of fertilization is assisted by insects, especially when the flowers are showy or odoriferous and nectar-

Fig. 71.—Single pistillate flower of Willow.

bearing; otherwise the wind is the principal agent. Flowers which depend on insects to effect the transfer of pollen from the anther to the stigma are said to be *entomophilous.* Those which depend upon the wind are *anemophilous.* The Willow belongs to the former class.

75. Maple. In early spring, while the branches are as yet bare of leaves, our Red Maples are covered with a profusion of scarlet and yellow blossoms, and the air about them is alive with busy insects gathering honey for themselves, and performing at the same time an important service for the trees in return; for it will be found on examining a few of the trees that, like the Willow, they do not all bear the same kind of flowers. In some, the ends of the reddish twigs will present the appearance shown in Fig. 72, with numerous stamens protruding from the scaly lateral buds. On looking into one of these buds it will be found that there are several flowers on short pedicels, each like that shown in Fig. 73, except that the number of stamens will probably be found to be somewhat variable. Observe the fleshy disk in the bottom of the calyx, upon which the stamens are inserted. These flowers with the projecting stamens are without pistils. They produce nothing but pollen, and the tree upon which you find them produces no other kind.

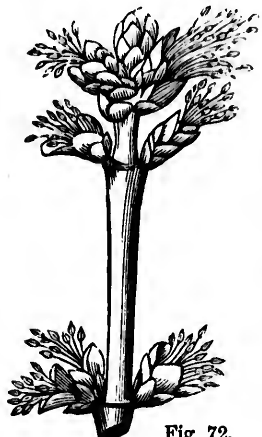


Fig. 72.

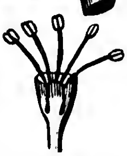


Fig. 73.

Fig. 72.—Twig of Red Maple bearing staminate flowers.
Fig. 73.—Single staminate flower. (Wood & Steele).

In other trees, the twigs will be found to resemble Fig. 74. The scaly buds are present, and the clusters of flowers within them as before, but the projecting stamens are wanting. If stamens are present at all, they are short and almost concealed in the calyx, as shown in Fig. 75, where two anthers are just visible over the edge of the calyx. The centre of the flower is occupied by a syncarpous pistil, having a two-celled ovary and two long styles, as shown in the figure.

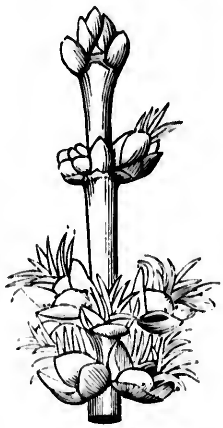


Fig. 74.

Fig. 75.

The flowers of the Maple, therefore, being sterile or staminate upon one tree, and fertile or pistillate upon another, are, as in Willow, said to be diœcious; or, if we take into account the fact that some of the flowers have stamens as well as pistils, we shall more accurately describe the whole inflorescence (or mode of flowering) as *polygamo-diœcious.*

In Maple, as in Willow, the assistance of insects is necessary to ensure the transfer of the pollen to the stigma. The flowers are, therefore, entomophilous.

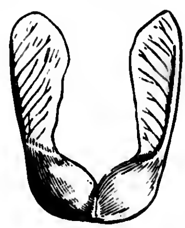


Fig. 76.

After fertilization, a *wing* is developed from the back of each of the two carpels, and the pedicels lengthen, so that as the fruit ripens it presents the familiar aspect of hanging clusters of double *samaras*, as these winged fruits are called (Fig. 76).

Fig. 74.—Twig of Red Maple bearing pistillate flowers.
Fig. 75.—Single pistillate flower. (Wood & Steele.)
Fig. 76.—Winged fruit or samara of Maple.

The Red Maple ripens its seeds early in the summer, and these, on falling, germinate immediately, so that by the autumn of the same year a vigorous young tree, a foot or more in height, is produced. The seeds will not germinate if kept over till the following spring.

The Sugar Maple, on the other hand, flowers later, the leaves and flowers appearing about the same time, and the seeds do not ripen till the fall. If kept slightly moist through the winter they will germinate the following spring.

76. The several species of common occurrence should be carefully studied and distinguished. Their characteristics are given in the proper place in Part II.

The Maples form a subordinate group of the natural Order *Sapindaceæ*. They are distinguished by the following characters:

1. *The flowers are diœcious (or polygamo-diœcious), and commonly unsymmetrical.*
2. *The ovary is two-lobed and two-celled, with two ovules in each cell, only one of which, however, is ripened.*
3. *The fruit is a double samara.*
4. *The leaves are opposite.*

77. From this type there are important deviations in other representatives of the Order. Horse-chestnut, for instance, while its flowers are unsymmetrical and somewhat irregular, as in the Maples, produces a *three-celled* ovary, with two ovules in each cell. But as in Maple, again, only one ovule in each cell forms a seed. The fruit, however, is not a samara, but a leathery pod which splits into three pieces at maturity, liberating the three large shining seeds.

Schedules descriptive of the Maple should be filled up, taking that of Willow as the model.

CHAPTER XI.

CHARACTERISTICS POSSESSED IN COMMON BY ALL THE PLANTS PREVIOUSLY EXAMINED—STRUCTURE OF THE SEED IN DICOTYLEDONS.

78. Before proceeding further in our examination of plants, we shall direct your attention to some characters of those already examined, which they all possess in common. The leaves of every one of them are *net-veined.* Some leaves, at least, of each of them have distinct petioles and blades. The parts of the flowers we found, as a general thing, to be in *fives.* In one or two instances they were in *fours*, that is four sepals, four petals, and so on.

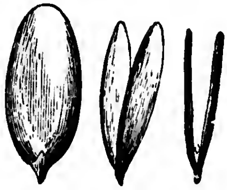


Fig. 77. Fig. 78. Fig. 79.

79. Now, in addition to these resemblances, there are others which do not so immediately strike the eye, but which, nevertheless, are just as constant. One of these is to be found in the structure of the embryo. Take a Cucumber or a Pumpkin seed, and having soaked it for some time in water, remove the outer coat. The body of the seed will then readily split in two, except where the parts are joined at one end (Figs. 77, 78, 79). The thick lobes are called *cotyledons*, or *seed-leaves*, and as there are two, the embryo is *dicotyledonous.* The pointed end where the cotyledons

Figs. 77, 78, 79.—Different views of Pumpkin seed, showing radicle, cotyledons, and plumule.

are attached, and from which the root is developed, is called the *radicle*, a term meaning "little root." As it is strictly, however, a rudimentary *stem*, and not a root, the term *caulicle* would be better. Between the cotyledons, at the summit of the radicle, you will find a minute upward projection. This is a bud, which is known as the *plumule*. It developes into the stem.

80. If you treat a Pea or a Bean (Figs. 80, 81) in the same manner as the Cucumber seed, you will find it to be constructed on the same plan. The embryo of the Bean is dicotyledonous also. But you will observe that in these cases the embryo occupies the whole of the interior of the seed. In describing the seed of the Buttercup, it was pointed out that the embryo occupies but a very small space in the seed, the bulk of the latter consisting of *albumen*. Seeds like those of the Buttercup are therefore called *albuminous* seeds, while those of the Bean and Pea are *exalbuminous*. But, notwithstanding this difference in the structure of the seed, the *embryo* of the Buttercup, when examined under a strong magnifier, is found to be dicotyledonous like the others. In short, the dicotyledonous embryo is a character common to all the plants we have examined—common, as a rule, to all plants possessing the other characters enumerated above. From the general constancy of all these characters, plants possessing them are grouped together in a vast Class, called Dicotyledonous plants, or, shortly, **Dicotyledons.**

Fig. 80.

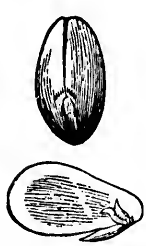


Fig. 81.

Figs. 80 and 81.—Seed of the Bean.

81. Besides the characters just mentioned, there is still another one of great importance which Dicotyledons possess in common. It is *the manner of growth of the stem.* In the Willow, and all our trees and shrubs without exception, there is an outer layer of bark on the stem, and the stem increases in thickness, year by year, by forming a new layer just inside the bark and *outside the old wood.* These stems are therefore called *exogenous*, that is, *outside growers.*

Now, in all Dicotyledonous plants, whether herbs, shrubs, or trees, the stem thickens in this manner, so that **Dicotyledons** are also **Exogens**.

CHAPTER XII.

EXAMINATION OF COMMON PLANTS CONTINUED—DOG'S-TOOTH VIOLET—TRILLIUM—IRIS—ORCHIS.

82. **Dog's-tooth Violet.** This plant (Fig. 82), which flowers in spring, may be pretty easily recognized by its peculiar blotched leaves. It may be found in rich, moist pasture lands and low copses. The name "Violet" is somewhat unfortunate, because the plant is not in any way related to the true Violets. To obtain a complete specimen requires some trouble, owing to the fact that the root is commonly six inches or so below the surface of the ground; you must therefore insert a spade or strong trowel sufficiently deep to avoid cutting or breaking the tender stem. Having cleared away the adhering earth, you will find that the roots proceed from what appears to be the

swollen end of the stem. This swollen mass is coated on the outside with thin scales. A section across the middle shows it to be more or less solid, with the stem growing

Fig. 82.

up through it from its base. It is, in fact, not easy to say how much of this stem-like growth is in reality stem,

Fig. 82.—Dog's-tooth Violet.

because it merges gradually into the scape, which bears the flower, and the petioles of the leaves, which sheathe the scape. The swollen mass is called a *bulb.*

83. The leaves are two in number, gradually narrowing at the base into sheaths. If you hold one of them up to the light, you will observe that the veins do not, as in the leaves of the Dicotyledonous plants, form a network, but run only in one direction: namely, from end to end of the leaves. Such leaves are consequently called *straight-veined.*

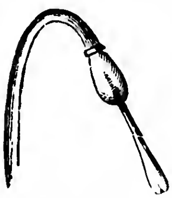


Fig. 83.

84. In the flower there is no appearance of a green calyx. There are six yellow leaves, nearly alike, arranged in two sets, an outer and an inner, of three each. In such cases, we shall speak of the coloured leaves collectively as the *perianth.* If the leaves are free from each other we shall speak of the perianth as *polyphyllous,* but if they cohere we shall describe it as *gamophyllous.* Stripping off the leaves of the perianth, we find six stamens with long upright anthers which open along their outer edges. If the anthers be pulled off, the filaments will be found to terminate in long, sharp points.

The pistil (Fig. 83) has its three parts—ovary, style, and stigma—well marked. The stigma is evidently formed by the union of three into one. The ovary, when cut across, is seen to be three-celled (Fig. 84), and is, therefore, syncarpous.

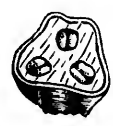


Fig. 84.

Fig. 83.—Pistil of Dog's-tooth Violet.
Fig. 84.—Cross section of the pistil.

DOG'S-TOOTH VIOLET.

ORGAN.	No.	COHESION.	ADHESION.	REMARKS
Perianth.		Polyphyllous.	Inferior.	
Leaves.	6			
Stamens.	6	Hexandrous.	Hypogynous.	Filaments terminating in sharp points.
Pistil.		Syncarpous.	Superior.	
Carpels.	3			

Fig. 85.

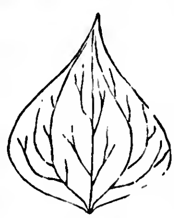


Fig. 87.

Fig. 86.

85. **Trillium.** This plant (Fig. 85) may be found in flower about the same time as the one just described. The perianth of Trillium consists of six pieces in two sets, but in this case the three outer leaves are green, like a common calyx. The stamens are six in number. There are three styles, curving outwards, the whole of the inner side of each being stigmatic. The ovary (Fig. 86) is six-angled, and on being cut across is seen to be three-celled.

Fig. 85.—Trillium. Fig. 86.—Cross section of the pistil.
Fig. 87.—Net-veined leaf of Trillium.

86. Comparing this flower with that of Dog's-tooth Violet, we find the two to exhibit a striking resemblance in structure. But in one respect the plants are strikingly unlike: *the leaves of the Trillium are net-veined* (Fig. 87), as in the Exogens. From this circumstance we learn that we cannot altogether rely on the veining of the leaves as a *constant* characteristic of plants whose parts are not in fives.

TRILLIUM.

ORGAN.	NO.	COHESION.	ADHESION.	REMARKS.
Perianth.		Polyphyllous.	Inferior.	Sepals persistent.
Sepals.	3			
Petals.	3			
Stamens.	6	Hexandrous.	Hypogynous.	
Pistil.		Syncarpous.	Superior.	The inner face of each style stigmatic.
Carpels.	3			
Leaves net-veined.				

87. The two plants just examined are types of the natural Order *Liliaceæ*. The distinguishing characters are as follows:

1. *The parts of the flower are almost invariably in sets of three, the perianth being of two such sets, and also the stamens. The flowers are therefore symmetrical; they are also regular.*
2. *The stamens are opposite the divisions of the perianth.*
3. *The ovary is nearly always 3-celled, and is superior.*

The representatives of this large Order are very numerous. From the gardens may be had lilies of various sorts, Asparagus, Star-of-Bethlehem, Tulip, Onion, Hyacinth, &c., whilst the fields and woods supply the Bellwort, Clintonia, Solomon's Seal, Smilacina, and others. As a rule the plants flower in spring and early summer.

88. **Iris.** For this lesson any variety of the common garden Flag will answer very well. In our marshes in early summer abundant specimens of a wild species may be obtained without much trouble, but the cultivated plants will probably be more accessible. Note first the fleshy underground stem or root-stock, with the fibrous roots below (Fig. 88). If you have a sufficient length of this root-stock you will notice the scars upon the older portions, showing where the leaves of former seasons have been sent up. The new buds expand into a crowded cluster of leaves, the shape and arrangement of which should be carefully observed. Cut the whole cluster across near the base, and the section will be as represented in Fig. 89, the section of each leaf being V-shaped,

Fig. 89.

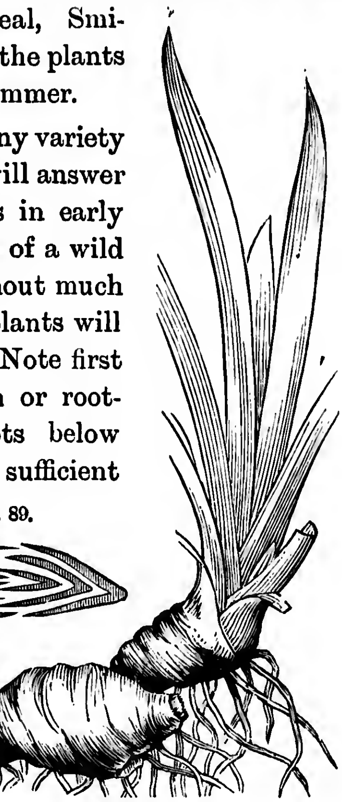


Fig. 88.

Fig. 88.—Root-stock and leaves of Iris. (Gray.)
Fig. 89.—Cross section of cluster of equitant leaves. (Gray.)

and *astride* the next one within. Leaves disposed in this manner are consequently said to be *equitant* (*eques*, a horseman). As the leaf rises upward it alters in shape, becoming flat and sword-like. Besides being equitant, these leaves, on account of their direction, are described as *vertical.* You will observe, also, that they are straight-veined.

From the centre of the cluster of leaves rises the scape which bears the flower. If your specimen has a flower-bud upon it, as is most likely, you will notice the way in which its leaves are folded. The mode of folding here exhibited is common to a great many flowers, and is described as *convolute.* In the full-blown flower the perianth will be found to consist of six pieces, in two distinct sets of three each; the outer three are considerably larger than the others, and are bent backwards or *reflexed;* the inner ones are erect. There are three stamens, each of them beneath and close against an over-arching body, the nature of which is not at first quite manifest. Cut away the perianth and the stamens, and you will then have left the three radiating coloured arches (Fig. 90), which will be seen to unite below into a slender column. You have also left what is apparently the swollen top of the scape. This, when cut across, is found to be a three-celled ovary, which is thus, of course, *inferior.* The slender column above is the style, and the

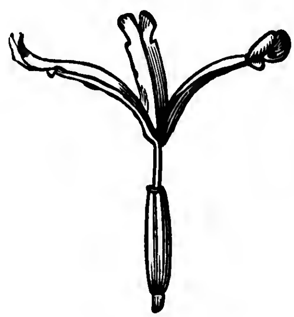


Fig. 90.

Fig. 90.—Pistil of Iris. (Wood and Steele.)

three petal-like arches are its branches. Immediately beneath the tip of each arch will be found a thin lip or plate, which is the stigma.

The anthers open *outwards* to discharge the pollen, and this fact, in addition to the peculiar situation of the anther as regards the stigma, makes it almost impossible that self-fertilization should take place in this flower. As was the case with other flowers already examined, the Iris is honey-bearing, and, besides, exceedingly showy. The nectar is situated in a cavity at the bottom of the flower, and cross-fertilization is accomplished by the aid of insects. It will be remembered that flowers thus fertilized are said to be entomophilous.

89. The Crocus and Gladiolus of the gardens and the Blue-eyed Grass of our low meadows may be examined and compared with the Iris. They are all types of the natural Order *Iridaceæ*, which you will observe differs from *Liliaceæ* chiefly in having flowers with only three stamens and an inferior ovary.

IRIS.

ORGAN.	No.	COHESION.	ADHESION.	REMARKS.
Perianth. *Leaves.*	6	Gamophyllous	Superior.	2 sets. Outer, large and reflexed; inner, erect.
Stamens.	3	Triandrous.	Perigynous.	Opposite the stigmas.
Pistil. *Carpels.*	3	Syncarpous.	Inferior.	Stigmas petal-like, arching over the extrorse anthers.

90. **Showy Orchis.** The flower of this plant (Figs. 91, 92) is provided with floral envelopes, all coloured like a corolla. As in Dog's-tooth Violet, we shall call them collectively the perianth, although they are not all alike. One of them projects forward in front of the flower,

Fig. 91.

forming the *lip*, and bears underneath it a long, hollow *spur* which, like the spurs of Columbine, is honey-bearing. The remaining five converge together, forming a kind of

Fig. 91.—Showy Orchis.

arch over the centre of the flower. Each flower springs from the axil of a leaf-like bract, and is apparently raised on a pedicel. What seems to be a pedicel, however, will, if cut across, prove to be the ovary, which in this case is inferior. Its situation is similar to the situation of the ovary in Willow-herb, and, as in that flower, so in this the calyx-tube adheres to the whole surface of the ovary, and the three outer divisions of the perianth are simply upward extensions of this tube. Notice the peculiar *twist* in the ovary. The effect of this twist is to turn the lip away from the scape, and so give it the appearance of being the lower petal instead of the *upper* one, as it really is.


Fig. 92.

91. The structure of the stamens and pistil remains to be examined, and a glance at the flower shows you that we have here something totally different from the common arrangement of these organs. In the axis of the flower, immediately behind the opening into the spur, there is an upward projection known as the *column*. The face of this column is the stigma; on each side of the stigma, and adhering to it, is an anther-cell. These cells, though separated by the column, constitute but a *single stamen*. The stamen, then, in this case is *united with the pistil*, a condition which is described as *gynandrous*.


Fig. 93.

92. If you have a flower in which the anther-cells are bursting open, you will see that the pollen does not issue from them in its usual dust-like form, but if you use the

Fig. 92.—Single flower of Orchis.
Fig. 93.—Pollen-mass of Orchis, greatly enlarged.

point of your needle carefully you may remove the contents of each cell *in a mass*. These pollen-masses are of the form shown in Fig. 93. The grains are kept together by a fine tissue or web, and the slender stalk, upon which each pollen-mass is raised, is attached by its lower end to a sticky disk on the front of the stigma just above the mouth of the spur. Insects, in their efforts to reach the honey, bring their heads in contact with these disks, and, when they fly away, carry the pollen-masses with them and deposit them on the stigma of the next flower visited. In fact, it is difficult to see how, without the aid of insects, flowers of this sort could be fertilized at all.

SHOWY ORCHIS.

Organ.	No.	Cohesion.	Adhesion.	Remarks.
Perianth.		Gamophyllous	Superior.	
Leaves.	6			
Stamens.	1	Monandrous.	Gynandrous.	Pollen-grains collected in masses.
Pistil.		Syncarpous.	Inferior.	
Carpels.	3			Ovary twisted.

93. Showy Orchis is a representative of the vast Order *Orchidaceæ*, the members of which are chiefly tropical. Some of our handsomest Canadian wild flowers, however, belong to it, such as the Lady's Slipper, the Rattlesnake Plantain, the beautiful little Calypso, and the Habenarias. Most of our orchids will be found in low and wet situations, and they flower rather early

in the year. The most remarkable characteristics of the Order are the gynandrous arrangement of the stamen or stamens, and the cohesion of the pollen-grains, though this latter peculiarity is exhibited also by other groups —notably, the Milkweeds.

CHAPTER XIII.

EXAMINATION OF SPADICEOUS PLANTS—INDIAN TURNIP—CALLA.

94. **Indian Turnip.** This plant may be easily met with in our woods in early summer. If you are not familiar with its appearance, the annexed cut (Fig. 94) will help you to recognize it. Procure several specimens: these will probably at first seem to you to be alike in every respect, but out of a number some are pretty sure to differ from the rest. Notice the bulb from which the stem springs. It differs from that of the Dog's-tooth Violet, and Lilies generally, in having a much larger solid part. It is called a *corm.* Between the pair of leaves you observe a curious striped sheath, having an arching, hood-like top, and enclosing an upright stalk, the top of which almost touches the hood (Fig. 95). Can this be a flower? It is certainly the only thing about the plant which at all resembles a flower, and yet how different it is from any we have hitherto examined! Carefully cut away the sheaths

from all your specimens. Most, and perhaps all, of them will then present an appearance like that in Fig. 96. If none of them be like Fig. 97 it will be well to gather a few more plants. We shall suppose, however,

Fig. 94.

that you have been fortunate in obtaining both kinds, and will proceed with our examination. Take first a specimen corresponding with Fig. 96. Around the base of the column are compactly arranged many spherical green bodies, each tipped with a little point. Separate

Fig. 94.—Indian Turnip.

one of these from the rest and cut it across. It will be found to contain several ovules, and is, in fact, an ovary, the point at the top being a stigma. In the autumn a great change will have taken place in the appearance of plants like the one we are now examining. The arched hood will have disappeared, as also the long naked top of the column, whilst the part below, upon which we are now engaged, will have vastly increased in size, and become a compact ball of red berries. There can be no doubt, then, that we have here a structure analogous to that found in the Cucumber and the Willow, the fertile, or pistillate, flowers being clustered together separately. But in the Cucumber all the flowers were observed to be furnished with calyx and corolla, and in the Willow catkins, though floral envelopes were absent, each pair of stamens and each pistil was subtended by a bract. In the present plant there are no floral envelopes, nor does each pistil arise from a separate bract.

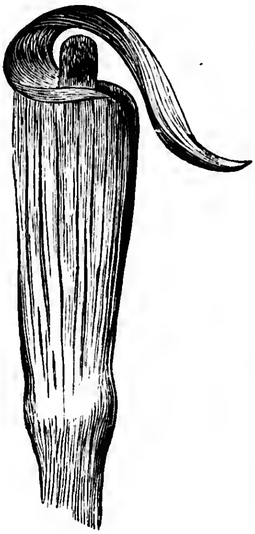


Fig. 95.

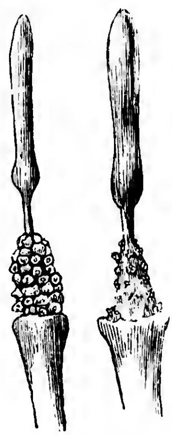


Fig. 96. Fig. 97.

95. But, you will now ask, what is this sheathing hood which we find wrapped about our column of pistils?

Fig. 95.—Spathe of Indian Turnip.
Fig. 96.—Fertile spadix of the same. Fig. 97.—Sterile spadix.

There is no doubt that we must look upon it as a *bract*, because from its base the flower-cluster springs. So that, whilst the flowers of Indian Turnip are, like those of Willow, imperfect and diœcious, the clusters differ in having but a single bract instead of a bract under each flower.

96. We must now examine one of the other specimens; and we shall have no difficulty in determining the nature of the bodies which, in this case, cover the base of the column. They are evidently stamens, and your magnifying-glass will show you that they consist mostly of anthers, the filaments being extremely short, and that some of the anthers are two-celled and some four-celled, all discharging their pollen through little holes at the top of the cells.

INDIAN TURNIP.

ORGAN.	NO.	COHESION.	ADHESION.
♂ Stamens.	1	Monandrous.	0
♀ Pistil.		Apocarpous.	0
Carpels.	1		

Flowers crowded on a spadix, and surrounded by a spathe.
Leaves net-veined.

97. The column upon which, in plants like Indian Turnip, the flowers are crowded, is known as a *spadix*, and the surrounding bract as a *spathe*.

You will observe that the leaves of this plant are *net-veined*, as we found them in the Trillium.

98. **Marsh Calla.** This plant must be looked for in low, marshy grounds, where it will be found in flower generally in the month of June. With the knowledge which you have of the structure of Indian Turnip, you

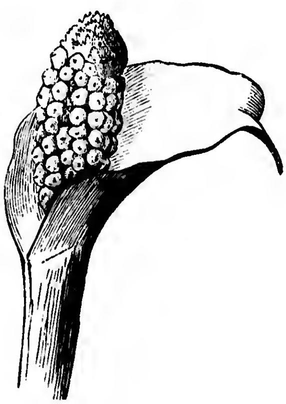


Fig. 98.

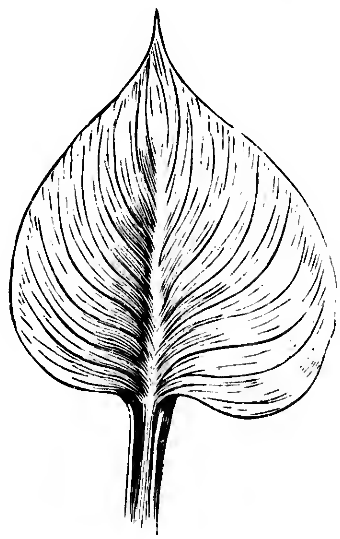


Fig. 99.

will hardly doubt that the Calla is closely related to it. You will easily recognize the spadix and the spathe (Fig. 98), though in the present instance the spadix bears flowers to the top, and the spathe is open instead of enclosing the column. Observe, however, that the veining of the leaf (Fig. 99) is different, that of Calla being straight, like the Dog's-Tooth Violet. There is also a difference in the flowers. Those of Indian Turnip were found to be diœcious, but the spadix, in the present

Fig. 98.—Spadix and spathe of Marsh Calla.
Fig. 99.—Leaf of the same.

case, bears both stamens and pistils, and most of the lower flowers, if not all, are *perfect;* sometimes the upper ones consist of stamens only. Fig. 100 shows one of the perfect flowers much enlarged. The stamens, it will be observed, have two-celled anthers, opening lengthwise.

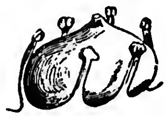


Fig. 100.

MARSH CALLA.

ORGAN.	NO.	COHESION.	ADHESION.
Perianth.		Wanting.	
Stamens.	6	Hexandrous.	Hypogynous.
Pistil.		Apocarpous.	Superior.
Carpels.	1		

99. These two plants, Indian Turnip and Marsh Calla, are representatives of the Order *Araceæ.* The characters which distinguish it are very well displayed in the two types we have selected for examination. The great feature is the aggregation of the flowers on a spadix. Generally, though not invariably, a spathe is also present. Among wild plants the Skunk Cabbage and Sweet Flag (the latter without a spathe) are common Araceous types, while the familiar green-house and window plant, known as the Calla-Lily, will serve very well for examination in winter. It may be added that the plants of this Order have a very acrid juice.

Fig. 100.—Perfect flower of Calla.

CHAPTER XIV.

EXAMINATION OF GLUMACEOUS PLANTS—TIMOTHY AND OTHER GRASSES.

100. **Timothy.** The top of a stalk of this well-known grass is cylindrical in shape, and upon examination will be found to consist of a vast number of similar pieces compactly arranged on very short pedicels about the stalk as an axis. Carefully separate one of these pieces from the rest, and if the grass has not yet come into flower the piece will present the appearance shown in Fig. 101. In this Fig. the three points in the middle are the protruding ends of stamens. The piece which you have separated is, in fact, a flower enclosed in a pair of bracts, and all the other pieces which go to make up the top are flowers also, and, except perhaps a few at the very summit of the spike, precisely similar to this one in their structure.

Fig. 101.

Fig. 102.

101. Fig. 102 is designed to help you in dissecting a flower which has attained a greater degree of development than the one shown in Fig. 101. Here the two bracts which enclose the flower have been drawn asunder. To these bracts the name *glumes* is applied. They are present in all plants of the Grass Family, and are often

Fig. 101.—Closed flower of Timothy.
Fig. 102.—Expanded flower of the same.

found enclosing several flowers instead of one as in Timothy. Inside the glumes will be found a second pair of minute chaff-like bracts, which are known as *palets* or *pales*. These enclose the flower proper.

102. The stamens are three in number, with the anthers fixed by the middle to the long slender filament. The anthers are therefore *versatile*. The styles are two in number, bearing long, feathery stigmas. The ovary contains a single ovule, and when ripe forms a seed-like *grain*, technically known as a *caryopsis*.

TIMOTHY.

ORGAN.	No.	COHESION.	ADHESION.
Glumes.	2		
Palets.	2		
Stamens.	3	Triandrous.	Hypogynous.
Pistil.		Apocarpous.	Superior.
Carpels.	1		

103. It will be observed that the stalk of Timothy is hollow except at certain swollen knot-like joints. This peculiar stem of the Grasses is called a *culm*. Occasionally, however, it is not hollow. The leaves are long and narrow and straight-veined, and each of them at its base surrounds the culm with a *split sheath*. Observe also that at the

junction of the blade and the sheath there is a thin appendage which is called a *ligule*.

104. In many grass-flowers, besides the parts described above there will be found one or two minute scales below the pistil. These are known as *lodicules*, and are analogous to the perianth in ordinary flowers. They are, on account of their minuteness, very liable to be overlooked in a superficial examination.

Fig. 104. Fig. 103.

105. The immense Order *Gramineæ* (Grass Family) includes all our valuable grains, and is, on the whole, the most important and useful of all the Orders. Its representatives are to be found in every part of the world, and they vary in size from the stunted growths of the polar regions to the tree-like Bamboo of the tropics. Wheat, Indian Corn, Barley, Oats, Rye, Sugar-cane, Rice, are all Grasses, as well as the plants which make the verdure of our meadows and pastures. The flowers of all are very similar, but the Order is sub-divided on the basis of

Fig. 103.—Panicle of Red-top.
Fig. 104.—Single flower. (Gray.)

modifications which will be best understood by studying a few examples.

Fig. 105.

106. Procure specimens of the common Red-top, and first compare the general aspect of the flower-cluster (Fig. 103) with that of Timothy. Instead of a dense spike we have here a loose, open inflorescence; it is technically known as a *panicle*. You will see that it is an irregular branched raceme. As in Timothy, *each pair of glumes encloses but one flower* (Fig. 104), and we must observe that the term *spikelet*, so far as Grasses are concerned, is applied to the pair of glumes and whatever is contained in them, whether one flower, or many, as is often the case. In Red-top and Timothy, *the spikelets are 1-flowered.* Observe the very thin texture of the *palets*, and also that one of them (the lower, *i.e.*, the one farthest from the stalk) is nearly twice as large as the other, and is marked with three nerves.

Fig. 106.

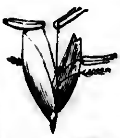


Fig. 107.

Fig. 105.—Common Meadow-Grass.
Fig. 106.—Spikelet enlarged, showing the glumes at the base.
Fig. 107.—Single flower of same.

107. Next let us inspect a specimen of the Common Meadow-Grass. The inflorescence of this very common grass (Fig. 105) is a greenish panicle. The spikelets (Fig. 106) contain from three to five flowers, and are laterally compressed. The *glumes* are the lowest pair of scales, and they are generally shorter than the flowers within them. Observe the delicate whitish margin of the lower palet of each flower (Fig. 107), and the thin texture of the upper one. Count also, if you can, the five nerves on the lower palet, and observe the two teeth at the apex of the upper one. In this Grass the principal thing to notice is that *there are several flowers within each pair of glumes.*

108. A common pest in wheat-fields is the Grass known as Chess. It is comparatively easy of examination on account of the size of the spikelets (Fig. 108) and flowers. The spikelets form a spreading panicle, each of them being on a long, slender, nodding pedicel, and containing from eight to ten flowers. Of the two glumes at the base of each spikelet one is considerably larger than the other. The outer or lower palet of each flower is tipped with a bristle or *awn* (Fig. 109), while *the upper palet at length becomes attached to the groove of the oblong grain.* Observe that the *glumes* are not awned.

Fig. 108. Fig. 109.

109. The Couch Grass is another very common weed in cultivated grounds. In this Grass the spikelets are

Fig. 108.—Spikelet of Chess. Fig. 109.—Single flower. (Gray.)

sessile on opposite sides of the zigzag peduncle, so that the whole forms a spike. Each spikelet is four- to eight-flowered, and there is but one at each joint of the peduncle, the *side* of the spikelet being against the stalk. The glumes are nearly equal in size, and the lower palet of each flower closely resembles the glumes, but is sharp-pointed or awned. The grass spreads rapidly by running root-stocks, and is troublesome to eradicate.

110. Old-Witch Grass is to be found everywhere in sandy soil and in cultivated grounds. The leaves are very hairy, and the panicle very large, compound, and loose, the pedicels being extremely slender. Of the two glumes one is much larger than the other. Unless you are careful you will regard the spikelets as 1-flowered; observe, however, that in addition to the one manifestly perfect flower *there is an extra palet below.* This palet (which is very much like the larger glume) is a rudimentary or abortive second flower, and the spikelet may be described as $1\frac{1}{2}$-flowered.

111. Barnyard Grass is a stout, coarse plant, common in manured soil. It is from one to four feet in height, and branches from the base. The spikelets form dense spikes, and these are crowded in a dense panicle which is rough with stiff hairs. The structure of the spikelets is much the same as in Old-Witch Grass, but the palet of the neutral flower is pointed with a rough awn or bristle.

112. In the common Foxtail the inflorescence is apparently a dense, bristly, cylindrical spike. In reality, however, it is a spiked panicle, the spikelets being much the same as in Barnyard Grass, but their *pedicels* are prolonged beyond them into awn-like bristles. In this

plant the bristles are in clusters and are barbed upwards. *The spikes are tawny-yellow in colour.*

113. These examples, if conscientiously studied with the aid of the plants themselves, will give you a good general idea of the kinds of variation which may be looked for in the Grasses. They may be said, roughly, to consist in the presence or absence of glumes, of awns, and of the upper palet; in the general aspect of the whole flower-cluster; in the number of flowers in the spikelets; and in the varying relative size of the glumes and of the palets.

114. The Order as a whole is distinguished by the following characters:

1. *The sheaths of the leaves are split on the side of the culm opposite the blade.*
2. *The separate flowers are enclosed in glumaceous bracts called palets.*
3. *The perianth is represented by the lodicules.*
4. *The stamens are three in number, and the pistil is syncarpous (two carpels), with a one-celled ovary producing a single seed, which is always albuminous with the embryo on one side.*

CHAPTER XV

COMMON CHARACTERISTICS OF THE PLANTS JUST EXAMINED—STRUCTURE OF THE SEED IN MONOCOTYLEDONS.

115. It is now to be pointed out that the plants examined in the last three chapters, though differing in various particulars, yet have some characters common to all of them, just as the group ending with Maple was

found to be marked by characters possessed by all its members. The flowers of Dicotyledons were found to have their parts, as a rule, in fours or fives; those of our second group have them in *threes* or *sixes*, never in fives.

116. Again, the leaves of these plants are straight-veined, except in Trillium and Indian Turnip, which must be regarded as exceptional, and they do not as a rule exhibit the division into petiole and blade which was found to characterize the Exogens.

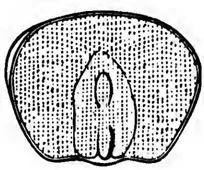


Fig. 110.

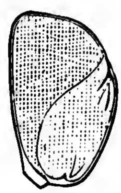


Fig. 112.


Fig. 111.

117. We shall now compare the structure of a grain of Indian Corn with that of the Cucumber or Pumpkin seed which we have already examined (page 59). It will facilitate our task if we select a grain from an ear which has been boiled. And, first of all, let us observe that the grain consists of something more than the seed. The grain is very much like the achene of the Buttercup, but differs in this respect, that the outer covering of the former is completely united with the seed-coat underneath it, whilst in the latter the true seed easily separates from its covering. Remove the coats of the grain, and what is left is a whitish, starchy-looking substance, having a yellowish body inserted in a hollow (Fig. 110) in the middle of one side. This latter body is the *embryo*, and may be easily removed. All the rest is *albumen.* Fig. 111 is a front view of the embryo, and Fig. 112 shows a vertical section of the same. The greater part of the

Figs. 110, 111, 112.—Sections of a grain of Indian Corn. (Gray.)

embryo consists of a *single cotyledon.* The radicle is seen near the base, and the plumule above. Compare an Oat (Fig. 113) with the grain of Corn and make out the corresponding parts. In all essential particulars they are alike.

118. Comparing the result of our observations with what we have already learned about the Cucumber seed, we find that whilst in the latter there are *two* cotyledons, in the present case there is but *one*, and this peculiarity is common to all the plants just examined, and to a vast number of others besides, which are consequently designated **Monocotyledonous** plants, or shortly **Monocotyledons.** The seeds of this great group may differ as to the presence or absence of albumen, just as the seeds of Dicotyledons do, but in the *number* of their cotyledons they are all alike. The Orchids, however, are very peculiar from having no cotyledons at all.

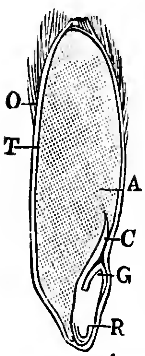


Fig. 113.

119. In addition to the points just mentioned, viz: the number of floral leaves, the veining of the foliage leaves, the usual absence of distinct petioles, and the single cotyledon, which characterize our second great group, there is still another, as constant as any of these, and that is, the mode of growth of the stem, which is quite at variance with that exhibited in Dicotyledonous plants. In the present group the increase in the thickness of the stem is accomplished not by the deposition of circle after circle of new wood outside the old, but by the production of new wood-fibres through the interior of the stem generally. These stems are therefore said to be

Fig. 113. — Vertical section of Oat grain; R, radicle; G, plumule; C, cotyledon; A, albumen (or endosperm); O, hairs; T, testa. (Thomé.)

endogenous, and the plants composing the group are called **Endogens,** as well as **Monocotyledons**. The term Endogen, however, is used in quite a different sense by some recent botanists, and is discarded by them as a synonym for monocotyledon, as having been given originally under a misconception as to the true mode of growth of the wood in stems of this kind. We shall explain more fully the structure of exogenous and endogenous stems when we come to speak of the minute structure of plants in a subsequent chapter.

120. The typical flower of the Monocotyledons is that of the Lily; it consists of five whorls, two belonging to the perianth, two to the anthers, and one to the pistil. Other flowers of the group, as we have seen, exhibit departures from the type, chiefly in the suppression of whorls or parts of whorls. Thus in the Iris one whorl of stamens is suppressed. In this plant, also, the ovary is *inferior*. In the spadiceous plants the perianth is suppressed, and in the Grasses there may be suppression in all the whorls.

CHAPTER XVI.

EXAMINATION OF CONIFEROUS PLANTS—WHITE PINE—GROUND-HEMLOCK.

121. The cone-bearing trees are so striking and important a feature in Canadian vegetation that even an elementary work like the present would be incomplete without a notice of them. They form, besides, a very distinct group of plants, intermediate in structure, as we shall see, between the groups upon which we have so far been

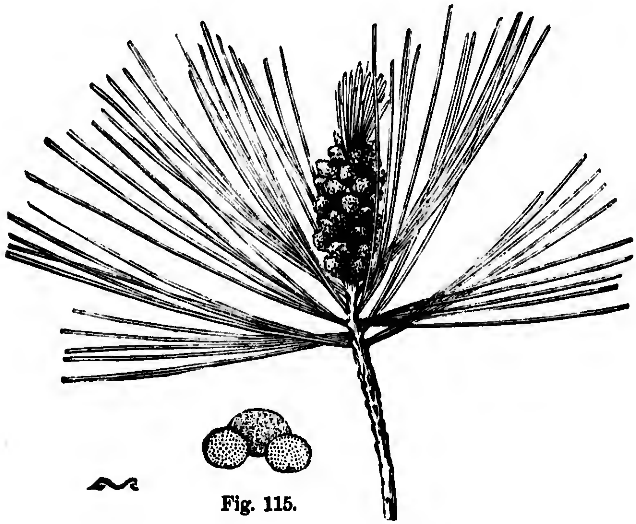


Fig. 115.

Fig. 114.

engaged and others to which we shall presently direct attention.

122. As perhaps the commonest Canadian type of the Coniferous Group, the White Pine first demands our attention. This noble tree, in its general aspect, is familiar to every one. It produces a straight trunk, which is continued upward year after year by the development of a strong terminal bud, the new branches of each year being developed from a circle of lateral buds formed behind the apex of the stem or old branch. The general aspect of the tree, therefore, unless it is a very old one, is that of a broad-based cone or spire. The leaves are straight

Fig. 114.—Leaves and cluster of staminate catkins of White Pine. (Wood and Steele.)

Fig. 115.—Pollen-grain of Pine. (Wood and Steele.)

needles, and are produced in clusters of five each. In the Red Pine, on the other hand, there are but two leaves in the cluster. Other species have bundles of three each. These leaves, as is well known, are *evergreen*, that is to say, they do not perish in the first autumn, but persist through the winter and until the new leaves of the following season are fully developed.

123. The flowers of the Pine must be looked for in spring just before the new leaves are put forth. They are monœcious or diœcious. The staminate flowers, consisting of a single stamen each, are produced around the bases of the new shoots, where they form dense clusters of small catkins (Fig. 114). Each anther is two-celled, and the pollen-grains (Fig. 115) are rather peculiar in shape, having, in fact, the appearance of three grains cohering together. The two outer portions, however, are only bladder-like developments of the outer coat *(extine)* of the real grain, which occupies the centre.

Fig. 116.

124. The pistillate or fertile flowers are aggregated together upon an elongated axis, forming in fact the well-known *cone* of the Pine (Fig. 116). The young cones will be found to occupy lateral positions on the branches; each of them is made up of many spirally arranged *scales*, each scale being in the axil of a bract (Fig. 117). At the base of each scale, on the inside, will be found two ovules turned downwards (Fig. 118). Observe that these ovules *are not enclosed in an ovary.* Because of this fact the group of plants of which the Pine is a type is said to be

Fig. 116.—Cone of Pine. (Wood and Steele.)

gymnospermous, that is, naked-seeded. All the plants previously examined, on the other hand, have their seeds enclosed in ovaries; hence they are all *angiospermous*. The scales of the cone are to be regarded as open carpellary leaves, and each of them, with its pair of ovules, constitutes a fertile flower. The pollen is carried by the wind directly to the micropyle of the ovule, there being no intervening stigma; but, as the quantity of pollen produced is immense, the chances of failure to reach the ovules are very slight. At the time of pollination, the air in a pine forest is full of pollen. The yellow scum often found on water after a summer shower is chiefly Pine pollen. After fertilization the ovules develope into seeds, and the scales of the cone, which are originally of rather soft texture, attain a woody consistency. This process of maturing, however, in the Pine takes considerable time. The cones do not ripen until the autumn of the second year, after flowering. At this time the scales diverge from the axis, and the seeds are allowed to escape, each of them being now furnished with a wing, which enables the wind more readily to waft it away.

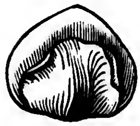


Fig. 117.

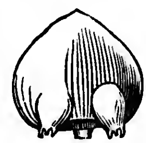


Fig. 118.

The number of cotyledons in the embryo is variable, but is always more than two; sometimes there are as many as twelve.

The wood of the Gymnosperms is essentially like that of the Dicotyledons, and the stem thickens in the same way. Certain differences will be noticed in another place.

Fig. 119.

Fig. 117.—Single scale of Pine cone with its bract. (Wood and Steele.)
Fig. 118.—Inner side of the scale, showing the two naked ovules. (Wood and Steele.)
Fig. 119.—Staminate catkins of Ground Hemlock.

125. It will be interesting now to compare with the structure of the Pine that of another member of the same group—the Ground Hemlock, a low shrub common enough in our Canadian woods. This, like the Pine, is evergreen. The leaves, however, are not needle-shaped, but flat; and they are not clustered, but project singly from the sides of the stem.

126. The staminate flowers (Fig. 119) grow in small catkins at the ends of very short lateral shoots which bear about their bases many scale-like bracts. The stamens are somewhat different from those of Pine, being umbrella-shaped (peltate), and bearing from three to eight pollen-sacs upon the under surface. The fertile flowers are also at the extremities of short, scaly-bracted branches, but in this plant the flowers occur singly, and are not aggregated in cones. Fig. 120 shows a section of a fertile branch with its bracts and the single naked ovule at its extremity. Around the base of the ovule there is a fleshy ring or disk (shown in section at *a* in the figure). The pollen is conveyed by the wind directly to the micropyle, and after fertilization, and during the development of the seed, the fleshy ring upon which it rests grows upward so as to surround the seed and give the fruit a remarkable berry-like appearance (Fig. 121). This fleshy covering (which is

Fig. 120.

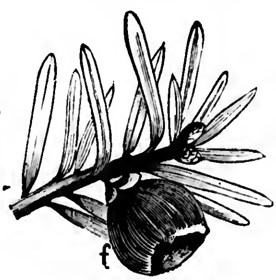


Fig. 121.

Fig. 120.—Section of fertile branch of Ground Hemlock; *s*, the apparently terminal ovule; *i*, its integument; *k*, the nucellus; *m*, the micropyle; *a a*, the rudiment of the aril, which finally surrounds the seed; *b b*, bracts. (Prantl).

Fig. 121.—The same with mature fruit, *f*. (Prantl).

bright red at maturity) is a good example of what is called an *aril.*

127. We find, then, that although there is at first sight little in common, apparently, between the cone of the Pine and the berry-like fruit of the Ground Hemlock (*Taxus baccata*), yet they both have the characteristic *naked ovules.*

128. Among our cone-bearing trees will readily be recognized the Arbor Vitæ (commonly called Cedar), the Larch or Tamarack, which, however, is not evergreen, and the various kinds of Spruce or Fir. The Juniper, also, belongs to this group, but is marked by the peculiarity that the few scales of the cone cohere together in ripening and become succulent, thus forming what looks like a berry.

129. To sum up the results of our observations upon plant-structure, we have found

(1) That all the plants to which our attention has so far been directed *produce flowers;* they are all, therefore, flowering or *phanerogamous* plants, or, briefly, *phanerogams.*

(2) That in a large number of the plants there are ovaries enclosing the seeds. All such plants are grouped as *angiosperms.*

(3) That in others the seeds are not enclosed in an ovary. Hence we have a group known as *gymnosperms.*

(4) That the angiosperms are either *dicotyledonous* or *monocotyledonous.*

These conclusions may be conveniently shown in a tabular form as follows:

- PHANEROGAMS.
  - ANGIOSPERMS.
    - DICOTYLEDONS.
    - MONOCOTYLEDONS.
  - GYMNOSPERMS.

CHAPTER XVII.

MORPHOLOGY OF ROOTS, STEMS, AND FOLIAGE-LEAVES OF PHANEROGAMS.

130. Before proceeding with the examination of other selected plants illustrative of other divisions of the vegetable kingdom, we shall present in a systematic way the more important facts in connection with the Phanerogams, dealing in turn with the organs of vegetation—the root, the stem, and the foliage-leaves—and then with the organs of reproduction as displayed in the flower. The various forms assumed by these organs, whether in different plants or in different parts of the same plant, will have our attention, as also their various modes of arrangement. We shall consider, also, rather more minutely than we have hitherto been able to do, the development of the seed from the ovule, the process of pollination and of fertilization, and the subsequent germination of the seed and development of the new plant. To this study of forms the name *Morphology* has been given. It need hardly be said that effective morphological work can only be accomplished by actual

contact with and inspection of the forms which are, for the time being, the objects of study. The young student must provide himself with specimens, and learn to associate the descriptive terms with the actual condition which the terms describe. Only in this way can this branch of botanical work be relieved of the element of drudgery, and made what it ought to be—a means of developing in a high degree those powers of observation with which the young are so exceptionally endowed. It is believed that with proper management even the more difficult technical terms, which are derived from Latin and Greek, and specially devised for botanical purposes, will be learned without extraordinary effort. It is the writer's experience that a term is insensibly acquired and almost indelibly impressed upon the mind *if there is first created the want of the term* to describe what is seen when some new form has been the subject of observation, and its peculiarities have been thoroughly grasped through the medium of the eye. With a good many of the terms there will be found no difficulty whatever, since they have the same meaning in their botanical applications as they have in their every-day use.

131. **The Root.** This organ is called the descending axis of the plant, from its tendency to grow downward into the soil from the very commencement of its development. Its chief use is to imbibe liquid nourishment, and transmit it to the stem, from which it is well distinguished by the presence of the root-cap (Fig. 122, *a*) and the absence of leaves. The absorbing surface of a young root or rootlet is largely increased by the development of *root-hairs*, the nature of which will be explained later on when we come to treat of trichomes or hair-like growths

generally. It must be mentioned here, also, that there are some exceptions to the general statement that roots do not produce buds. It is well known that new stems are sent up by the roots of Poplars and of Apple trees, for example, especially if the roots have been injured. These cases must be regarded as abnormal.

132. You will remember that in our examination of some common seeds, such as those of the Pumpkin and Bean (Figs. 77–81), we found at the junction of the cotyledons a small pointed projection called the *radicle.* Now, when such a seed is put into the ground, under favorable circumstances of warmth and moisture, it begins to grow or *germinate*, and the radicle, which in reality is a minute stem, not only lengthens, in most cases, so as to push the cotyledons upwards, but developes a *root* from its lower extremity. All seeds, in short, when they germinate, produce roots from the extremity of the radicle, and *in a direct line with it*, and roots so produced are called *primary roots.* In Monocotyledons the primary root is but very slightly developed, the fibrous roots characteristic of these plants bursting forth *from the sides* of the radicle at an early period of growth. In other plants the primary root either assumes the form of a distinct central axis larger than any of its branches, and called a *tap-root* (Fig. 123), examples of which are furnished by the Mallow, the Carrot, and the

Fig. 122.

Fig. 123.

Fig. 122.—Magnified tip of Hyacinth root; *a*, the root-cap. (Hooker.)
Fig. 123.—Tap-root of Dandelion.

Bean, or it may *branch* at an early stage into numerous similar threads, and so form a fibrous root, as in Buttercup.

133. Tap-roots receive different names according to the particular shape they happen to assume. Thus, the Carrot (Fig. 124) is *conical*, because from a broad top it tapers gradually and regularly to a point. The Radish, being somewhat thicker at the middle than at either end, is *spindle-shaped*. The Turnip, and roots of similar shape, are *napiform* (*napus*, a turnip).

Fig. 124.

These fleshy tap-roots belong, as a rule, to biennial plants, and are designed as storehouses of food for the plant's use during its second year's growth. Occasionally fibrous roots also thicken in the same manner, as in the Peony, and then they are said to be *fascicled* or *clustered*. (Fig. 125).

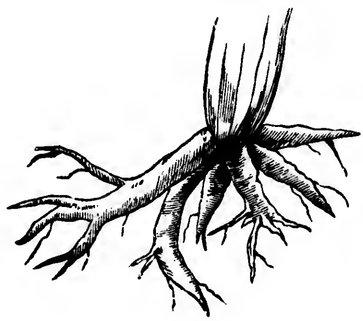


Fig. 125.

134. But you must have observed that plants sometimes put forth roots in addition to those developed from the embryo of the seed. The Verbena of our gardens, for example, will take root at every joint if the stem be laid upon the ground (Fig. 126). The runners of the Strawberry take root at their extremities; and nothing is more familiar than that cuttings from various plants will make roots for themselves if put into proper soil, and supplied with warmth and moisture.

Fig. 124.—Tap-root of Carrot. Fig. 125.—Fascicled roots of Peony.

All such roots, not developed from the end of the radicle and in a straight line with it, are called *secondary* or *adventitious* roots. Under this head should, of course, be placed the fibrous roots of all Monocotyledonous plants, the true primary roots of which are but very feebly developed. So, also, all branches of primary roots should be regarded as adventitious. When such roots are developed from parts of the stem which are not in contact with the ground, they are *aerial*, as, for example, the roots developed from the lower joints of the stem of Indian Corn.

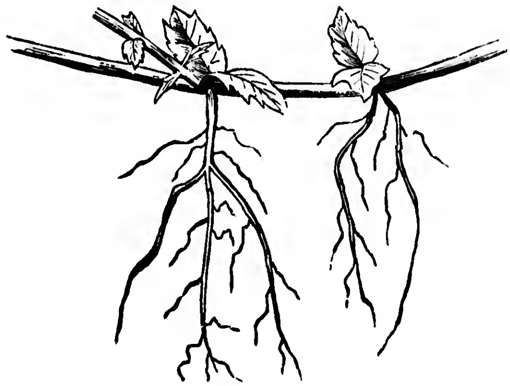


Fig. 126.

135. There are a few curious plants whose roots never reach the ground at all, and which depend altogether upon the air for food. These are called *epiphytes*. There are others whose roots penetrate the stems and roots of other living plants, and thus receive their nourishment as it were at second-hand. These are *parasitic* plants. The Dodder and Beech-drops, of Canadian woods, are well-known examples. Others, again, subsist upon decomposing animal or vegetable matter, and are hence known as *saprophytes*. Indian Pipe and Coral-root are good examples of saprophytic plants. Both parasites and saprophytes are usually destitute of green leaves,

Fig. 126.—Adventitious roots of Verbena.

being either pale or brownish. The Mistletoe, however, is a green parasite.

136. As to duration, roots (and, consequently, the plants themselves) are either *annual*, or *biennial*, or *perennial*. The plant is called an annual if its whole life, from the germination of the seed, is limited to one season. It is biennial if it flowers and ripens its seed in the second season. Between these two classes it is difficult to draw a sharp line, because, with proper care, some annuals may be induced to live for two years; and, on the other hand, some plants, as the Radish, which are properly biennial if the seed is sown in the fall, will flower and produce seed in one season if sown in the spring. Something, also, depends upon the climate in which the plant is grown, its life, in some cases, being prolonged in a more favourable situation. Perennials live on year after year, as is the case with all our shrubs and trees, and also with some herbaceous plants, as Peony and Dahlia, which only die down to the surface of the ground in the autumn.

137. **The Stem.** As the root is developed from the lower end of the radicle of the embryo, so the stem is developed from the upper end, but with this important difference, that a *bud* always precedes the formation of the stem or any part of it or its branches. If a bud, such as that of the Lilac, be picked to pieces, it will be found to consist mostly of minute leaves closely packed together on a short bit of stem. A bud, in fact, is only a special condition of the extremity of the stem, and is not to be regarded as an organ distinct from it. As the bud unfolds, the stem may lengthen so as to exhibit the internodes, or

it may remain short, in which case the expanded leaves form a cluster or rosette, as in Dandelion. The tender leaves of the bud are not uncommonly protected from the weather by coverings in the form of tough scales, with the additional safeguard sometimes of a wax-like coating on the surface of the latter, as seen in the conspicuous buds of the Horse-Chestnut, and the cap-like coverings of those of the Spruce.

138. Between the cotyledons of the Bean (Fig. 81), at the top of the radicle, we found a minute bud called the *plumule.* Out of this bud the first bit of stem is developed (leaving out of consideration the radicle itself), and during the subsequent growth of the plant, wherever a branch is to be formed or a main stem to be prolonged, there a bud will invariably be found. The branch buds are always in the axils of leaves, and so are called *axillary*, and it not uncommonly happens that several buds are found together in this situation.

139. *Adventitious* buds, however, are sometimes produced in plants like the Willow, particularly if the stem has been wounded. As already mentioned, they are also occasionally produced upon roots, as, for example, upon those of the Poplars.

140. The bud from which the main stem is developed, or a branch continued, is of course at the end of the stem or branch, and so is *terminal.*

141. **Branching** or **Ramification.** By a branch is meant an off-shoot similar in structure to the member from which it springs. Hence the side-shoots of roots are root-branches ; so, also, the lateral out-growths of the stem which resemble the stem itself in structure are

stem-branches. It is found that the branching of stems proceeds upon two well defined plans.

142. *Monopodial Branching.* This system is distinguished by the circumstance that all the branches are the result of the development of strictly lateral buds. In other words, there is invariably a terminal bud at the apex of the stem distinct from the lateral buds produced behind the apex. Of this system there are several

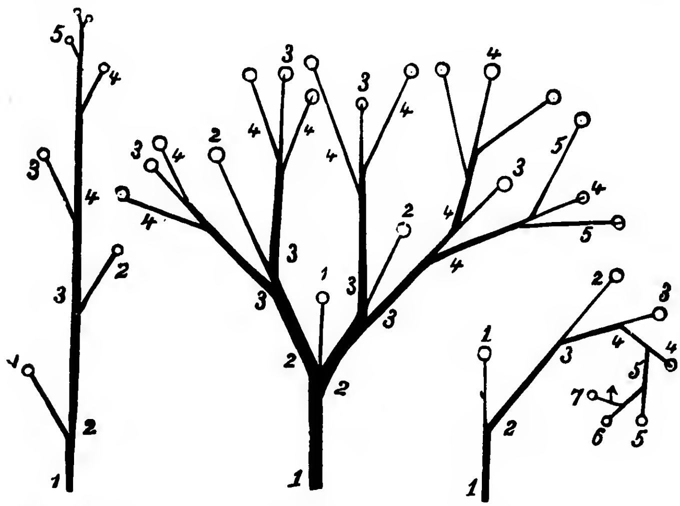


Fig. 130. Fig. 127. Fig. 128.

modifications. If the terminal bud develops regularly, as well as the lateral ones, it is clear that we shall have a straight and well-defined trunk, easily distinguished by its vigorous growth from the branches. The Pine or the Spruce is an excellent example of this effect.

Figs. 127, 128, 130.—Diagrams of various forms of monopodial branching. (Sachs.)

But if the terminal bud, though produced, ceases to grow, while the lateral buds are vigorously developed, as is well exhibited in the spring by the annual shoots of the Lilac, then it is clear that the branches will overtop the original stem, and the latter will finally become unrecognizable.

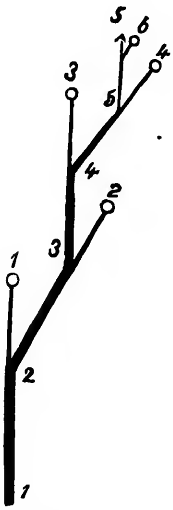


Fig. 129.

143. The Pine and the Spruce and similar forms are said to be *racemose* or *botryose*, and the Lilac, in the development of its annual shoots, is said to be *cymose*. Fig. 127 is a representation of the latter mode. Here 1 is the extremity of the main stem, but the terminal bud at that point has failed to grow, while two vigorous branches have been produced. The terminal buds of these branches (2 and 2), have in their turn failed, and the laterals immediately behind them have, as before, given rise to new shoots. This is the result, then, when both the lateral buds grow with equal vigour, and it is known as a *forked cyme.*

144. But sometimes one member of each pair of buds is developed far more strongly than the other. If the strong buds are developed in succession on the same side of the stem an effect will be produced like that represented in Fig. 128. This is known as a *helicoid* cyme. If, however, the strong buds are developed alternately on both sides of the stem, we get the form shown in Fig. 129, which is then called a *scorpioid* cyme. Not-un-

Fig. 129.—Diagram to illustrate scorpioid cyme. (Sachs.)

commonly this latter form becomes straightened out, as in Fig. 130, so that the successive branches are in the same line, and look like a stem developed from the terminal bud. As the *foot* or support is not in this case the continuation of a single axis, but is made up of a number of successive branches superposed, these forms are said to be *sympodial*, the prefix in this term having the same significance as in "syncarpous" and the like, and implying that the foot is composed of several coherent parts. In these cases, then, we have a *sympodial monopodium*.

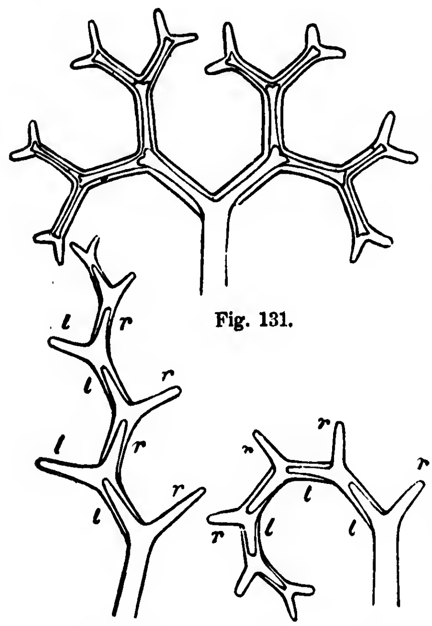


Fig. 131.

Fig. 133.

Fig. 132.

145. *Dichotomous Branching.* In this system the growing point at the apex of the stem *divides into two new growing points*, both of which are, therefore, *terminal* and not lateral, as in the first mode. The growing points of the branches, in their turn, are each converted into two new ones, as shown in Fig. 131. As in the monopodial mode, there may be helicoid and scorpioid dichotomy, due to the superior development of the growing points on

Figs. 131, 132, and 133.—Diagrams to illustrate dichotomous branching. (Sachs.)

one side, or on alternate sides of the stem, as shown in Figs. 132 and 133. These forms are, of course, sympodial.

146. A comparison of Figs. 127 and 131 will show that there is a superficial resemblance between the forms. On this account the forked cyme is sometimes referred to as a *dichasium* or *false dichotomy*.

147. Dichotomous branching is rare, but occurs in the roots of Club-Mosses, and in Lichens. In the phanerogams, monopodial branching is the almost invariable rule. The flowering stems, which afford the best illustrations, will be referred to hereafter.

148. If you examine a few stems of plants at random, you will probably find some of them quite soft and easily compressible, while others will be firm and will resist compression. The stem of a Beech or a Currant is an instance of the latter kind, and any weed will serve to illustrate the former. The Beech and the Currant have *woody* stems, while the weeds are *herbaceous*. Between the Beech and the Currant the chief difference is in size. The Beech is a *tree*, the Currant a *shrub*. But you are not to suppose that there is a hard and fast line between shrubs and trees, or between herbs and shrubs. A series of plants could be constructed, commencing with an unquestionable herb and ending with an unquestionable tree, but embracing plants exhibiting such a gradual transition from herbs to shrubs and from shrubs to trees, that you could not say at what precise point in the series the changes occurred.

149. The forms assumed by stems above ground are numerous, and they are described mostly by terms in common use. For instance, if a stem is weak and trails

along the ground, it is *trailing* or *prostrate ;* and if, as in the runners of the Strawberry, it takes root on the lower side, then it is *creeping.* Such a shoot as the runner of the Strawberry, which takes root at a distance from the parent plant, is commonly called a *stolon.*

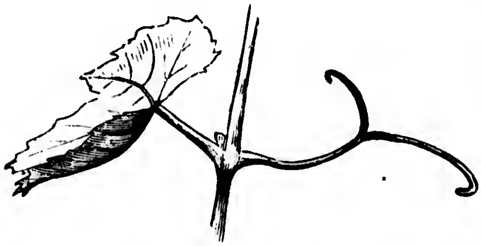


Fig. 134.

150. Many weak stems raise themselves by clinging to any support that may happen to be within their reach. In some instances the stem itself winds round the support, assuming a spiral form, as in the Morning-Glory, the Hop, and the Bean, and is therefore distinguished as *twining.* In other cases the stem puts forth thread-like leafless branches called *tendrils* (Fig. 134), which grasp the support, as in the Virginia Creeper and the Grape. In the Pea, the end of the extended mid-rib of the leaf is transformed into a tendril (Fig. 135). Sometimes the leaf-stalks themselves serve the same purpose, as in the Clematis or Virgin's Bower. In these cases the stems are said to *climb.* Our Poison Ivy climbs over logs, &c., by the aid of its aerial roots.

Fig. 135.

The stems of wheat and grasses generally are known as

Fig. 134.—Leaf and tendril of Grape-vine.
Fig. 135—Tendril of the Pea.

culms. They are jointed, and usually hollow except at the joints.

151. Besides the stems which grow above ground, there are varieties to be found below the surface. Pull up a Potato plant, and examine the underground portion (Fig. 136). It is not improbable that you will regard the whole as a mass of roots, but a very little trouble will undeceive you. Many of the fibres are unquestionably

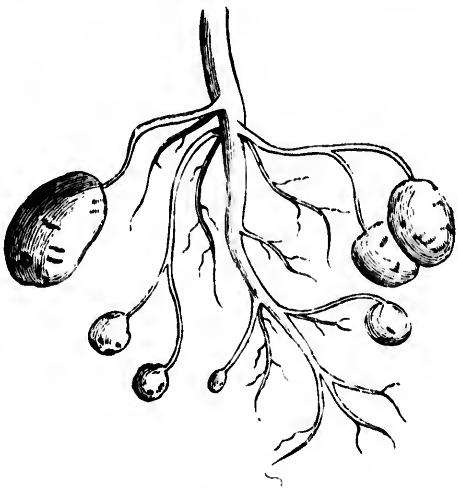


Fig. 136.

roots, but an inspection of those having potatoes at the ends of them will show you that they are quite different from those which have not. The former will be found to be furnished with little scales, answering to leaves, each with a minute bud in the axil; and the potatoes themselves exhibit buds of the same kind. The potato, in short, is only *the swollen end of an underground stem.* Such swollen extremities are known as *tubers*, whilst the

Fig. 136.—Tubers of the Potato.

underground stem is called a *root-stock* or *rhizome*, and may almost always be distinguished from a true root by the presence of buds. The Solomon's Seal and Toothwort of Canadian woods, and the Canada Thistle, are common instances of plants producing these stems. Fig. 137 shows a rhizome.

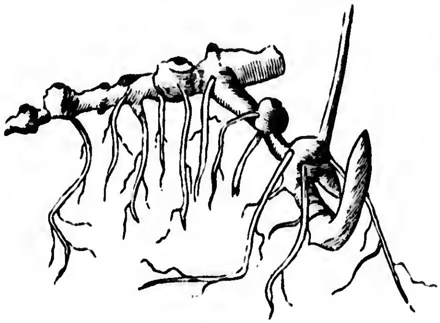


Fig. 137.

152. Take now an Onion, and compare it with a Potato. You will not find any such outside appearances upon the former as are presented by the latter. The Onion is smooth, and has no buds upon its surface. From the under side there spring roots, and this circumstance will probably suggest that the Onion must be a stem of some sort. Cut the Onion through from top to bottom (Fig. 138). It will then be seen to be made up of a number of coats. Strip off one or two, and observe that whilst they are somewhat fleshy where the Onion is broadest, they gradually become thinner towards the top. The long, green tubes which project from the top of the Onion during its growth are, in fact, the prolongations of these coats. But the tubes are the leaves of the plant itself. The mass of our Onion, therefore, consists

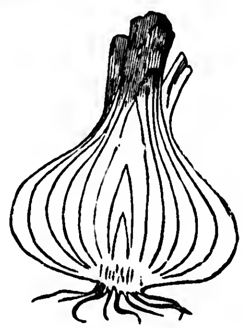


Fig. 138.

Fig. 137.—A rhizome.
Fig. 138.—Vertical section of bulb of the Onion.

of the *fleshy bases of the leaves.* But you will observe that at the bottom there is a rather flat, solid part

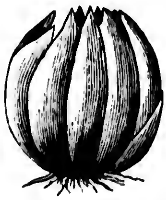


Fig. 139.

upon which these coats or leaves are inserted, and which must consequently be a stem. Such a stem as this, with its fleshy leaves, is called a *bulb.* If the leaves form coats, as in the Onion, the bulb is *coated* or *tunicated;* if they do not, as in the Lilies (Fig. 139), it is *scaly.*

153. Tubers and bulbs, then, consist chiefly of masses of nourishing matter; but there is this difference, that in the latter the nourishment is contained in the fleshy leaves themselves, whilst in the former it forms a mass more or less distinct from the buds.

154. The thickened mass at the base of the stem of our Indian Turnip (Fig. 94) is more like a tuber than a bulb in its construction. It is called a *corm* or solid bulb. The Crocus and Gladiolus of the gardens are other examples. The chief difference between the corm and the ordinary bulb is in the relative space occupied by the stem or solid part. In the former it is very much greater than in the latter. The student should dissect specimens of Indian Turnip, Crocus, Tulip, Hyacinth, &c., when these differences will be readily apprehended.

155. In the axils of the leaves of the Tiger Lily are produced small, black, rounded bodies, which, on examination, prove to be of bulbous structure. They are, in fact, *bulblets*, and new plants may be grown from them.

156. **Foliage-Leaves.** These organs are usually more or less flat, and of a green colour. In some plants,

Fig. 139.—Bulb of a Lily.

however, they are extremely thick and succulent; and in the case of parasites and saprophytes, such as Indian Pipe and Beech-drops, they are usually either white or brown, or of some colour other than green. The scaly leaves of underground stems are also, of course, destitute of colour. The green colour is due to the presence of granular particles of a substance called *chlorophyll.* It is formed, as a rule, only in those parts which are exposed to the action of sunlight, and it is intimately connected with the process of assimilating nutritious matter for the plant's use during growth. Further reference will be made to it later on.

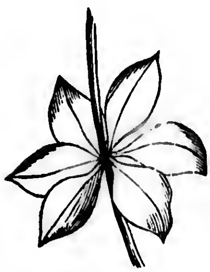


Fig. 140.

157. As a general thing, leaves are extended horizontally from the stem or branch, and turn one side towards the sky and the other towards the ground. But some leaves are *vertical,* and in the case of the common Iris (Figs. 88 and 89) each leaf is doubled lengthwise at the base, and *sits astride* the next one within. Such leaves are called *equitant.*

158. **Phyllotaxis** or **Leaf-Arrangement.** As to their arrangement on the stem, leaves are *alternate* when only one arises from each node (Fig. 3). If two are formed at each node, they are sure to be on opposite sides of the stem, and so are described as *opposite.* If, as in Mint and Maple, each pair of opposite leaves stands at right angles to the next pair above, then the arrangement is *decussate.* Sometimes there are several leaves at the same node, in which case they are *whorled* or *verticillate* (Fig. 140).

Fig. 140.—Whorled leaves of Galium.

159. Even if the leaves are placed singly and apparently irregularly at intervals along the stem, it will be found on examination that their arrangement is governed by definite laws. Take, for instance, a branch of Poplar with a number of leaves upon it. Fix upon any one leaf near the lower end of the branch, and then from its point of insertion draw a line, *by the nearest way*, to the insertion of the next higher leaf, and from this to the next, and so on till you reach a leaf which is exactly over the first one. If the branch itself has not been twisted out of its normal shape, it will be found that the *sixth* leaf is always precisely over the first, the seventh over the second, the eighth over the third, and so on, and that the line joining the points of insertion of successive leaves forms a spiral round the stem. It will also be found that this spiral goes *twice* round the stem before passing through the sixth leaf. The sixth leaf, as standing exactly over the first, begins a new set, which lasts in a similar manner till we reach the eleventh. The leaves are therefore in sets or cycles of five each, and the phyllotaxis in this case is conveniently described by the fraction $\frac{2}{5}$, the denominator of which gives the number of leaves in the cycle, and the numerator the number of turns in the spiral.

160. Now, if through the insertions of the leaves which are vertically over each other—that is, through those numbered 1, 6, 11, 16, etc., and then through those numbered 2, 7, 12, 17, and so on—lines be drawn, it is evident we shall have five such vertical lines on the stem. These lines mark the *ranks* of leaves, or *orthostichies*. The number of orthostichies in any case always corresponds to the number of leaves in the cycle.

161. In the Elm, the phyllotaxis is much simpler. Here, starting with any given leaf, it will be found that the next one is exactly half way round the circumference of the stem, and the third one exactly over the first, and so on. So that the spiral completes the circuit in one turn, and the number of orthostichies is only two, the phyllotaxis being therefore described as $\frac{1}{2}$. The $\frac{1}{3}$ arrangement is also common. The Poplar, as we see, has a $\frac{2}{5}$ arrangement; this is extremely common.

162. If we set down these fractions in order, thus: $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, it will be noticed that the sum of the first two numerators gives the third numerator; so also with the denominators. If we proceed to make other fractions in this way, the series would read $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, and these are, as it happens, the actual cases of phyllotaxy which we commonly meet with. The cone of the White Pine furnishes a very good exercise. In this case the scales (which, of course, are leaf-forms) have a $\frac{5}{13}$ arrangement.

163. The conclusion come to from a close examination of the incipient buds is, that the newer leaves are produced over the widest intervals between those next below. In short, the arrangement is that which secures to the leaves the most advantageous conditions for exposure to the light, and at the same time economizes space. As has been aptly said, the growth of the new leaves follows the "lines of least resistance."

164. When leaves are in whorls instead of in spirals, the members of any whorl stand over the spaces of the whorl below, as might be expected. As to leaves which are clustered or fascicled, like those of the Pine and Larch, it may be pointed out that the clustering is due simply to

the non-development of internodes. The clusters when carefully examined, show in some cases an alternate, and in others a whorled, arrangement.

165. As branches are produced in the axils of leaves, it is clear that the arrangement of branches will be the same as that of the leaves. It rarely happens, however, that all the buds develope into branches. Many of them fail, so that generally branches appear to have no very definite arrangement.

166. **Vernation** or **Præfoliation.** These terms have reference to the mode in which the new leaves are folded in the bud. Very commonly the leaf is simply doubled lengthwise, the upper side of the leaf within; then its vernation is said to be *conduplicate.* In the Maple and Mallow the folding is fan-like, and is described as *plaited.* In the Cherry the leaf is coiled in a single coil beginning with one edge: this is *convolute* vernation; but if the coiling is from both edges to the mid-rib, it is said to be *involute;* if both edges are rolled backward, it is *revolute.* The vernation is *circinate* when the leaf is coiled from the tip, as in Ferns.

167. **Forms of Foliage-Leaves.** Leaves present an almost endless variety in their forms, and accuracy in describing any given leaf depends a good deal upon the ingenuity of the student in selecting and combining terms. The chief terms in use will be given here.

Compare a leaf of the Round-leaved Mallow with one of Red Clover (Figs. 141, 142). Each of them is furnished with a long petiole and a pair of stipules. In the blade, however, there is a difference. The blade of the former consists of a *single piece;* that of the latter is in three separate pieces, each of which is called a *leaflet*, but all of which, taken collectively, constitute the blade of the *leaf*. The leaf of the Mallow is **simple**; that of the Clover is **compound.** Between the simple and the compound form there is every possible shade of gradation. In the Mallow leaf the *lobes* are not very clearly defined. In the Maple (Fig. 143) they are well

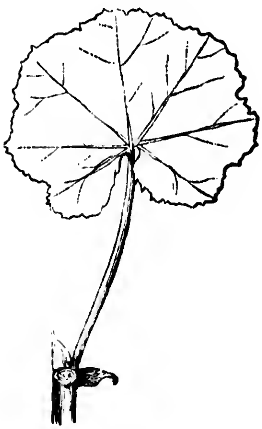


Fig. 141.

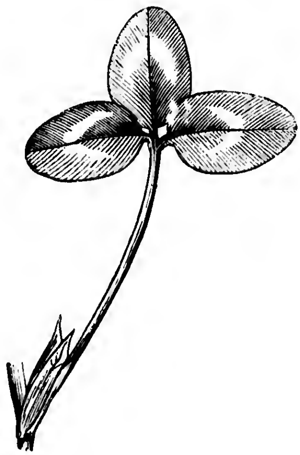


Fig. 142.

marked. In other cases, again, the lobes are so nearly separate that the leaves appear at first sight to be really compound.

168. You will remember that in our examinations of dicotyledonous plants, we found the leaves to be invariably net-veined. But, though they have this general character in common, they differ considerably in the details of their veining, or **venation,** as it is called. The two leaves employed as illustrations in the last section will

Fig. 141.—Simple palmately-veined leaf of Mallow.
Fig. 142.—Compound leaf of Clover.

serve to illustrate our meaning here. In the Mallow, there are several ribs of about the same size, radiating from the end of the petiole, something like the spread-out fingers of a hand. The veining in this case is therefore described as *digitate*, or *radiate*, or *palmate*. The *leaflet* of the Clover, on the other hand, is divided exactly in the middle by a single rib (the *mid-rib*), and from this the veins are given off on each side, so that the veining, on the whole, presents the appearance of a feather, and is, therefore, described as *pinnate* (*penna*, a feather).

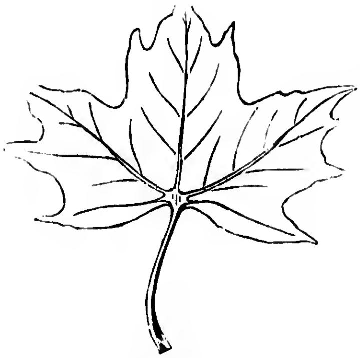


Fig. 143.

169. Both simple and compound leaves exhibit these two modes of venation. Of simple pinnately-veined leaves, the Beech, Mullein, and Willow supply familiar instances. The Mallow, Maple, Grape, Currant, and Gooseberry have simple radiate-veined leaves. Sweet-Brier (Fig. 43), Mountain Ash, and Rose have compound pinnate leaves, whilst those of Virginia-Creeper (Fig. 144), Horse-Chest-nut, and Hemp are compound digitate.

Fig. 144.

Fig. 143.—Palmately-lobed leaf of Maple.

Fig. 144.—Palmate leaf of Virginia Creeper.

As has already been pointed out, the leaves of Monocotyledonous plants are almost invariably straight-veined.

170. In addition to the venation, the description of a simple leaf includes particulars concerning: (1) the **general outline,** (2) the **edge** or **margin,** (3) the **point** or **apex,** (4) the **base.**

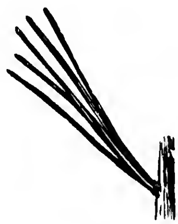


Fig. 145.

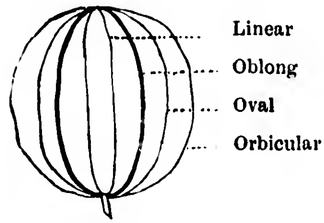


Fig. 146.

171. Outline. As to outline, it will be convenient to consider first the forms assumed by leaves without lobes, and whose margins are therefore more or less continuous. Such leaves are of three sorts, viz.: those in which both ends of the leaf are alike, those in which the apex is

Fig. 147.

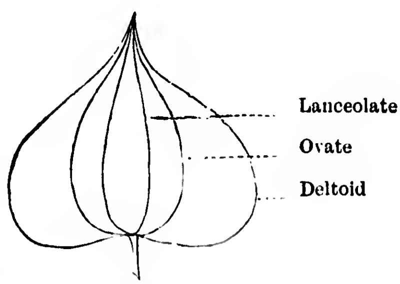


Fig. 148.

Figs. 145 to 148.—Various forms of foliage-leaves.

narrower than the base, and those in which the apex is broader than the base.

172. In the first of these three classes it is evident that any variation in the outline will depend altogether on the

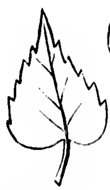


Fig. 152.


Fig. 153.


Fig. 149.


Fig. 150.

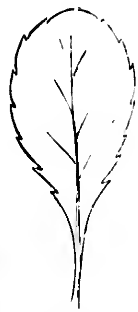


Fig. 151.

relation between the length and the breadth of the leaf. When the leaf is extremely narrow in comparison with its length, as in the Pine, it is *acicular* or *needle-shaped* (Fig. 145). As the width increases, we pass through the forms known as *linear*, *oblong*, *oval*, and finally *orbicular*, in which the width and length are nearly or quite equal (Fig. 146).

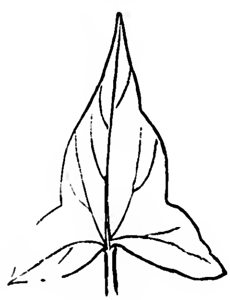


Fig. 154.

173. In the second class the different forms arise from the varying width of the base of the leaf, and we thus have *subulate* or *awl-shaped* (Fig. 147), *lanceolate*, *ovate*, and *deltoid* leaves (Fig. 148).

Figs. 149 to 154.—Various forms of foliage-leaves.

174. In the third class, as the apex expands, we have the forms *spathulate* (Fig. 149), *oblanceolate*—that is, the reverse of lanceolate (Fig. 150), and *obovate* (Fig. 151).

175. In leaves of the second kind we frequently find the base indented, and then the leaf is *cordate* or *heart-*

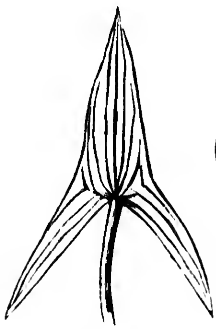


Fig. 155.

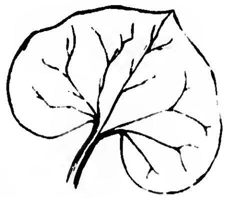


Fig. 156.

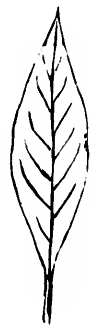


Fig. 157.

shaped (Fig. 152). The reverse of this—that is, when the indentation is at the apex—is *obcordate* (Fig. 153). The *hastate* or spear-shaped (Fig. 154), *sagittate* or arrow-shaped (Fig. 155), and *reniform* or kidney-shaped (Fig. 156) forms are modifications of the second class, and will be readily understood from the annexed figures.

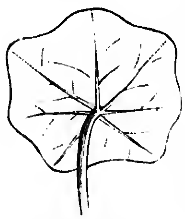


Fig. 158.

If the petiole is attached to any part of the under surface of the leaf, instead of to the edge, the leaf is *peltate* (shield-shaped) (Fig. 158).

176. Leaves which are lobed are usually described by stating whether they are palmately or pinnately veined; and

Figs. 155 to 158.—Various forms of foliage-leaves.

if the former, the number of lobes is generally given. If the leaves are very deeply cut, they are said to be *palmatifid* or *pinnatifid*, according to the veining (Fig. 159). If the leaf is pinnatifid and the lobes point backwards towards the base, as in Dandelion, the leaf is said to be *runcinate.* If the leaf is palmately lobed, and the lobes at the base are themselves lobed, the leaf is *pedate* (Fig. 160), because it looks something like a bird's foot. If the lobes of a pinnatifid leaf are themselves lobed, the leaf is *bipinnatifid.* If the leaf is cut up into fine segments, as in Dicentra, it is said to be *multifid.*

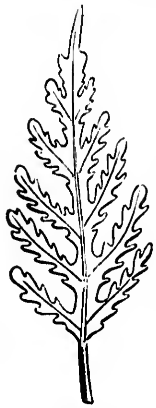


Fig. 159.

177. **Apex.** The principal forms of the apex are the *mucronate* (Fig. 157), when the leaf is tipped with a sharp point, as though the mid-rib were projecting beyond the blade; *cuspidate*, when the leaf ends abruptly in a very short, but distinctly tapering, point (Fig. 161); *acute*, or sharp; and *obtuse*, or blunt.

Fig. 160.

It may happen that the apex does not end in a point of any kind. If it looks as though the end had been cut off square, it is *truncate.* If the end is slightly notched, but not sufficiently so to warrant the description obcordate, it is *emarginate.*

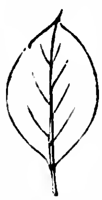


Fig. 161.

178. **Margin.** If the margin is not indented in any way, it is said to be *entire.* If it has sharp teeth, *pointing*

Figs. 159 to 161.—Various forms of foliage-leaves.

in the direction of the apex, it is *serrate*, and will be coarsely or finely serrate, according to the size of the teeth. Sometimes the edges of large teeth are themselves finely serrated, and in that case the leaf is *doubly serrate* (Fig. 162). If the teeth point *outwards*, that is, if the two edges of each tooth are of the same length, the leaf is *dentate*; but if the teeth, instead of being sharp, are *rounded*, the leaf is *crenate* (Fig. 163). The term *wavy* explains itself.

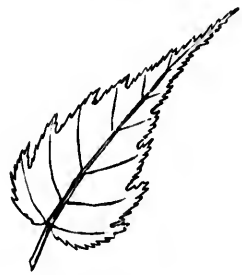


Fig. 162.

179. **Base.** There are two or three peculiar modifications of the bases of simple sessile leaves which are of considerable importance in distinguishing plants. Sometimes a pair of lobes project backwards and cohere on the other side of the stem, so that the stem appears to pass through the leaf. This is the case in our common Bellwort, the leaves of which are accordingly described as *perfoliate* (Fig. 164). Sometimes two opposite sessile leaves grow together at the base and clasp the stem, as in the upper leaves of Honeysuckle, in the Triosteum, and in one of our species of Eupatorium. Such leaves are said to be *connate* or *connate-perfoliate* (Fig. 165). In one of our Everlastings the margin of the leaf is continued on each side below the point of insertion, and the lobes grow fast to the sides of the stem, giving rise to what is called the *decurrent* form (Fig. 166).

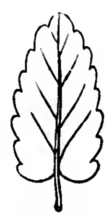


Fig. 163.

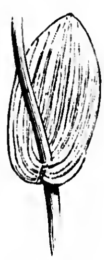


Fig. 164.

Figs. 162 to 164.—Various forms of foliage-leaves.

The terms by which simple leaves are described are applicable also to the leaflets of compound leaves, to the sepals and petals of flowers, and, in short, to any flat forms.

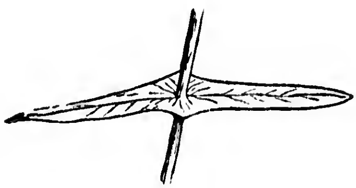


Fig. 165.

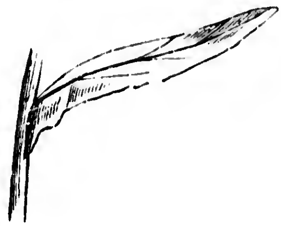


Fig. 166.

180. We have already explained that compound leaves are of two forms, *pinnate* and *palmate*. In the former the leaflets are arranged on each side of the mid-rib. There may be a leaflet at the end, in which case the leaf is *odd-pinnate;* or the terminal leaflet may be wanting, and then the leaf is

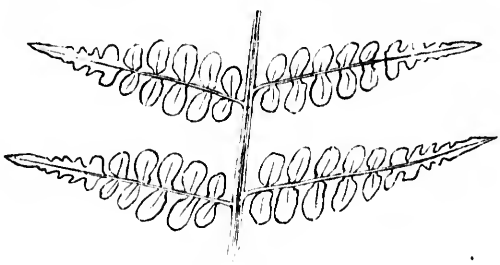


Fig. 167.

abruptly pinnate. In the Pea, the leaf is pinnate and terminates in a *tendril* (Fig. 135). Very frequently the primary divisions of a pinnate leaf are themselves pinnate, and the whole leaf is then *twice-pinnate* (Fig. 167). If

Figs. 165 to 167.—Various forms of foliage-leaves.

the sub-division is continued through another stage, the leaf is *thrice-pinnate*, and so on. Sometimes, as in the leaves of the Tomato, very small leaflets are found between the larger ones, and this form is described as *interruptedly pinnate* (Fig. 168).

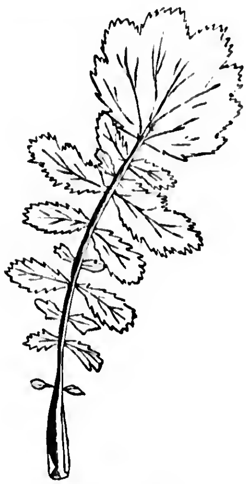


Fig. 168.

In the palmate or digitate forms the leaflets spread out from the end of the petiole, and, in describing them, it is usual to mention the number of divisions. If there are three, the leaf is *tri-foliolate* ; if there are five, it is *quinque-foliolate.*

181. In the examination of the Mallow we found a couple of small leaf-like attachments on the petiole of each leaf, just at the junction with the stem. To these the name *stipules* was given. Leaves which have not these appendages are *exstipulate.*

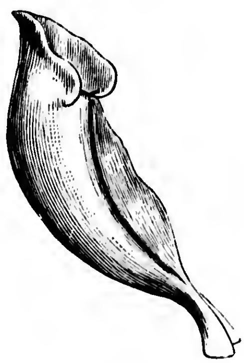


Fig. 169

182. Besides the characters of leaves mentioned above, there remain a few others to be noticed. With regard to their **surface**, leaves present every gradation from perfect smoothness, as in Wintergreen, to extreme roughness or woolliness, as in the Mullein. If hairs are entirely absent,

Fig. 168.—Interruptedly pinnate leaf.
Fig. 169.—Leaf of Pitcher-Plant.

the leaf is *glabrous*; if present, the degree of hairiness is described by an appropriate adverb; if the leaf is completely covered, it is *villous* or *villose*; and if the hairs are on the margin only, as in our Clintonia, it is *ciliate*. Some leaves, like those of the Cabbage, have a kind of bloom on the surface, which may be rubbed off with the fingers; this condition is described as *glaucous*.

183. A few plants have **anomalous leaves**. Those of the Onion are *filiform*. The Pitcher-Plant of our northern swamps has very curious leaves (Fig. 169), apparently formed by the turning in and cohesion of the outer edges of an ordinary leaf so as to form a tube, closed except at the top, and armed on the inner surface with bristles pointing towards the base of the leaf.

184. Finally, as leaves present an almost infinite variety in their forms, it will often be necessary in describing them to combine the terms explained above For instance, a leaf may not be exactly linear, nor exactly lance-shaped, but may approximate to both forms. In such a case the leaf is described as *lance-linear*, and so with other forms.

The following form of schedule may be used with advantage in writing out descriptions of leaves. Two leaves — one of Maple and one of Sweet Brier — are described by way of illustration. If a leaf is compound, the particulars as to outline, margin, apex, base, and surface will have reference to the leaflets.

The exercise-book prepared to accompany this work contains a supply of blank schedules for leaf-description, with space for drawings.

LEAF SCHEDULE.

Leaf of	Maple.	Sweet Brier.
1. Position.	Cauline.	Cauline.
2. Arrangement.	Opposite.	Alternate.
3. Insertion.	Petiolate.	Petiolate.
4. Stipulation.	Exstipulate.	Stipulate.
5. Division.	Simple.	Odd pinnate, 7 leaflets.
6. Venation.	Palmate.	
7. Outline.		Roundish or oval.
8. Margin.	Deeply lobed.	Doubly serrate.
9. Apex.	Pointed.	Acute.
10. Base.	Cordate.	Hardly indented.
11. Surface.	Glabrous above; whitish beneath.	Downy above; covered with glands beneath.

CHAPTER XVIII.

MORPHOLOGY OF FLOWER-LEAVES—INFLORESCENCE—THE CALYX—THE COROLLA—THE STAMENS—THE PISTIL—THE FRUIT—THE SEED—GERMINATION.

185. From an examination of the various forms presented by foliage-leaves, we proceed now to those of the floral ones, and we shall first consider the chief modifications in the *arrangement of flowers as a whole*, to which the term **inflorescence** is applied.

As the organs of which flowers are made up are strictly leaf-forms, the special stalks upon which they are produced (peduncles and pedicels) are true branches, and their development is in strict accordance with the principles enunciated in sections 141–144. As there stated, the almost invariable mode of branching in phanerogams is monopodial, either after the *botryose* type or after the *cymose* type. So inflorescence is found to proceed upon one or other of these two plans.

186. To understand these let us recur to our specimens of Shepherd's Purse and Buttercup. You will remember that in the former the peduncle continues to lengthen as long as the summer lasts, and new flowers continue to be produced at the upper end. Observe, however, that every one of the flowers is produced on the side of the stem, that as the stem lengthens new lateral buds appear, and that *there is no flower on the end of the stem.* The production of the flowering branches (pedicels) and the continuation of the main axis are, in fact, exactly analogous to the growth of the Spruce, as explained in section 142.

You will easily understand, then, that the production of flowers in such a plant is only limited by the close of the season or by the exhaustion of the plant. Such inflorescence is, therefore, called **indefinite,** or **indeterminate,** or **axillary.** It is sometimes also called *centripetal,* because if the flowers happen to be in a close cluster, as are the upper ones in Shepherd's Purse, the order of development is from the outside *towards the centre.*

187. If you now look at your Buttercup you will be at once struck with the difference of plan exhibited. The main axis or stem has *a flower on the end of it,* and its further growth is therefore checked. And so, in like manner, from the top downwards, the growth of the branches is checked by the production of flowers at their extremities. The mode of inflorescence here displayed is **definite,** or **determinate,** or **terminal.** It is also called *centrifugal,* because the development of the flowers is the reverse of that exhibited in the first mode. The upper, or, in the case of close clusters, the *central,* flowers open first.

188. In either mode the flowers are said to be *solitary,* if (1) single flowers are produced in the axils of the ordinary foliage-leaves (botryose), or (2) if a single flower terminates the stem, as in Tulip (terminal).

189. Of **indeterminate** or **botryose inflorescence** there are several varieties. In Shepherd's Purse we have an instance of the *raceme,* which may be described as a cluster in which each flower is supported on a lateral pedicel of its own, usually in the axil of a bract. If the pedicels are absent and the flowers consequently

sessile in the axils, the cluster becomes a *spike*, of which the common Plantain and the Mullein furnish good examples. The *catkins* of the Willow (Figs. 68 and 69) and Birch and the *spadix* of the Indian Turnip (Figs. 96 and 97) are also spikes, the former having scaly bracts and the latter a fleshy axis. If you suppose the

Fig. 170.

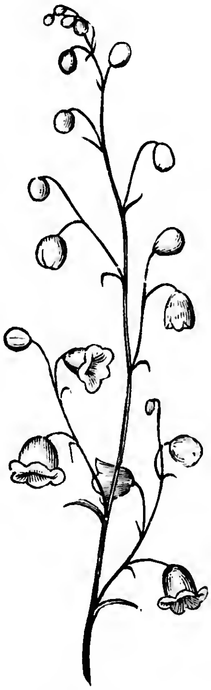


Fig. 171.

internodes of a spike to be suppressed so that the flowers are densely crowded, you will have a *head*, of which Clover and Button-bush supply instances. If the lower pedicels of a raceme are considerably longer than the

Fig. 170.—Plan of the simple corymb.
Fig. 171.—Compound raceme. (Gray.)

upper ones, so that all the blossoms are nearly on the same level, the cluster is a *corymb* (Fig. 170). If the flowers in a head were elevated on separate pedicels of the same length, radiating like the ribs of an umbrella, we should have an *umbel*, of which the flowers of Geranium and Parsnip (Fig. 51) are examples. A raceme will be *compound* (Fig. 171) if, instead of a solitary flower, there is a *raceme in each axil*, and a similar remark will apply in the case of the spike, the corymb, and the umbel.

190. The inflorescence of most Grasses is what is called a *panicle*. This is a compound form, and is

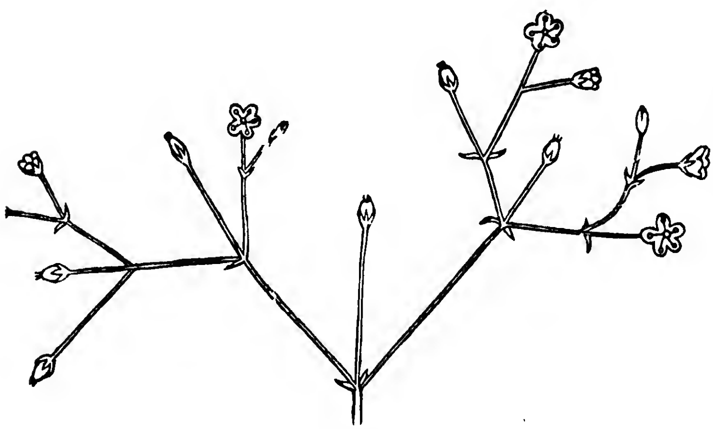


Fig. 172.

usually a kind of raceme having its primary divisions branched in some irregular manner.

191. Of **determinate inflorescence** the chief modification is the *cyme*. This is a rather flat-topped

Fig. 172.—A cyme. (Gray.)

cluster, having something the appearance of a compound corymb, but easily distinguished by this peculiarity : that the *central blossom opens first*, then those at the ends of the first set of branches of the cluster, then those on the secondary branches, and so on until the outer buds are reached. The Elder, Dogwood, and St. John's Wort furnish good examples of the cymose structure. Fig. 172 shows a loose, open cyme.

Helicoid and *Scorpioid* cymes have already been described in section 144.

192. Besides the two distinct modes of inflorescence just described, forms are met with which exhibit the peculiarities of both modes. For example, the flower-cluster of the Lilac is botryose or racemose as to the production of its primary branches, but the development of the flowers on the branches is according to the cymose type. On the other hand it sometimes happens, in many of the Composites for example, that the primary branches are cymose while the secondary are botryose. In the Lilac and the Horse-Chestnut the compact mixed cluster is called a *thyrse.* Panicles, also, instead of being altogether botryose, may be of a similar mixed character.

193. In many plants of the Mint Family the flowers appear to form dense whorls at intervals about the stem. Each of these whorls, when analysed, is found to consist of two cymose clusters on opposite sides of the stem. Such whorls are, therefore, mixed, and are often spoken of as *verticillasters.*

194. It has already been pointed out that cauline leaves tend to diminish in size towards the upper part of the stem where the flowers are found. Such reduced

leaves, containing flowers in their axils, are called *bracts*. In the case of compound flower-clusters this term is limited to the leaves on the peduncle or main stem, the term *bractlet* being then applied to those occurring on the pedicels or subordinate stems. In the case of the *umbel* and the *head*, it generally happens that a *circle* of bracts surrounds the base of the cluster. They are then called, collectively, an *involucre*, and in the case of compound clusters a circle of bractlets is called an *involucel*. Bracts are often so minute as to be reduced to mere *scales*. On the other hand they are occasionally very conspicuous and showy, as, for instance, in the four white bracts resembling a flower in the Bunchberry. From our definition it will be evident, also, that the *spathe* surrounding the spadix in Indian Turnip is merely a bract.

195. *Floral symmetry.* Before dealing with the morphology of the separate leaf-forms which go to make up the flower, a few words are necessary in regard to the relations of the different sets of floral organs, both as to number and as to position. The leaves which constitute the flower are arranged about the axis either in whorls, when the flowers are said to be *cyclic*; or in spirals, after the manner of most foliage-leaves, in which case the flowers are *acyclic*. Occasionally the outer sets (the perianth) are in whorls, while the stamens are spirally arranged; then the flowers are said to be *hemicyclic*. The spiral arrangement prevails, as a rule, where the floral organs are very numerous, as, for instance, in the Water Lily and in Buttercup; though Columbine, with very numerous stamens, has cyclic flowers.

196. In cyclic flowers, whilst there is usually one whorl each of sepals, petals, and carpels, there are not unfrequently two whorls of stamens. If each whorl is made up of the same number of members the flower is *isomerous*, and will, at the same time, be *monomerous*, *dimerous*, *trimerous*, *tetramerous*, or *pentamerous*, according as each whorl contains one, two, three, four, or five members. If the numbers of the members in the whorls do not correspond, the flowers are *heteromerous*.

197. The relations of the whorls to each other in any particular case may be very conveniently exhibited by a diagram. Fig. 173, for example, shows the plan of a Lily. The dot at the top of the figure represents the position of the axis of the plant, and should always be shown in a floral diagram. The side of the flower towards the stem is the *posterior* side, the opposite one being *anterior*, and a plane passing through the centre of the flower and also through the stem or axis is called the *median plane*. We have in the flower of the Lily an outer whorl of three members; then alternately with these (and this is the usual plan in cyclic flowers) a second whorl of three members; then the outer whorl of stamens, also three in number; then the three inner stamens; and, finally, the three carpels.

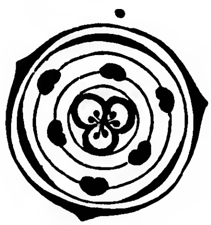


Fig. 173.

198. The composition of this flower may also be expressed by a formula, as follows: K_3, C_3, A_{3+3}, $G^{(3)}$, where K stands for calyx, C for corolla, A for anthers, G for gynœcium. The brackets enclosing the figure

Fig. 173.—Diagram of Lily flower. (Prantl.)

which follows G show the carpels to be united, and the placing of the figure *above* the short line indicates that the ovary is superior; if inferior, the figure would be written below the line. Fig. 174 shows the plan of a Grass-flower. Here parts which are suppressed, and the position of which can in general be easily inferred from that of those which are present, are represented by dots. The formula would be: K_0, C_2, A_{3+0}, $G^{(\underline{2})}$.

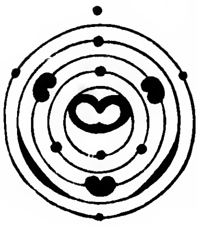


Fig. 174.

199. The gynœcium is very frequently made up of fewer members (carpels) than the other whorls, and in all such cases the position of the carpels is more or less irregular.

200. Fig. 175 gives the plan of Shepherd's Purse. This shows the four sepals to be in two whorls of two sepals each; the four petals, however, are arranged alternately with the four sepals, as if the latter were all in one whorl; the position of the stamens indicates that the *two* posterior ones, as well as the two anterior ones, occupy the place of single stamens, and have, therefore, probably arisen from the early division of single stamens into pairs. The formula would be: K_{2+2}, C_4, A_{2+2^2}, $G^{(\underline{2})}$; the expression 2^2 indicating the reduplication of the inner stamens.

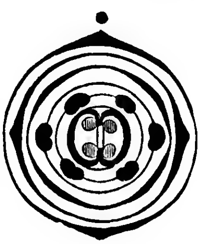


Fig. 175.

201. If there is no clear distinction between the calyx and corolla, the letter P (for perianth) may be used to include both; and, finally, if the members of any whorl

Fig. 174.—Diagram of a Grass-flower. (Prantl.)
Fig. 175.—Diagram of flower of Shepherd's Purse. (Prantl.)

stand *opposite* those of the one exterior to it, a vertical line may be placed between the symbols, thus: $C_5 \mid A_5$.

202. Other methods of indicating symbolically the relations of the parts of the flower are in vogue; the one just given is recommended by Prantl, and is sufficiently convenient.

203. It has already been mentioned that flowers are said to be irregular when the members of any whorl are of different sizes or shapes, as, for example, in the Pea; and regular, when the opposite is true. Fig. 173 represents one of these regular flowers. A moment's reflection will show that any line whatever drawn across the centre of this diagram will divide it into two exactly similiar halves. The term *actinomorphic*, as well as "regular," is applied to all such flowers. Flowers, on the other hand, which can be cut symmetrically in one vertical plane only are *zygomorphic*.

204. In this book, as in most English books, the term "symmetrical" is employed to indicate that the whorls consist of the same number of members each, and it is, in fact, the same in meaning as "isomerous." The later German botanists define a symmetrical flower as "one which can be divided vertically into two halves resembling each other like an object and its reflected image."

We shall now proceed to consider in detail the variations in form assumed by the floral organs individually.

205. **The Calyx.** As you are now well aware, this term is applied to the outer circle of floral leaves. These are usually green, but not necessarily so; in some Exogens, and in nearly all Endogens, they are of some other colour. Each division of a calyx is called a *sepal*, and if the sepals

are entirely distinct from each other, the calyx is *polysepalous;* if they are united in any degree, it is *gamosepalous.* A calyx is *regular* or *irregular* according as the petals are of the same or different shape and size

206. In a gamosepalous calyx, if the sepals are not united to the very top, the free portions are known as *calyx-teeth*, or, taken collectively, as the *limb* of the calyx. The united portion, especially if long, as in Willow-herb, is called the *calyx-tube*, and the entrance to the tube its *throat.* In many plants, particularly those of the Composite Family, the limb of the calyx consists merely of a circle of bristles or soft hairs, and is then described as *pappose.* In other cases the limb is quite inconspicuous, and so is said to be *obsolete.* A calyx which remains after the corolla has disappeared, as in Mallow (Fig. 31), is *persistent.* If it disappears when the flower opens, as in our Bloodroot, it is *caducous;* and if it falls away with the corolla, it is *deciduous.*

We must repeat here, that when calyx and corolla are not both present, the circle which is present is considered to be the calyx, whether green or not.

207. **The Corolla.** The calyx and corolla, taken together, are called the *floral envelopes.* When both envelopes are present, the corolla is the inner one; it is usually, though not invariably, of some other colour than green. Each division of a corolla is called a *petal*, and the corolla is *polypetalous* when the petals are completely disconnected; but *gamopetalous* if they are united in any degree, however slight. The terms *regular* and *irregular*, applied to the calyx, are applicable also to the corolla, and the terms used in the description of leaves are applicable

to petals. If, however, a petal is narrowed into a long and slender portion towards the base, that portion is known as the *claw*, whilst the broader upper part is called the *limb* (Fig. 176). The leaf-terms are then applicable to the limb.


Fig. 176.

208. Gamopetalous corollas assume various forms, most of which are described by terms easily understood. The forms assumed depend almost entirely on the shape of the petals which, when united, make up the corolla. If these, taken separately, are linear, and are united to the top, or nearly so, the corolla will be tubular (Fig. 177). If the petals are wedge-shaped, they will, by their union, produce a *funnel-shaped* corolla (Fig. 178). In the *campanulate* or *bell-shaped* form, the enlargement from base to summit is more gradual. If the petals are narrowed abruptly into long claws, the union of the claws into a tube and the spreading of the limb at right angles to the tube will produce the *salver-shaped* form, as in Phlox (Fig. 179). The *rotate* corolla differs from this in having a *very short* tube. The corolla of the Potato is rotate.


Fig. 177.


Fig. 178.

209. The most important *irregular* gamopetalous corollas are the *ligulate*, which has been fully described in the examination of the Dandelion, and the *labiate*, of which we found an example in Catnip (Fig. 59). The corolla of Turtle-head (Fig. 180) is another

Fig. 176.—Single petal of a Pink. Fig. 177.—Tubular corolla of a Honeysuckle.
Fig. 178.—Funnel-shaped corolla of Calystegia.

example. When a labiate corolla presents a wide opening between the upper and lower lips, it is said to be *ringent;* if the opening is closed by an upward projection of the lower lip, as in Toadflax (Fig. 181), it is said to be *personate*, and the projection in this case is known as the *palate.* A good many corollas, such as those of Toadflax, Dicentra, Snapdragon, Columbine, and Violet, have protuberances or *spurs* at the base. In Violet one petal only is spurred; in Columbine the whole five are so.

Fig. 179.

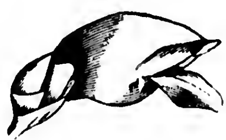


Fig. 180.

Fig. 181.

210. *Æstivation.* This is the term applied to the mode in which the sepals and petals are folded in the bud. In general, the members of a calyx or of a corolla overlap in the bud, or they do not. If they stand edge to edge, as in the calyx of Mallow, the æstivation is *valvate.* If there is overlapping, and one or more of the members have *both* edges covered, the æstivation is *imbricate;* and if each member has one edge covered and the other uncovered, as in the corolla of Mallow, Evening Primrose, Phlox, &c., it is then said to be *convolute.* Gamopetalous corollas are frequently *plaited* in the bud, and the plaits may be convolute, as in Morning Glory.

Fig. 179.—Salver-shaped corolla of Phlox.
Fig. 180.—Labiate corolla of Turtle-head.
Fig. 181.—Personate corolla of Toadflax.

211. **The Stamens.** As calyx and corolla are called collectively the floral envelopes, so stamens and pistil are spoken of collectively as the *essential organs* of the flower. The circle of stamens alone is sometimes called the *andrœcium.* A complete stamen consists of a slender stalk known as the *filament*, and one or more small sacs called collectively the *anther.* The filament, however, is not uncommonly absent, in which case the anther is *sessile.* As a general thing, the anther consists of two oblong cells with a sort of rib between them called the *connective*, and that side of the anther which presents a distinctly *grooved* appearance is the *face*, the opposite side being the *back.*

Fig. 182.

Fig. 183.

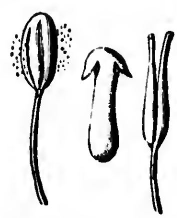
Fig. 184.

The filament is invariably attached to the connective, and may adhere through the entire length of the latter, in which case the anther is *adnate* (Fig. 182); or the base of the connective may rest on the end of the filament, a condition described as *innate* (Fig. 183); or the extremity of the filament may be attached to the middle of the back of the connective, so that the anther swings about: it is then said to be *versatile* (Fig. 184). In all these cases, if the face of the anther is turned towards the centre of the flower, it is said to be *introrse;* if turned outwards, *extrorse.*

Figs. 182, 183, 184.—Stamens showing adnate, innate, and versatile attachments of the anther.

The cells of anthers commonly open along their outer edges to discharge their pollen (Fig. 185). In most of the Heaths, however, the pollen is discharged through a minute aperture at the top of each cell (Fig. 186), and in our Blue Cohosh each cell is provided with a lid or valve near the top, which opens on a kind of hinge (Fig. 187). Occasionally, examples of barren or abortive stamens are met with, as the fifth stamen in Turtle Head and Pentstemon. These are filaments without anthers, and are known as *staminodes*.

212 Stamens may be either entirely distinct from each other—in which case they are described as *diandrous*, *pentandrous*, *octandrous*, &c., according to their number (or, if more than twenty, as indefinite)—or they may be united in various ways. If their anthers are united in a circle, while the filaments are separate (Fig. 57), they are said to be *syngenesious;* but if the filaments unite to form a tube, while the anthers remain distinct, they are said to be *monadelphous* (Fig. 32); if they are in two groups they are *diadelphous* (Fig. 37); if in three, *triadelphous;* if in more than three, *polyadelphous*.



Figs. 185. 187. 186.

Figs. 185, 186, 187.—Anthers exhibiting different modes of dehiscence.

213. As to **insertion**, when stamens are inserted on the receptacle they are *hypogynous;* when borne on the calyx, *perigynous;* when borne on the ovary, *epigynous;* and if inserted on the corolla, *epipetalous*. They may, however, be borne even on the style, as in Orchis, and then they are described as *gynandrous*.

214. If the stamens are four in number, and in two

pairs of different lengths, they are said to be *didynamous* (Fig. 60); if six in number, four long and two short, they are *tetradynamous* (Fig. 28); and, finally, if the stamens are hidden in the tube of a gamopetalous corolla they are said to be *included*, but if they protrude beyond the tube they are *exserted* (Fig. 177).

215. **The Pistil.** This is the name given to the central organ of the flower. It is sometimes also called the *gynœcium.* As in the case of the stamens, the structure of the pistil must be regarded as a modification of the structure of leaves generally. The pistil may be formed by the folding of a single carpellary leaf, as in the Bean (Fig. 188), in which case it is *simple;* or it may consist of a number of carpels, either entirely separate from each other or united together in various ways, in which case it is *compound.* By some botanists, however, the term compound is restricted to the case of united carpels. If the carpels are entirely distinct, as in Buttercup, the pistil is *apocarpous;* if they are united in any degree, it is *syncarpous.* A pistil of one carpel is *monocarpellary;* of two, *dicarpellary;* and so on, to *polycarpellary.*

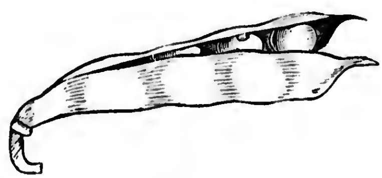


Fig. 188.

216. The terms *inferior* and *superior*, as applied to the pistil, describe its situation upon the axis relative to that of the calyx, corolla, and stamens. It will be remembered that the end of the peduncle is usually enlarged, forming what is called the *torus* or receptacle. Usually the receptacle is a little higher in the centre

Fig. 188.—Legume of the Bean.

than at its margin, and as the gynœcium occupies this central part, its position is above that of the other floral leaves, as shown in Fig. 189. Here the pistil is *superior*, and the stamens and petals hypogynous. But frequently the outer part of the receptacle grows more vigorously than the centre, forming, in fact, a cup with the pistil in the bottom of it, and the stamens and petals around

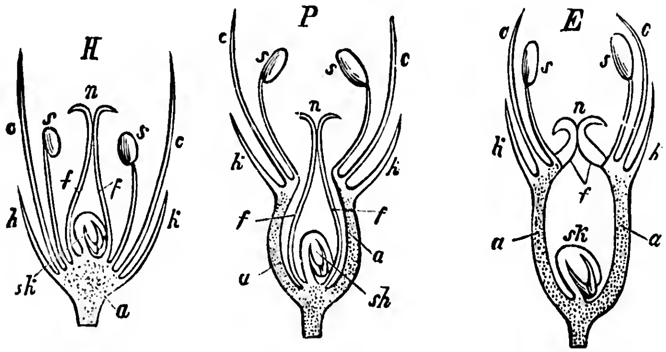


Fig. 189. Fig. 190. Fig. 191.

its margin (Fig. 190). In this case the pistil may be described as half-inferior, and the stamens and petals as perigynous. Often the cup-shaped receptacle grows fast to the ovary all round. In other cases, the carpels, instead of being developed from the bottom of the cup, spring from the margin, thus forming a roof-like disk, around the edge of which the stamens are attached (Fig. 191). Here the stamens are epigynous, and the ovary is truly *inferior*. Other cases of epigyny and perigyny arise from the adnation (growing together) of the floral whorls without exceptional development of the

Figs. 189, 190, 191.—Diagrams illustrating hypogynous (*H*), perigynous (*P*), and epigynous (*E*) flowers; *a*, axis; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels; *n*, stigma; *sk*, ovule. (Prantl.)

receptacle. The cases of the Rose, Cherry, and Apple have already been referred to (Chapter VI.).

217. In our examination of the Marsh Marigold (Figs. 24 and 25) we found an apocarpous pistil of several carpels. We found also that each carpel contained a number of seeds, and that in every case the seeds were attached to that edge of the carpel *which was turned towards the centre of the flower*, and that, as the carpels ripened, they invariably split open along that edge, but not along the other, so that the carpel when opened out presented the appearance of a leaf with seeds *attached to the margins.* The inner edge of a simple carpel, to which the seeds are thus attached, is called the *ventral suture*, the opposite edge, corresponding to the mid-rib of a leaf, being the *dorsal suture.*

218. If we suppose a number of simple carpels to approach each other and unite in the centre of a flower, it is evident that the pistil so formed would contain as many cells as there were carpels, the cells being separated from each other by a *double wall*, and that the seeds would be found arranged about the centre or axis of the pistil ; and this is the actual state of things in the Tulip, whose pistil is formed by the union of three carpels. When the pistil ripens, the double walls separating the cells split asunder. To these separating walls the name *dissepiment* or *partition* is given.

219. The cells are technically known as *loculi.* An ovary with one cell is *unilocular ;* with two, *bilocular ;* with several, *multilocular.* Between the unilocular and multilocular forms there are all shades of gradation. In some cases, as, for example, in Saxifrage, the carpels

are united below but separate above. Sometimes, also, false partitions are formed across the loculi in the course of growth. In the Mints, for instance, there are at first but two loculi; eventually, however, there are four, which completely separate at the time of ripening.

220. But it often happens that though several carpels unite to form a compound pistil, there is but *one cell* in the ovary. This is because the separate carpellary leaves have not been folded before uniting, but have been joined edge to edge, or rather with their edges slightly turned inwards.


Fig. 193.


Fig. 192.

In these cases the seeds cannot, of course, be in the centre of the ovary, but will be found *on the walls*, at the junction of the carpels (Figs. 192 and 193). In some plants the ovary is one-celled, and the seeds are arranged round a column which rises from the bottom of the cell (Figs. 194 and 195). This case is explained by the early obliteration of the partitions, which must at first have met in the centre of the cell. Special cases, however, are found in which no trace of partitions has been observed, and these must consequently be explained by the actual upward growth of the axis into the centre of the ovary.


Fig. 194.


Fig. 195.

221. In all cases the line or projection to which the seeds are attached is called the *placenta*, and the term **placentation** has reference to the manner in which the placentas are arranged. In the simple pistil the placentation is *marginal* or *sutural*. In the syncarpous

Figs. 192, 193.—Compound one-celled ovary of Mignonette.

Figs. 194, 195.—Sections of ovary of a Pink, showing free central placentation.

pistil, if the dissepiments meet in the centre of the ovary, thus dividing it into separate cells, the placentation is *central* or *axile*; if the ovary is one-celled and bears the seeds on its walls, the placentation is *parietal*; and if the seeds are attached to a central column it is *free central.*

222. Besides the union of the ovaries there may also be a union of the styles, and even of the stigmas.

223. A very exceptional pistil is found in plants of the Pine Family. Here the ovules, instead of being enclosed in an ovary, are usually simply attached to the inner surface of an open carpellary leaf or scale, the scales forming what is known as a *cone* (Figs. 196, 197, and 198). The plants of this family are hence called *gymnospermous*, or naked-seeded.

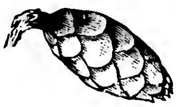


Fig. 196

Figs. 197, 198.

224. **Nectaries.** This name is given to that part of a flower which has been specially formed for the secretion of honey. The nectaries need not, however, be looked upon as separate or independent organs. Sometimes they are to be found at the base of the petals, as in Buttercup; sometimes at the base of the stamens, as in the Grape. Very commonly they are at the bottom of deep spurs formed on one or more divisions of the perianth, as in Violet, many Orchids, and in Columbine.

225. **Phyllome** and **Trichome.** To all leaf-forms, whether ordinary foliage-leaves or those special modifications which make up the flower—sepals, petals, stamens

Fig. 196.—A cone.
Fig. 197.—Single scale showing position of the two seeds on the inner face.
Fig. 198.—One of the winged seeds removed.

and carpels—the general term *phyllome* is applicable. The characteristic of the phyllome is that it is a lateral outgrowth of the stem or its branches.

226. The term *trichome*, on the other hand, is applicable to any hair-like appendage on the surface of the plant generally, whether of root, stem, or leaf. The commonest form of trichome is the *hair*. The root-hairs which generally clothe the surface of young roots are of great importance as absorbing agents. Each root-hair consists of a single, delicate, tube-like cell with extremely thin walls. Other hairs may consist of several such cells placed end to end. Others, again, may branch extensively. It sometimes happens that the terminal cell of a hair produces a gummy substance which comes away with the slightest touch. The sticky surfaces of many common plants are due to the presence of such hairs, which are then described as *glandular*. Gummy matters are also secreted by *glands* close to the surface of the plant. *Peltate* hairs are occasionally met with, as in the leaves of Shepherdia. They give a scurfy appearance to the surface upon which they grow. Then there are hairs which secrete *odorous* fluids, as, for example, those upon the surface of the Sweet Brier. These probably serve to attract insects. *Stinging* hairs are also common. They contain an irritating fluid. When the point of the hair pierces the skin it is broken off, and the fluid then escapes into the wound.

227. Besides the trichome forms just mentioned, there are also *bristles*, formed from hairs by the gradual thickening and hardening of their walls, and *prickles*, such as those of Sweet Brier (Fig. 199), which consist of many

hard-walled woody cells closely packed together. That prickles are really trichomes is shown by the fact that when the bark is stripped off they come away along with it. *Spines*, on the other hand (Fig. 200), are lateral outgrowths of the stem. They are, in fact, generally stunted branches, and will be found to spring originally from the axils of leaves. Occasionally the petiole of a leaf is converted into a spine, which then becomes a true phyllome. Ovules are generally regarded as trichomes since they arise from the inner surface of the carpels.

Fig. 199.

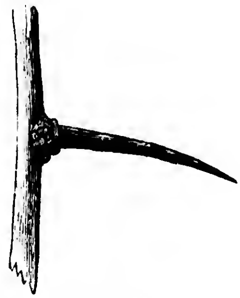


Fig. 200.

228. **The Fruit.** In coming to the consideration of the fruit, you must for the present lay aside any popular ideas you may have acquired as to the meaning of this term. You will find that, in a strict botanical sense, many things are fruits which, in the language of common life, are not so designated. For instance, we hardly speak of a pumpkin or a cucumber as fruit, and yet they are clearly so, according to the botanist's definition of that term. A fruit may be defined to be *the ripened pistil together with any other organ, such as the calyx or receptacle, which may be adherent to it.* This definition will, perhaps, be more clearly understood after a few specimens have been attentively examined.

229. For an example of the simplest kind of fruit let

Fig. 199.—Prickles of Sweet Brier. Fig. 200.—Spines of the Hawthorn.

us revert to our Buttercup. As the carpels ripen, the style and stigma are reduced to a mere point. On cutting open one of these carpels when fully ripe, we find it contains a single seed, not quite filling the cavity, but attached at one point to the wall of the latter. What you have to guard against, in this instance, is the mistake of considering the entire carpel to be merely a seed. It is a seed enveloped in an outer covering which we called the ovary in the early stages of the flower, but which, now that it is ripe, we shall call the *pericarp*. This pericarp, with the seed which it contains, is the fruit. The principal difference between the fruit of Marsh Marigold and that of Buttercup is that, in the former, the pericarp envelopes several seeds, and, when ripe, *splits open down one side*. The fruit of Buttercup does not thus split open. In the Pea, again, the pericarp encloses several seeds, but splits open along *both* margins. The fruits just mentioned all result from the ripening of *apocarpous* pistils, and they are consequently spoken of as *apocarpous fruits.*

230. In Willow-herb, you will recollect that the calyx-tube adheres to the whole surface of the ovary. The fruit in this case, then, must include the calyx. When the ovary ripens, it splits longitudinally into four pieces (Fig. 41), and, as the pistil was *syncarpous*, so also is the fruit.

231. In the Peach, Plum, Cherry, and *stone-fruits* or *drupes* generally, the seed is enclosed in a hard shell called a *putamen.* Outside the putamen is a thick layer of pulp, and outside this, enclosing the whole, is a skin-like covering. In these fruits all outside the seeds is the pericarp. In one respect these stone-fruits resemble the

fruit of the Buttercup: they do not split open in order to discharge their seeds. All fruits having this peculiarity are said to be **indehiscent,** whilst those in which the pericarp opens, or separates into pieces, are **dehiscent**.

232. In the Apple (Fig. 50) and Pear, the seeds are contained in five cells in the middle of the fruit, and these cells are surrounded by a firm fleshy mass, which is mainly an enlargement of the calyx. In fact, the remains of the five calyx-teeth may be readily detected at the end of the apple opposite the stem. As in Willow-herb, the calyx is adherent to the ovary, and therefore calyx and ovary together constitute the pericarp. These *fleshy fruits*, or *pomes*, as they are sometimes called, are of course *indehiscent.*

233. In the Currant, as in the Apple, you will find the remains of a calyx at the top, so that this fruit, too, is *inferior*, but the seeds, instead of being separated from the mass of the fruit by tough cartilaginous cell-walls, as in the Apple, lie imbedded in the soft, juicy pulp. Such a fruit as this is a *berry.* The Gooseberry and the Grape are other examples. The Pumpkin and other *gourds* are similar in structure to the berry; but, besides the soft inner pulp, they have also a firm outer layer and a hard rind. The name *pepo* is generally given to fruits of this sort.

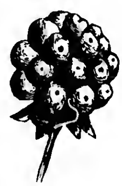


Fig. 201.

234. A Raspberry or Blackberry (Fig. 201) proves, on examination, to be made up of a large number of juicy little drupes, aggregated upon a central axis. It cannot, therefore, be a true berry, but may be called an *aggregated* fruit.

Fig. 201.—Aggregated ruit of the Raspberry.

235. A strawberry (Fig. 202) is a fruit consisting chiefly of a mass of pulp, having its surface dotted all over with little carpels (achenes), similar to those of the Buttercup. The flesh of the Strawberry is simply an enlarged *receptacle;* so that this fruit, also, is not a true berry.

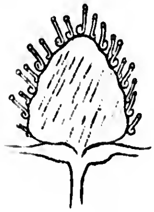


Fig. 202.

236. The fruit of Sweet Brier (Fig. 45) consists of a red fleshy calyx, lined with a hollow receptacle which bears a number of achenes. This fruit is, therefore, analogous to that of the Strawberry. In the latter the achenes are on the outer surface of a *raised* receptacle, while in the former they are on the inner surface of a *hollow* receptacle.

When other parts of the flower are combined with the ovary in fruit, as in Apple, Rose, and Strawberry, the result is sometimes described as a *pseudocarp*, or spurious fruit.

237. The cone of the Pine (Fig. 116) is a fruit which differs in an important respect from all those yet mentioned, inasmuch as it is the product, not of a single flower, but of as many flowers as there are scales. It may, therefore, be called a *collective* or *multiple* fruit. The Pine Apple is another instance of the same thing.

238. Of dehiscent fruits there are some varieties which receive special names. The fruit of the Pea or Bean (Fig. 188), whose pericarp splits open along *both* margins, is called a *legume;* that of Marsh Marigold (Fig. 25), which opens down one side only, is a *follicle.* Both of these are apocarpous.

Fig. 202.—Section of a Strawberry.

239. Any syncarpous fruit having a dry *dehiscent* pericarp is called a *capsule*. The dehiscence of syncarpous or polycarpellary fruits is of several kinds. If the rupture takes place along the partitions the fruit will be split up into its original carpels; this form of dehiscence is *septicidal* (Fig. 203). But the dehiscence may take place along the dorsal suture of each carpel, half-way between the partitions, so that the opening is into the loculus; this mode is known as *loculicidal* (Fig. 204). Or again, the valves (separate pieces of the pericarp) may fall away, leaving the partitions standing; this dehiscence is *septifragal* (Fig. 205).

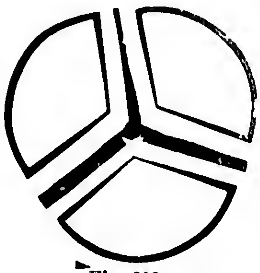


Fig. 203.

Fig. 204.

240. A long and slender capsule, having two cells separated by a membranous partition bearing the seed, and from which, when ripe, the valves fall away on each side, is called a *silique* (Fig. 206). If, as in Shepherd's Purse (Fig. 29), the capsule is short and broad, it is called a *silicle*. If the capsule opens *horizontally*, so that the top comes off like a lid, as in Purslane (Fig. 207), it is a *pyxis*.

Fig. 205.

241. Any dry, one-seeded, *indehiscent* fruit is called an *achene*, of which the fruit of Buttercup (Fig. 14) is an

Figs. 203, 204, 205.—Diagrams illustrating septicidal, loculicidal, and septifragal dehiscence.

example. In Wheat the fruit differs from that of Buttercup in having a closely fitting and *adherent* pericarp. Such a fruit is called a *caryopsis* or *grain*. A *nut* is usually syncarpous, with a hard, dry pericarp. A *winged* fruit, such as that of the Maple (Fig. 208), is called a *samara* or *key*.

Fig. 206.

242. A fruit which splits up when ripe into several one-seeded pieces is called a *schizocarp*. The samara of the Maple is a good example; also the fruit of Catnip, which splits up at maturity into four one-seeded portions. The fruit of Mallow is another common instance. The separate portions in these cases are called *mericarps*. In some leguminous plants the pod breaks up *transversely* into one-seeded portions, giving rise to the form called a *loment*.

Fig. 207.

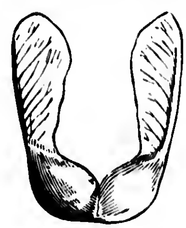


Fig. 208.

243. A special schizocarp is that of Umbelliferous plants (Fig. 209). Here the fruit splits into two mericarps, each attached, however, by a fibre to the axis. Such a fruit is called a *cremocarp*.

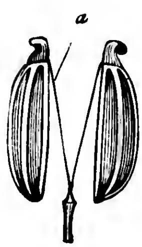


Fig. 209.

244. **The Seed**. The seed has already been described as the *fertilized ovule*. During the formation of the carpels, the ovules arise as outgrowths from the inner surface of the ovary, mostly, as has been pointed out, upon the *margins* of the carpellary leaves, but occasionally also upon the surface generally. At first the ovule

Fig. 206.—Silicle of Stock. Fig. 207.—Pyxis of Purslane.
Fig. 208.—Samara of Maple.
Fig. 209.—Cremocarp of an Umbellifer; *a*, the fibre attaching the mericarp to the axis. (Thomé.)

is a simple, soft mass with no indication whatever of the covering so manifest in ripe seeds of all kinds. Very soon, however, after the appearance of the body of the ovule, a circular ridge is developed upon it, and this gradually extends upwards over the surface so as to form a coat, which at length entirely covers it except at the very apex, where a minute opening is left. Very commonly, but not always, a second coat is developed exactly in the same manner, outside the first, and an opening is left in this coat also, precisely over the other. This minute passage through both coats to the ovule body has already been named the *micropyle*. The two coats are known as the *primine* (generally, though not always, applied to the outer) and the *secundine*, and the central body is the *nucleus*.

245. If the ovule appears to arise directly from the placenta without the intervention of a stalk, it is *sessile*; but if a stalk is present, this is known as the *funiculus*. In the accompanying diagram (Fig. 210) which represents a section of the complete ovule, *k* is the nucleus; *ai*, the primine; *ii*, the secundine; *m*, the micropyle; *f*, the funiculus. The point *(c)* where the two coats and the nucleus are blended together is called the *chalaza*. The portion of the nucleus marked *em* is the cavity called the embryo-sac, already referred to in Chapter II.

246. It must now be pointed out that though the ovules at the commencement of their growth are straight, as in the diagram just described, yet they do not commonly remain so. Very often the ovule bends over so as to appear completely inverted, in which case the funiculus grows fast to one side of the primine, becoming completely fused

with it, and forming what is then called the *raphe.* Fig. 211 represents this condition, *r* being the raphe, *s* the chalaza, and the other letters corresponding to those in Fig. 210.

Sometimes the curving of the ovule upon itself is not carried to this extreme, and an intermediate form is presented, as in Fig. 212.

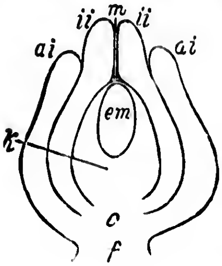


Fig. 210.

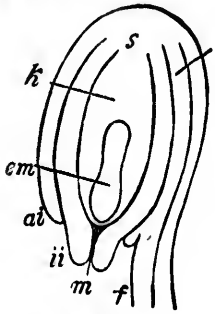


Fig. 211.

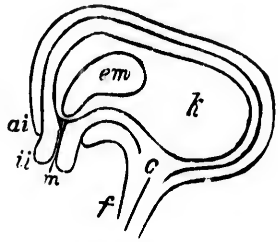


Fig. 212.

If the ovule remains straight it is said to be *orthotropous;* if completely inverted, *anatropous;* if half bent over, *campylotropous.*

247. **Pollination.** The process of fertilization, by which the ovule is converted into the seed, has been briefly described in Chapter II. A few words may be added here upon *pollination*—the process of supplying pollen to the stigma. In very many flowers which have both stamens and pistil (and hence called *hermaphrodite*), the process is very simple. Either the anthers and stigma are so close together that the pollen cannot fail to be deposited upon the stigma immediately upon the opening of the anther, or the stigma is upon a lower level, so that the pollen drops upon it, or, in special cases, as in

Figs. 210, 211, 212.—Diagrams of orthotropous, anatropous, and campylotropous ovules. (Prantl.)

Impatiens and Wood Sorrel, besides the ordinary large flowers, there are special small ones (known as *cleistogamous* flowers) whose floral envelopes do not open, thus *compelling* self-fertilization. But it is well established that in a vast number of cases the ovules in any given flower have to depend for fertilization upon the pollen of some other flower. Nature seems to have provided against self-fertilization by various contrivances. Sometimes the relative positions of the anthers and the stigma in the same flower are such as to render it impossible. Sometimes the pollen comes to maturity and is shed from the anthers before the stigma is in a suitable condition to receive it; whilst, on the other hand, the stigma is often developed first and has withered before the opening of the anthers. (Flowers showing these peculiarities are said to be *dichogamous*.) When for any reason cross-fertilization has become a necessity, the conveyance of the pollen from one flower to another is ensured in various ways. When the flowers are inconspicuous, as in Grasses, the wind is the great agent, and flowers so fertilized are said to be *anemophilous*. In other cases the flowers, either by their brightness or their odour, attract insects in quest of honey, and these then become the carriers of the pollen. Flowers of this sort are said to be *entomophilous*, and are usually so constructed as to the situation of their honey receptacles, and the relative position of anthers and stigma, as to ensure the transfer of the pollen from the anther of one flower to its destination upon the stigma of another. The case of the Orchids has already been referred to in section 92.

248. After fertilization, the embryo, or young plantlet, as exhibited in the seed, begins its growth in that end of

the embryo-sac which is next the micropyle, and about the same time, in the other end of the embryo-sac, there begins a deposit of matter intended for the nourishment of the embryo during the germination of the seed. This deposit has been already referred to under the name of *albumen*. It is also known as *endosperm*. As the embryo developes, this endosperm or albumen may be completely absorbed by it, so that at maturity the embryo will occupy the whole space within the seed-coats, as in the Bean. In this case the seed is *exalbuminous*. In other cases, as in Indian Corn, the endosperm remains as a distinct mass with the embryo embedded in it, or sometimes wrapped round it. Seeds of this kind are *albuminous*. Rarely this nourishing material is deposited outside the embryo-sac, in the body of the ovule. It is then known as *perisperm*.

249. The ripened seed presents very different aspects in different plants. It may be resolved, however, into the *nucleus* and the *integument* (the *spermoderm* of some botanists). The former is made up of the embryo, together with the endosperm or perisperm, if present, while the latter consists of two layers: an outer, known as the *testa*, and an inner, the *tegmen*. The scar showing where the seed has been attached to the placenta is called the *hilum;* it is very distinct in the Bean.

250. Besides the integument just mentioned, occasionally an additional outer coat is formed, to which the term *aril* is applied. The fleshy red covering of the seed in our Ground Hemlock is a good example.

251. The seeds of Willow-herb, Milkweed, and many other plants are furnished with tufts of hair-like bristles

which facilitate their dispersion by the wind. These tufts grow from the testa of the seed, and are not to be confounded with the pappus of the Thistle, Dandelion, &c.; the latter, it will be remembered, is an outgrowth of the calyx.

252. The embryo, as already explained, generally consists of an axis or stem called the *radicle* (or, more properly, the *caulicle*, because it is in all respects a true stem and not a root), and one or more leaves called *cotyledons*, with sometimes, also, a bud known as the *plumule*. As to the number of cotyledons, it may be repeated here that seeds are, as a rule, either dicotyledonous or monocotyledonous. Some plants of the Pine Family, however, have six cotyledons, whilst, on the other hand, in the Orchids and a few other plants, these organs are altogether wanting.

253. The cotyledons vary greatly in thickness. In the Maple, for example, they are very thin, while in the Pea, the Bean, and the Oak they are extremely thick and fleshy.

254. **Germination.** If a seed is supplied with proper warmth and moisture it soon begins to swell and soften by absorption of water, with the effect of bursting the seed-coats to a greater or less degree. At the same time the process of *growth* is begun. This early growth of the embryo is *germination*. The details of the process vary somewhat according to the structure of the seed. In dicotyledons, if the seed-leaves are thin and leaf-like, containing within themselves but scanty store of nourishment, the radicle will grow throughout its length so as to raise the cotyledons above the soil, where they at once

expand and become the earliest leaves of the new plant; and during this upward extension of the radicle a root also is being rapidly developed from its lower end. It is important, also, to notice here that the mode of growth of the root portion is at variance with that of the radicle or stem proper, for while the latter grows *throughout its length*, the former grows by the addition of successive new portions *to its extremity*. (The protection of the growing root by a *root-cap* has already been referred to.) As soon as the root is prepared to absorb nourishment from the soil, then, and not till then, the development of the next bit of stem commences between the first pair of leaves.

255. But when the cotyledons are loaded with nourishment, as in the Bean, it will generally be found that the elements of additional bits of stem (the plumule) are already present in the embryo, and although the radicle may lengthen so as to lift the cotyledons above the surface, yet these do not, as in the thin-leaved embryos, fully perform the office of foliage-leaves; their true function is to supply the newly developing parts with nourishment, and when this duty is performed they usually drop off. In fact, it is not uncommon for such extremely fleshy cotyledons to remain under the surface altogether, as in the case of the Pea and the Acorn. In these cases the growth of the radicle is but slight. The plumule and the end of the radicle are liberated from the seed, and the former at once grows vigorously upward, being practically independent of the root as long as the stock of nourishment in the cotyledons holds out. Simultaneously with the development of the stem, the root is strongly developed from the end of the short radicle.

256. In the monocotyledons the process of germination is much the same as that just described, with the important difference, however, that the primary root from the end of the radicle can scarcely be said to develope at all, a cluster of fibrous roots bursting out almost at once from its sides. Indian Corn answers very well as an illustration. Here the seed, largely made up of endosperm or albumen, remains in the ground. The single cotyledon is wrapped round the plumule and adheres by its back to the endosperm, acting thus as a medium through which nourishment is absorbed, and of course not being carried up to the surface. The plumule is rapidly carried upward, developing alternate leaves, and the numerous fibrous roots are given off from the sides of the short radicle.

257. The young student is strongly recommended to investigate for himself the phenomena of germination as exhibited in common seeds. For this purpose he may place a few Windsor beans and grains of Indian Corn between layers of moist flannel or coarse paper in a shallow dish. If kept damp, germination will begin in a day or two, and if sufficient specimens have been provided the process may be observed at various stages. Trial should also be made of the length of time during which seeds will retain their vitality. Many seeds, such as those of Elm and Poplar, will be found to germinate only if they have been kept fresh and not permitted to dry up, whilst others, such as Indian Corn and Wheat, and in general those containing starch, may be kept for a very long time without losing their germinating power.

CHAPTER XIX.

ON THE MINUTE STRUCTURE OF PLANTS — THE CELL — TISSUES—TISSUE-SYSTEMS—EXOGENOUS AND ENDOGENOUS STEMS.

258. Up to this point we have been engaged in observing such particulars of structure in plants as are manifest to the naked eye. It is now time to enquire a little more closely, and find out what we can about the *elementary* structure of the different organs. We have all observed how tender and delicate is a little plantlet of any kind just sprouting from the seed; but as time elapses, and the plant developes itself and acquires strength, its substance will, as we know, assume a texture varying with the nature of the plant, either becoming hard and firm and woody, if it is to be a tree or a shrub, or continuing to be soft and compressible as long as it lives, if it is to be an herb. Then, as a rule, the leaves of plants are of quite a different consistency from the stems, and the ribs and veins and petioles of foliage-leaves are of a firmer texture than the remaining part of them. In all plants, also, the newest portions, both of stem and root, are extremely soft compared with the older parts. It will be our object in this chapter to ascertain, as far as we can, the reason of such differences as these; and to accomplish this we shall have to call in the aid of a microscope of much higher power than that which has hitherto served our purpose.

259. First let us examine under our microscope a very thin slice of the pith of the Elder. You see at once that

the whole slice is made up of more or less rounded, nearly transparent bodies, rather loosely thrown together, as shown in Fig. 213. Next let us examine, in the same way, a thin slice of the tuber of the Potato. Here,

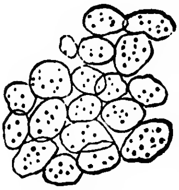


Fig. 213.

again, it is evident that the object under examination is wholly composed of enclosed spaces, not so much rounded, however, as those of the Elder pith, because they are more closely packed together. Fig. 214 is a representation of two of these spaces. Now look at the leaf of a Moss, and you see again that we have an aggregation of enclosed spaces as before (Fig. 215). So, also, if we examine a hair from the surface of a Petunia or a Geranium, we have some such appearance presented to us as that shown in Figs. 216 and 217, the hairs manifestly consisting of several enclosed spaces placed end to end. In short, the microscope reveals to us the fact that every part of a plant is made up of such enclosed spaces, varying greatly in shape and size and general aspect, it is true, but always (except in some of the very lowest plants) clearly exhibiting boundaries; and since these boundaries are visible, no matter in what direction we make our cutting, it is clear

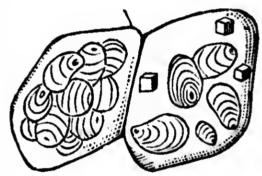


Fig. 214.

that the spaces must be shut in on all sides. These enclosed spaces are called *cells*, and their boundaries are known as the *cell-walls*.

Fig. 213.—Loosely-packed cells of Elder-pith.

Fig. 214.—Two cells of Potato tuber containing starch-granules and crystalloids. (Gray.)

260. Whilst looking at the parts of plants just submitted to examination, it must have struck you that the interior of the cell presents a very different appearance in different cases. The Potato section, for example, is not at all like the Moss-leaf section in the matter of *cell-contents*, and the cells of the Elder-pith appear to be quite empty. We shall discuss these differences presently. In the meantime let us study the appearance of some cells taken fresh from some part of a plant where growth is actually going on—say the point of a new rootlet. If our section is taken near enough to the point we shall get cells which have just been formed. Such a section is very well shown in Fig. 218. Here the cells are seen to be completely filled with liquid having a

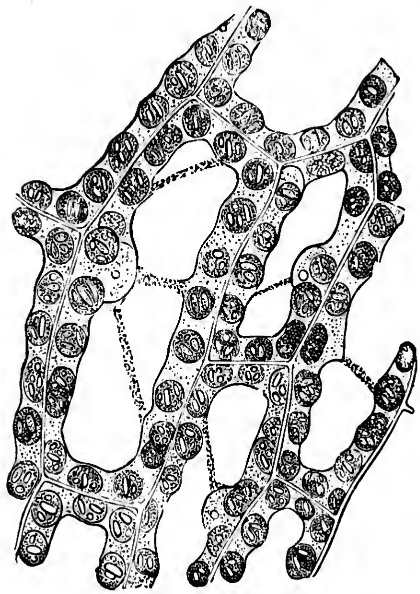


Fig. 215.

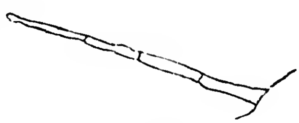


Fig 216.

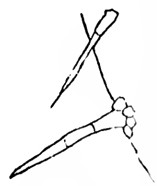


Fig. 217.

Fig. 215.—Cells from leaf of a Moss containing protoplasm and chlorophyll-granules.

Fig. 216.—Hair from Petunia leaf. Fig. 217.—Hairs from Geranium leaf.

granular appearance, and in the centre of each a rounded denser portion may be made out, each of these again enclosing one or more smaller bodies. This liquid which thus fills the newly-formed cells is called *protoplasm*; the large rounded central mass is the *nucleus*, consisting of denser protoplasm, and the smaller enclosed masses are the *nucleoli*.

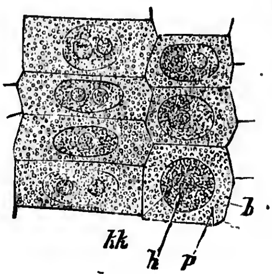


Fig. 218.

Now let us consider Fig. 219. This is a representation of a section of the same rootlet, taken a little farther back from the point, so that the cells now in view are a little older than the first ones. They are manifestly larger; that is to say, they have *grown*. The nucleus and the nucleoli can still be made out in some of them, but the protoplasm no longer entirely fills the cell. There are now transparent spaces (*vacuoles*) which are filled with water, and between these the protoplasm is seen in the form of strings or bands, as well as lining the cell.

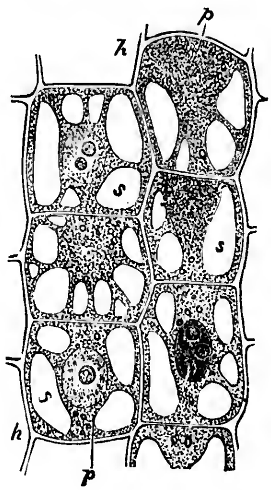


Fig. 219.

The water has been absorbed through the cell-wall, and after saturating the protoplasm the excess has formed the vacuoles.

Fig. 218.—Young cells filled with protoplasm (*p*); *b*, cell wall; *h*, nucleus; *kk*, nucleolus. (Sachs.)

Fig. 219.—Cells a little older, exhibiting vacuoles (*s*). (Sachs.)

Fig. 220 shows some cells from the same rootlet taken still farther back. It is clear that the change observed in Fig. 219 has been carried to a still greater extent. In some of these cells the protoplasm is restricted to the lining of the cell and the nucleus.

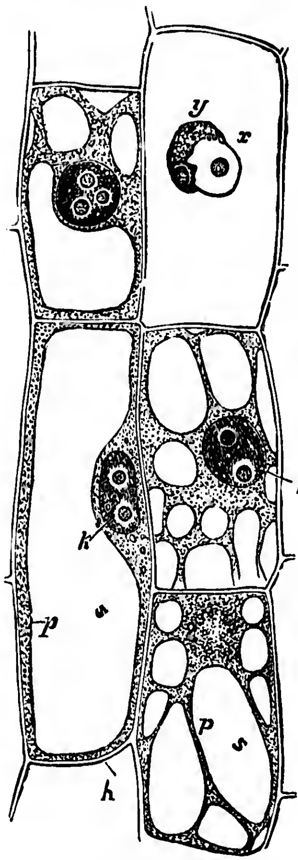


Fig. 220.

261. It is now to be observed that the protoplasm is the essential part of every living cell. Through its agency all the vital processes of the plant are carried on. Every cell of every plant at some time or other contains this substance, and when at length it disappears the cells which are deprived of it no longer take any active part in the growth of the plant, but serve merely mechanical purposes, such as that of support or conduction, and are in that stage of their history filled usually with air or water. The pith of the Elder is made up of such dead cells, as is also the greater part of the wood and bark and older parts generally of all plants.

262. The most marked feature of the living protoplasm is its *activity*. We may observe this property by

Fig. 220.—Cells still older; *h*, the wall; *s*, vacuoles; *p*, protoplasm; *k*, nucleus; *xy*, swelling of nucleus caused by water used in preparation of the section. (Sachs.)

examining plant-hairs and other parts under high powers of the microscope, when it will be seen that there are movements of two kinds. The whole mass of protoplasm has a rotary motion, sliding upon the cell-wall, downwards on one side and upwards on the other. This is the *mass-movement.* Also, currents may be traced passing across the protoplasm in different directions. This is the *streaming-movement.*

In some of the very lowest plants, where there is no cell-wall, and the whole is a mass of naked protoplasm, these movements may be observed more readily because they are less restricted.

263. There is some doubt as to the exact chemical composition of protoplasm. It is, however, a very complex substance belonging to a group of bodies known as *albuminoids,* of which nitrogen is an important constituent.

The consistence of protoplasm depends upon the amount of water it contains. In dry seeds, for example, it is tough and hard, but when the same seeds are soaked in water it becomes partially liquid.

Fig. 221.

264. **Forms of Cells.** As cells become older they tend as a rule to change their form, though sometimes we find them differing but little from their original conformation. Commonly a cell grows more rapidly in some one direction, thus giving rise to long forms, as is the case in stems generally, and in the petioles and veins of leaves, the superior toughness and strength of which

Fig. 221.—Prosenchyma of the wood. (Gray.)

are due to the lengthening and hardening of the cells of which they are composed (Fig 221).

265. **The Cell-wall.** In the portions of plants just selected for microscopic examination we have seen that the protoplasm is in every instance bounded by a wall. It has been ascertained that the wall is a chemical compound of carbon, hydrogen, and oxygen, and to this compound the name *cellulose* has been given.

We have said that the protoplasm is the active principle through the agency of which all the vital processes of the plant are carried on. It contains at some time or other every constituent of the plant. The cell-wall is itself, therefore, a product or *secretion* of the protoplasm, and is at first an extremely thin film, which, however, gradually increases in thickness by the addition of further material. This new material is deposited *between the molecules* of the original film, and so extends not only the surface of the wall, but, by deeper deposits, the thickness also. This process of acquisition of new material is known as *intussusception.*

266. As the wall between two cells increases in thickness, a distinct middle layer is discernible in it, known as the *middle lamella.* This portion of the common wall is different in chemical composition from the rest, so that it may, under proper treatment, be dissolved and the cells thereby separated.

267. It is in the earlier stages of their history, while the walls are comparatively thin, that the cells possess the greatest activity. By these alone is carried on the process of growth, which consists in the multiplication and enlargement of cells.

268. It is seldom the case that the wall is thickened uniformly. Often numerous round thin spots are left, so that the cell has a *dotted* appearance (Fig. 222). When the thin spots in adjacent cells are contiguous, as they commonly are, a ready means of intercommunication is afforded. Sometimes the spots, instead of being round, are oblong, so that the cell under the microscope presents a *ladder-like* appearance, and so is said to be *scalariform*. Then again, the thickening may take the form of *spiral bands* upon the inner surface; or, instead of a continuous spiral band, we may find a series of *isolated rings*, when the marking is said to be *annular*. *Reticulated* cells are also found, in which the markings, as the name implies, form a sort of network on the walls. Several of these forms are shown in Figs. 223 and 224.

Fig. 222.

269. Sometimes round thin spots will be left in the wall, and over each of these a thick-walled dome with an opening at the top will be formed. At the same time a similar dome is raised at exactly the same spot on the other side of the wall in the next cell; and, finally, the thin partition between the opposite domes breaks away, permitting free communication. Thus are formed what are called *bordered pits*, which abound in the wood of Conifers.

Fig 223.

Fig. 224

270. When cells stand end to end, and thin spots are

Fig. 222.—Dotted duct. (Gray.)
Fig. 223.—Spiral and annular markings on cell-wall. (Gray.)
Fig. 224.—Various markings on cell-wall. (Gray.)

left in the cross-partitions between them, *sieve-cells* are formed. Here, again, the thin spots finally disappear, thus practically uniting adjacent cells.

271. It sometimes happens that the thickening takes place throughout the length of a cell but in its *angles only*. Cells of this kind, which are often found immediately under the surface of the stem in the higher plants, are called *collenchyma* cells.

272. Besides the markings on the inside, cells often show markings on the outside. The pollen-grains of the Mallow, for instance, are seen under the microscope to be covered with pointed projections. Other pollen-grains, also, exhibit outside markings of different sorts.

273. The thickening deposit may be so excessive in some cases as to almost completely fill up the cavity of the cell (Fig. 225). The shells of nuts and the tough coatings of seeds consist of cells of this kind; but even in these cases the wall may be seen to be traversed by slender pores or canals, either simple or branched, radiating from the centre of the cell. To these hardened cells the name *sclerenchyma* is applied.


Fig. 225.

274. **The Contents of Cells.** If you look at Fig. 215, or, better still, if you have the opportunity of viewing a Moss-leaf through a good microscope, you will see that in the protoplasmic lining of the cells there are numerous greenish, rounded granules. These are the bodies to which the green parts of plants owe their colour. They are called *chlorophyll-granules*, and consist of protoplasmic matter in which particles of green

Fig. 225.—Sclerenchyma, the cell-cavity being almost obliterated. (Gray.)

colouring matter are embedded. The colouring matter itself is chlorophyll, and may be dissolved out of the granules, leaving the latter as ordinary protoplasm. Almost without exception chlorophyll requires the action of sunlight for its production, and the chlorophyll disappears from green parts when sunlight is withdrawn, as is well seen in the process of bleaching celery. In many of our brightly coloured foliage-plants the chlorophyll is concealed from view by other colouring matters. In flowers various colours are found in the protoplasm, but these, unlike chlorophyll, are produced in darkness as well as in sunlight.

275. Chlorophyll is of the utmost importance to the plant, seeing that only in the cells which contain it, and in the presence of sunlight, can the materials which the plant imbibes from the soil and the air be *assimilated*, that is, converted into matter which the plant can use for the purposes of growth.

276. Now consider Fig. 214. Here are exhibited cell-contents of an entirely different aspect. The rounded bodies here visible are *starch-granules*, as may be easily demonstrated by adding a drop of iodine solution to the Potato section under the microscope, a characteristic blue colour being at once produced. Such granules, differing somewhat in shape in different cases, abound in the cells of tubers and in grains of all sorts, where they have been stored up for use during the process of germination. They are originally formed during sunlight in the chlorophyll granules of the green parts. When the light is withdrawn, as at night, they are dissolved and carried in solution to other parts to promote growth or to be stored up.

277. If grains of wheat are masticated for a time it will be found that a portion remains in the mouth undissolved. This is because the starch of which the grain is so largely made up consists of two distinct parts: (1) a more soluble portion which is known as *granulose*, and (2) a less soluble part called *starch-cellulose.*

278. **Crystals.** These are of common occurrence in many plants, not only in the cell-cavities, but also imbedded in the substance of the cell-wall. They are also of various shapes, and may either occur separately or be massed together in clusters. The needle-shaped forms are known as *raphides.* These crystals consist for the most part of calcium oxalate, but calcium carbonate is also found, and may be readily distinguished from the former by the effervescence occasioned on the addition of hydrochloric acid. The oxalate dissolves in this acid without effervescence.

Crystals may be readily observed under the microscope in thin sections of scales from the Onion bulb, Rhubarb, Indian Turnip, and many other plants.

279. In the leaves of plants of the Nettle Family it frequently happens that a wart-like growth of cellulose takes place on the inside of the cell-wall, the inwardly projecting mass being attached to the wall by a slender stalk, and having multitudes of small crystals imbedded in it. Such inward growths are called *cystoliths;* they may be readily seen in cross-sections of the Nettle leaf.

280. **Crystalloids.** Seeds, especially those of an oily nature, as they approach maturity and become dry, develope in their cells multitudes of small rounded bodies of an albuminous nature known as *aleurone-grains,* and

these often envelope minute substances of crystalline aspect, which, however, under the action of potash and other re-agents, undergo such changes of form as to lead to the belief that they are not true crystals. They are called *crystalloids*, and are to be regarded as forms of protoplasm.

Occasionally crystalloids are observed without the albuminous envelope, as, for example, in the tuber of the Potato. Fig. 214 shows a cell having two or three such crystalloids of a cubical shape.

The aleurone-grains in seeds containing starch fill the spaces between the starch-granules. In oily seeds, such as the Brazil-nut, they replace the starch.

281. **Other cell-contents.** Besides the important substances already enumerated as products of the protoplasm, many others are found, such as sugar, inuline (a substance nearly related to starch, and found in a few special plants), fixed oils (castor, olive, linseed, &c., chiefly in seeds), essential oils (turpentine, oil of lemons, and essences of different kinds), gums, resins, and various acids.

282. **How new cells are formed.** There are several methods by which new cells are produced, but in the higher plants the common method is that of *cell-division.* We have already stated that only the newer thin-walled cells are capable of exercising this function. The process is briefly as follows: in the cell about to divide, the protoplasm first separates into two portions, each containing part of the nucleus; then a partition-wall of cellulose is developed between the two portions, thus forming two cells out of the original one. Each part then

enlarges and divides again, and so the process goes on. When cell-division takes place in one direction only, *filaments* or *threads* are formed; if in two directions, *surfaces* are formed; while division in three directions gives rise to *masses*.

It is evident that every part of a plant, however much altered in its later history, must in its earlier stages have consisted of this thin-walled cellular substance, or *meristem*, as it is called from its power of dividing.

283. Cell-division, then, is the method of new cell formation which prevails in the vegetative parts of the higher plants. In the production of pollen, however, and of the spores of vascular cryptogams, four new nuclei are formed in the cell, and the protoplasm collects about these, eventually secreting walls, so that four new and complete cells are formed *within* the original one, and these sooner or later make their escape. This mode is known as *free cell-formation*. In the production of the endosperm cells in the embryo-sac and the spores of many of the lower plants a similar process goes on; but here the division of the nucleus is not limited to four portions, as in the cases just mentioned, but may be carried on to an indefinite extent.

284. In some lower plants the entire contents of two adjacent cells may coalesce to form a single new cell. This mode is known as *conjugation*. Also, the contents of a cell may contract and develope a new cell-wall, a process known as the *rejuvenescence* or renewal of a cell.

285. **Tissues.** An aggregation of similar cells is called a *tissue*. Originally, every part of a plant consists of *meristem*, that is, of cells capable of dividing. But

changes set in, as we have seen, at a very early stage, and eventually all the cells assume *permanent* forms, some developing in one way, others in quite a different way, according to the function of each particular part. So that in any given plant we find tissues, or groups of cells, of very various kinds, and very different arrangements of these tissues in different cases. By examining sections taken in succession from the growing point backwards, every degree of change from meristem to permanent tissue may be made out.

286. In the growing parts of all plants, in the pulp of fruits, in the pith, in the green parts of leaves, and in the entire substance of many plants of low organization, we find tissue composed of short and comparatively thin-walled cells, to which the name *parenchyma* has been given. On the other hand, in the substance of wood, in the inner bark, in the petioles and veins of leaves, &c., we meet with tissue consisting of long, pointed, and overlapping cells, and known as *prosenchyma*. That of the wood is *fibrous* tissue, and that of the inner bark is the *bast*, specially characterized by the extraordinary length and flexibility of the cells. *Sclerenchyma* and *collenchyma* have already been referred to. In the former the cells are commonly, though not always, short; while in the latter they are usually long, but the ends are not pointed.

287. Cells have been described which are characterized by peculiar markings on their walls. When such cells stand end to end, the cross-partitions commonly disappear, with the effect of forming long tubes, generally of larger diameter than the other cells with which they

are associated. Such large cells are known as *vessels*, and tissue formed of them is called *vascular* or *tracheary* tissue. Hence we have *spiral*, *scalariform*, *annular*, *reticulated*, and *dotted* vessels. These different kinds of vessels are usually found associated with fibrous tissue, and the combination of the two is known as the *fibro-vascular system*.

288. Many plants, such as Dandelion, Blood-root, Milkweed, and Spurge, emit a coloured or milky juice when wounded. This juice is technically called the *latex*. It is contained in a special tissue which is peculiar to such plants, known as *laticiferous* tissue. Its form differs in different cases. In some instances it consists of long tubes which may or may not branch. In others, the cells composing it form a net-work. As in the case of vessels, the latex tubes are commonly formed by the coalescence of cells originally separate, but sometimes by the continued apical growth of single cells.

289. **Sieve-tissue** has been already noticed. The cells are usually rather wide, and the walls are not hardened, but the cross-partitions between the cells are thickened and perforated.

290. It may be added that *single cells* which resemble vessels in their markings are often spoken of as *tracheids*.

291. **Tissue-Systems.** While groups of similar cells are designated tissues, we may have also different combinations of these tissues in different plants, or in different parts of the same plant, and these various combinations are known as *tissue-systems*. These are now usually ranged under three heads: (1) *The Epidermal System*, including those combinations of tissue which go to

form the coverings of young stems, roots, and leaves; (2) *The Fibro-vascular System*, including such combinations as form the stringy masses which abound in the substance of the higher plants; and (3) *The Fundamental System*, including the combinations of cells which have undergone little or no change of form; in short, all the rest of the plant except the two systems first mentioned.

292. The **epidermal system** is most highly developed in Phanerogams. Fig. 226 shows a section through the thickness of a leaf. Here it will be observed that there is a closely-packed layer of cells forming the upper surface, and a similar layer forming the lower surface. These layers constitute the *epidermis* or skin of the leaf. The outer part of the epidermis is usually a continuous layer, and is known as the *cuticle*. It will be seen that the walls of these cells are much thicker than those of the cells in the body of the leaf, and also that the epidermal cells, unlike the interior ones, have been emptied of their protoplasmic contents and are rectangular in shape. It sometimes happens that the epidermis consists of two or three layers instead of one.

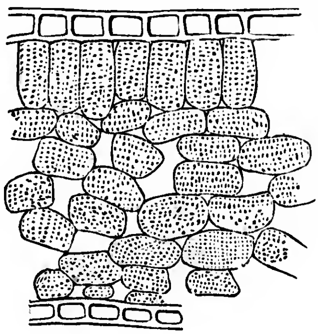


Fig. 226.

The outgrowths of the epidermis, included under the general term *trichomes*, have already been referred to; they must be regarded as part of the epidermal system.

Fig. 226.—Cross-section of a leaf, showing epidermis above and below, palisade cells under the upper epidermis, and loose tissue with intercellular spaces below the palisade cells. (Gray.)

293. An examination of the under surface of almost any leaf will show the presence of large numbers of oval openings, somewhat similar to that shown in Fig. 227. These are *stomata.* They are formed by two epidermal crescent-shaped cells with a space between them, and these have the power of separating or closing together according to circumstances; separating in the light, in moist weather, and closing in dry. The openings communicate with *intercellular spaces* in the body of the leaf, a number of which are seen in Fig. 226. In ordinary leaves with an upper and a lower surface, the stomata are far more numerous on the lower side; indeed, many such leaves are entirely without stomata on the upper surface. Vertical leaves have them rather equally distributed on both surfaces. Immersed leaves and underground stems have hardly any at all, and they are never found on roots. The use of the stomata will be referred to presently.

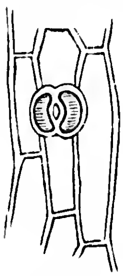


Fig. 227.

294. The stems of Dicotyledons lose their epidermis at a comparatively early period, and a tissue consisting of cells of *cork,* filled with air, takes its place. These cork-cells are modifications of the cells beneath the epidermis, and they form an effectual protection to the tissues within. The skin of the Potato-tuber exhibits this corky layer very clearly. The special tissue from which the cork is developed is called *phellogen.*

295. In the **fibro-vascular system** different plants exhibit a very different arrangement of the component

Fig. 227.—Stoma from the urface of a leaf, showing the crescent-shaped guard-cells.

tissues. As a rule, these tissues are capable of division into two groups, in one of which the wood is developed, and in the other the bast. To the former of these groups the general term *xylem* is applicable, and to the latter the term *phloem*. The xylem is made up of the elongated woody cells with pointed and overlapping ends, already referred to as fibrous tissue, the wide tubes (vessels) with variously marked walls, formed by the disappearance of the cross-partitions between cells placed end to end, and more or less short-celled tissue or parenchyma. The phloem is likewise made up of three constituents: the long, thick-walled, flexible cells called bast-cells, which correspond to the fibrous tissue of the xylem; the wide thin-walled sieve-cells, corresponding to the vessels; and a certain amount of thin-walled parenchyma.

296. The fibro-vascular *bundles*, as they are called, have their origin in the meristem of the growing point. This meristem is at first uniform, but soon groups of long cells arise in it, and these are then known as *procambium*, to distinguish them from the surrounding ground-tissue. This procambium is gradually converted into the fibro-vascular bundles.

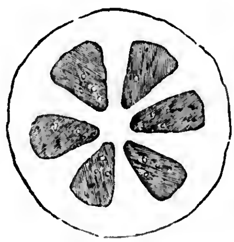


Fig. 228.

297. In dicotyledonous plants, the fibro-vascular bundles are more or less wedge-shaped, as shown in Fig. 228. The inner part of each bundle consists of xylem and the outer of phloem, and between the xylem and the phloem there is a layer of meristem, known as the *cambium*. The soft cells of

Fig. 228.—Cross-section of a young dicotyledonous stem, showing six bundles.

the cambium divide, and the new cells thus continually being formed become modified on the one hand into tissues which increase the thickness of the xylem, and, on the other, into tissues which are added to the phloem. Later on cambium cells are formed in the ground-tissue between the bundles, thus linking together the cambium-layers of the various bundles, and forming a continuous ring. The links are then known as *interfascicular* cambium, that of the bundles themselves being the *fascicular*. Bundles of this kind, characterized by the cambium-layer, and so capable of continuous enlargement, are called *open* bundles.

298. In monocotyledons, on the other hand, there is no cambium-layer, and consequently the bundle when once formed is incapable of further increase, and so is said to be *closed*. Fig. 229 is a representation of the cross-section of an endogenous stem in which many of these closed bundles are visible. Of course in such stems no bark is formed.

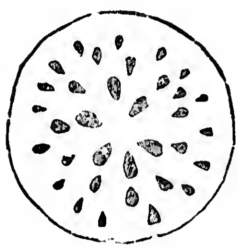


Fig. 229.

299. It has been explained that in the exogenous stem the xylem occupies one side of the fibro-vascular bundle, while the phloem occupies the other. In the closed bundles of Ferns and Club-Mosses, as well as of some monocotyledons, however, a different arrangement prevails, the xylem occupying the central part of the bundle, and the phloem forming a circle around it. The former arrangement is described as *collateral*, while the latter is *concentric*. In many of the monocotyledons, as well as in the exogens, the bundles are collateral.

Fig. 229.—Cross-section of monocotyledonous stem, showing closed bundles.

300. Fig. 230 shows a section of an exogenous stem somewhat older than that shown in Fig. 228. Here new bundles have been formed between the earlier ones, so that the whole centre of the stem, except the *pith* and the lines radiating from it, is occupied by the wood. This cylinder of wood is now encircled by a ring of cambium, beyond which are the tissues of the phloem.

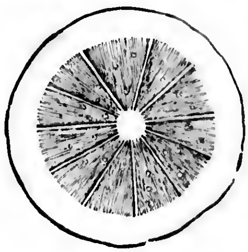


Fig. 230.

301. The appearance presented by the cross-section of an exogenous stem is that of a series of concentric rings, each ring showing the limit of a year's gr^wth. The portions of wood formed late in the summer are more compressed by the outlying tissue than those formed in spring, and hence the outer part of each year's ring appears denser, and is sharply marked off from the ring of the following year. No growth of the cambium takes place in winter. The rays which intersect these rings as fine lines consist of portions of the ground or fundamental tissue which have been squeezed into their present form by the increasing fibro-vascular bundles on each side of them; they are called *medullary rays*, and, as the stem grows, new ones are formed from the cambium. Only the *primary* ones, however, extend from the pith to the bark; those formed later are shorter.

302. In roots a special arrangement of the tissues of the bundles prevails, the xylem and phloem forming alternate *rays*. This is the *radial* arrangement.

303. The **fundamental** or **ground tissue** comprises all the parts of the plant not already included in

Fig. 230.—Section of an older dicotyledon, the bundles now forming a ring.

the epidermal and fibro-vascular systems. In the exogens it embraces the pith, the medullary rays, and parenchyma generally. The collenchyma found just beneath the epidermis, sclerenchyma occurring in different parts, and laticiferous tissue are also constituents of the fundamental system, as well as the cork cells already referred to. In the monocotyledons ground-tissue in the form of parenchyma fills the space between the closed bundles of the stem; while in many plants in which fibro-vascular bundles are not produced, the ground-tissue constitutes the whole of the interior.

304. In exogenous stems the wood developed from the cambium is often different from that of the primary bundle as developed from the procambium. Pines, for example, have vessels in the primary xylem, but none in the secondary, the latter being almost entirely made up of the cells with *bordered pits*, already described.

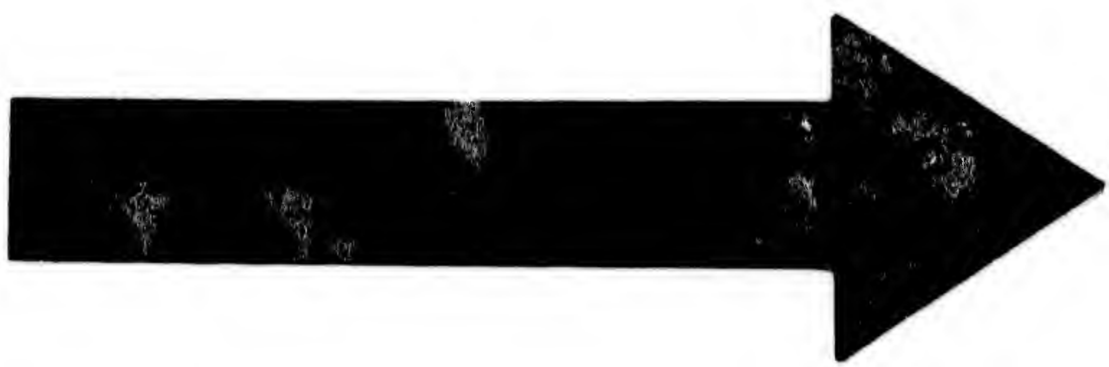
305. The bundles of the leaves are continuous with bundles in the stem. Leaves appear at first as protuberances on the side of the stem close to the growing point, and the upper ends of the primary bundles almost at the very beginning bend outwards towards the new leaves, the lower part being continued down the stem. In the monocotyledons these bundles first arch inwards towards the centre of the stem, and then outwards and downwards, thinning out as they descend. Hence, in a cross-section (Fig. 229) the bundles appear more crowded towards the circumference, and also smaller. Such a stem is, therefore, found to be harder at the outside than at the centre.

CHAPTER XX.

FOOD OF PLANTS—CHEMICAL PROCESSES—MOVEMENTS OF WATER—PHENOMENA OF GROWTH.

306. The materials of which the substance of a plant is made up are various, and some of them occur in far larger quantities than others. Water forms a very considerable percentage of the whole weight, but is present to a greater extent in some portions of a plant than in others. Fleshy roots, for example, may contain as much as 90 per cent. of water, while dry seeds contain only about 12 per cent.

307. The water may be expelled by careful drying, and if what is left is then burnt, what is called the *organic* part of the plant disappears, and a small quantity of *ash* remains behind. The organic part is found to consist mainly of carbon, hydrogen, oxygen, nitrogen, and sulphur; while the inorganic part (or ash) contains very small quantities of phosphorus, iron, calcium, magnesium, and potassium. All these materials are obtained from the air or the soil. There is constantly present in the air carbonic acid gas, a compound of carbon and oxygen, which is exhaled from the lungs of animals, and which is always found wherever wood or coal, or carbon in any form, is being burned. This gas is carried down into the soil dissolved in rain-water, and the solution is then absorbed by the roots and transmitted by the stem to the leaves, where, in the presence of chlorophyll and in sunlight, the gas is decomposed into its carbon and oxygen. The excess of oxygen is then exhaled and the carbon chemically combined with the other elements to



form starch for purposes of growth. The oxygen required by the plant is derived chiefly from the carbonic acid gas and from water. Hydrogen is obtained by the decomposition of water, and nitrogen from the ammonia, which, like the carbon dioxide, is carried down from the air by rain, and also from nitrates contained in the soil. Sulphur is obtained from salts (such as calcic sulphate) found in the soil, as are also, of course, all the inorganic elements.

Of all these constituents of the *dry* plant, carbon is the most abundant, amounting to about half of the entire weight.

308. The inorganic elements, though small in quantity, are, nevertheless, essential. If, for example, a plant be altogether deprived of iron it will produce no chlorophyll; while, if potassium is withheld, it will not produce starch. These facts are proved by causing seeds to grow under conditions which enable us to accurately control the supply of nutrition in the form of carefully prepared solutions of the different ingredients. Several substances of common occurrence in the ash of plants, as silica, sodium, and some others, are in this way shown not to be essential to healthy growth.

309. The process by which the carbon, obtained from the carbon dioxide, is combined with the elements of water to form starch is called *assimilation*. As already explained, the particles of starch which are formed by the chlorophyll granules in sunlight are converted by combination with oxygen into soluble forms, and carried away, when the light is withdrawn, to other parts where growth is going on, or to storehouses such as tubers and seeds. This oxidising and converting process is *metastasis*.

In consequence of having such a store of material, tubers can grow in the dark as long as the material holds out, but will not, of course, produce green leaves.

Besides starch, oil is a common form of reserve material, particularly in seeds. Sugar, also, is found; as, for example, in the Sugar-Beet.

310. Parasites and saprophytes, which are as a rule without chlorophyll, do not assimilate, but obtain their nourishment from the stores of other plants or from decomposing organic matter.

311. The so-called carnivorous plants, such as the Bladder-wort and the Pitcher-plant, obtain a portion of their nitrogen by entrapping insects and other small animal organisms, and absorbing them as they decompose. Some such plants appear to cover their prey with an acid secretion, and to go through a digestive process not altogether unlike that performed by animals.

312. **Respiration.** Plants, like animals, are continually inhaling oxygen, and the presence of this gas is essential to their existence. The oxygen so inhaled is combined with carbon to form carbon dioxide, and this in the day-time is at once decomposed and the carbon assimilated. The absorption of oxygen and its subsequent combination with organic matters in the plant is accompanied by evolution of heat, a fact well illustrated in the process of malting, where damp barley is heaped together. As soon as the grain begins to sprout, oxygen is rapidly absorbed, and a very decided rise of temperature takes place. The starch of the grain is oxidised and converted into sugar, and the growth is then stopped by rapid drying. The sugar, on fermenting, produces alcohol.

313. **Transpiration.** The openings in the epidermis, called *stomata*, have already been described. Through these the excess of water-vapour in the plant is exhaled. It may often be observed, in hot, bright weather, that the leaves of plants droop if exposed to the sun. This is because the rate of evaporation through the stomata is greater than the rate of supply at the roots. At night, however, the stomata close and the balance being restored the plant recovers. The water which is thus supplied to the leaves appears to be conveyed through the stem by means of the *cell-walls* of the wood-prosenchyma, since the supply is not diminished if a ring of bark and the underlying bast and cambium be removed.

314. But water is also supplied to the growing points, and in a different way. It is well known that if two liquids (or gases) of different density are separated by a porous diaphragm they will tend to change places, the fluid of less density passing through the diaphragm more rapidly than the other. This is the principle of *osmose*, and wherever in a plant a cell-wall separates cell-contents of different density it is found to apply. Hence, water is absorbed by freshly-formed cells, containing dense protoplasm, from neighboring cells which are a little older and in which the protoplasm has been diluted. These absorb from the older cells behind them, and so on. Such water is transmitted, not through the prosenchyma of the wood, but through the parenchyma and the meristem.

315. It is a matter of common observation that the stems of many plants "bleed" if cut in the spring. This is due to the upward pressure of the water with which the roots are charged at that time, and it takes place in the

absence of transpiration. When the leaves are formed and transpiration sets in actively, the root-pressure is relieved and the stems will no longer bleed immediately on being wounded. In some plants the excessive root-pressure even causes drops of water to exude from the leaves.

316. We may observe, then, three distinct movements of water in the plant: (1) the rapid movement to make up for the loss by transpiration, (2) the slow movement to supply the growing cells with requisite moisture, and (3) the movement due to root-pressure.

317. **Growth.** Growth has already been referred to as consisting in the formation and subsequent enlargement of new cells, accompanied in many cases by change of form. It has also been mentioned that the enlargement is the result of the introduction of new particles of vegetable material into the spaces between the molecules of the parts already formed—a process known as intussusception. It is now generally admitted that each of the molecules of which the plant-body is made up is enveloped in a sheath of water. We know that the presence of water is essential to growth; when it is absorbed by a growing cell the immediate effect is to stretch the cell, as it were, to its utmost capacity; in other words, to separate the molecules as far as possible and so increase the amount of water between them, thus making it possible to interpose new molecules of solid matter. The use of the water, also, as a vehicle for conveying the new material is obvious. This new material, the presence of which is essential to growth, is commonly supplied to the growing points from older parts which serve the purpose of storehouses, as seeds and tubers, or of manufactories, as the leaves.

318. Stems and roots, as a rule, exhibit three distinct regions according to the stage of development at which they have arrived. There is, first, the growing point, the chief characteristic of which is the rapid formation of new cells by division; secondly, the elongating part, chiefly characterized by the growth of the cells in length, there being practically no further division here; and, thirdly, the fully developed part, in which there is no further division or enlargement, though the cells may continue to discharge various important functions.

319. Growth, whilst dependent upon an adequate supply of water and of new material, is also largely affected by external conditions, such as temperature and light. Growth may be stopped altogether by either too low or too high a temperature, and between the limits within which any given plant is found to be capable of growth there will be found a particular degree of temperature more favourable to growth than any other either above it or below it. This may be called the *optimum*. The effect of temperature differs considerably according to the amount of water present in the part affected, dry seeds, for instance, resisting a temperature, either high or low, to which soaked seeds would at once succumb.

320. Light is essential to assimilation, but seeds and tubers, as well as many of the lower plants which are without chlorophyll, such as Mushrooms, will grow in the absence of light as long as the stock of assimilated material upon which they draw is not exhausted. The growth which takes place in the cambium-layer of dicotyledons and in roots is another example of increase in size in the absence of light. The assimilated material

in all these cases, however, has been previously elaborated elsewhere.

321. Light is found to exercise a retarding influence upon growth. A plant, for instance, in a window will bend towards the light, because the cells on the side nearest the window grow more slowly than those which are shaded, thus causing curvature of the stem and petioles.

322. Gravitation also affects growth, as we know that the stem and root, or *axis* of the plant, are usually in the line of the radius of the earth at the place of growth. If a seedling plantlet be laid with the stem and root horizontal, the stem will curve upward and the root downward in the endeavour to restore the vertical direction.

323. The twining movement of the stems of many plants is due to inequality of growth at successive points in the sides of the stems. Leaves unfold from the bud because the growth on the upper side at the time of unfolding is more rapid than on the under side. These movements are called *nutations*, and are not due to the external action of light, but entirely to internal causes. The movements of tendrils, however, are affected by contact with the object which they grasp.

CHAPTER XXI.

EXAMINATION OF A FERN—A HORSETAIL—A CLUB-MOSS.

324. We shall now proceed to the examination of some common plants which will be found to be typical of groups differing in important respects from the phanerogams.

Ferns. Fig. 231 is a representation of our common Polypody. You may find it in almost any shaded rocky place. Running horizontally beneath the surface you will find the stem of the plant, which in this case is, therefore, a *rhizome.* A portion of the rhizome is shown in the lower part of the figure, with fibrous roots on the under side. From the upper side are developed the leaves, which, as you see, have long petioles, and if you find one which is still in the bud you will observe that it is rolled up lengthwise, as shown in Fig. 232. The vernation is, therefore, *circinate*, and this is the case in nearly all the Ferns. On examining the back of the leaf (Fig. 231 shows the back) we observe rows of brownish dots on each side of the middle veins of the upper lobes. Fig. 233 is an enlarged view showing the position of these dots at the extremities of the veinlets. When we put one of these dots under the microscope it is seen to be a cluster of minute, stalked bodies, such as that shown in Fig. 234. These bodies are further found to be sacs filled with extremely fine dust, and the dust consists of multitudes of rounded particles all exactly alike. They are, in short, *spores*, and the sacs in which they are contained are the spore-cases, or *sporangia;* while the clusters of sporangia are the *fruit-dots*, or *sori.* Around each sporangium there is an elastic jointed ring which breaks at maturity, and by its elasticity ruptures the spore-case, which then discharges its spores, as shown in Fig. 234. The leaf of the Fern, then, is something more than an ordinary foliage-leaf, and is known as the *frond*. The petiole is called the *stipe*, while the mid-rib is the *rhachis*.

325. A spore under proper conditions developes a slender thread-like cell which eventually gives rise to a thin, flat, green expansion, resembling that shown in Fig. 235. This is called the *prothallium*. From the under surface root-hairs are produced as shown in the figure. On the same surface, among the root-hairs, arise minute projections

Fig. 233.

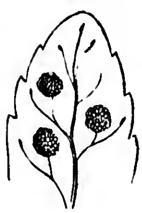
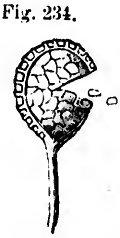


Fig. 234.



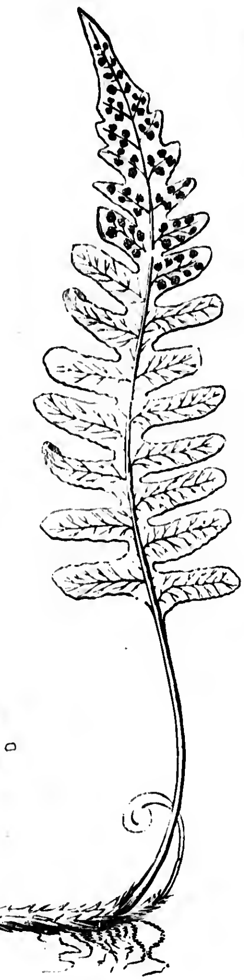


Fig. 231.

Fig. 232.

Fig. 231. Root-stock and frond of Polypody.
Fig. 232.—Circinate vernation of the frond.
Fig. 233.—Magnified view of the sori.
Fig. 234.—Sporangium discharging spores; greatly magnified.

of tissue in which are developed cells corresponding to the pollen-grains of phanerogams. These projections are the *antheridia;* they contain cells in which are fertilizing bodies known as *antherozoids.* Also on the under surface of the prothallium, near the notch, we find structures analogous to the embryo-sac of the phanerogamous ovule. These are the *archegonia.* They are mostly flask-shaped bodies, having a germ-cell—the *oosphere*—in the lower end. The antherozoids, on escaping from the antheridia, make their way down the necks of the archegonia, and coming in contact with the oospheres fertilize them. As a result of this fertilization, a plant is developed in all respects like the one which originally bore the spores on its fronds.

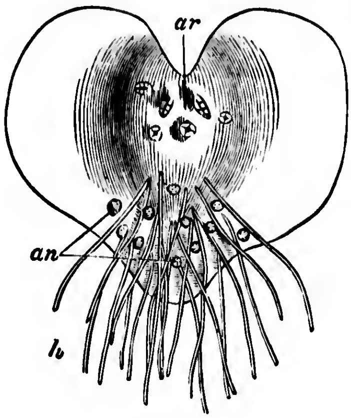


Fig. 235.

326. It is manifest, then, that we have here two distinct *generations*: first, the spore produces the prothallium which bears the antheridia and archegonia; secondly, the interaction of these gives rise to a plant which bears the spores. This phenomenon is spoken of as the *alternation of generations.*

327. The stems and roots of Ferns are found to contain vascular bundles which, like those of monocotyledons, are closed.

Fig. 235.—Prothallium of a Fern, under side; *h*, root-hairs; *an*, antheridia; *ar*, archegonia. Magnified 10 times. (Prantl.)

328. From the account here given of the mode of reproduction in the Ferns, it will be evident that the Gymnosperms occupy an intermediate position between them and the Angiosperms.

For a description of other common Ferns differing in detail from the Polypody, the student is referred to Part II., page 146.

329. **The Horsetails.** At page 160, Part II., will be found a description of the common Horsetail, with an illustration of the fertile stem, or rather branch, because both the pale spore-bearing branch and the later green shoots with whorled branches are sent up from an underground stem or rhizome. The spores, upon germination, give rise to prothallia bearing antheridia and archegonia precisely as in the Ferns. The prothallium is usually small, flat, and irregularly branched or lobed, developing the antheridia at the projecting ends of the lobes, and the archegonia in the angles between them; or, in other cases, the prothallia may be diœcious. Fertilization of the germ-cell, which occupies a cavity at the base of the archegonium, takes place exactly as in the Ferns, and, as a result of fertilization, the germ-cell developes into a spore-bearing plant similar to the original one. Here, therefore, we have again exhibited an alternation of generations.

Other species of Equisetum of common occurrence, instead of producing a special fertile branch, develope sporangia at the extremities of the ordinary leafy stems.

330. These plants, like the Ferns, exhibit fibro-vascular bundles, and the epidermis is especially characterized by the excessive amount of silica contained in it, some of the species being used for scouring or polishing by reason of this property.

331. The curious *elaters* (Fig. 236) attached to the spores doubtless assist them to escape from the spore-cases, and subsequently aid in dispersing them.

Fig. 236.

332. **The Club-Mosses.** Fig. 237 is a representation of a branch of *Lycopodium clavatum*, one of our common Club-Mosses. The creeping stem lies flat upon the ground, and often attains a great length, sending up at intervals erect branches with crowded linear-awl-shaped leaves, some of which, like the one shown in the figure, are terminated by a slender peduncle bearing one or more cylindrical spikes. These are the fertile branches, and the leaves upon them, or at all events upon the slender upper part, are very much smaller than upon the ordinary sterile branches.

Fig. 237.

It is to be observed that the stems and roots of these plants branch *dichotomously* (145).

333. The sporangia are produced in the axils of the leaves of the terminal spike. One of these leaves, greatly magnified, with its attached sporangium, is shown in Fig. 238. The sporangium opens by a slit at the top to discharge the spores.

334. It is only quite recently that the prothallium has been detected. It is described in the case observed as a "yellowish-white

Fig. 236.—Spore of Equisetum with elaters; highly magnified.
Fig. 237.—Branch of *Lycopodium clavatum;* natural size. (Thomé.)

irregular lobed body, sparingly furnished on its under surface with small root-hairs." The antheridia and archegonia appear to be produced on the upper surface, and these by their interaction, give rise to the new plant which bears the spores, just as in the Ferns and Horsetails ; so that again there is an alternation of generations.

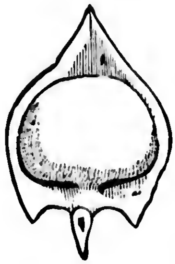


Fig. 238.

335. It is a fact of great interest that in some plants nearly related to the Club-Mosses, *two kinds* of spores—large and small—are produced in separate sporangia. The large ones develope prothallia upon which archegonia are formed, and the smaller others upon which antheridia appear.

336. The three plants just considered, while evidently differing in certain details of structure and in general aspect, nevertheless have a number of characters in common :

1. *They agree in their mode of reproduction, which is by spores, these bodies being quite unlike the* SEEDS *with which we are now familiar, and which, you will recollect, always contain the embryo of the new plant.*
2. *They all exhibit an alternation of generations.*
3. *They all have true roots.*
4. *The three tissue-systems—the epidermal, the fibro-vascular, and the fundamental—though not all developed to so high a degree as in the Phanerogams, still can be very clearly made out in both roots and stems. The fibro-vascular bundles are always closed, as in monocotyledons, and are, as a general rule, concentric (299).*

Fig. 238.—Leaf of *Lycopodium* bearing sporangium ; greatly magnified. (Thomé.)

337. Plants with these common characteristics constitute a group called **Pteridophytes** or **Vascular Cryptogams,** "cryptogam" being a general term applicable to all plants which do not produce true flowers, as "phanerogam" applies to all those which do.

CHAPTER XXII.

EXAMINATION OF A MOSS AND A LIVERWORT.

338. **Mosses.** Fig. 239 is a representation of the common Hair-Moss (*Polytrichum commune*), which may be found in early summer almost anywhere. It grows in dense masses, and upon examination it will be found that while many of the stems resemble that shown in Fig. 239, the upper extremities of others form rosettes, as in Fig. 240, whilst others again terminate in ordinary vegetative buds.

339. Let us first examine a specimen as represented in Fig. 239. There is, it will be observed, a well-marked stem, or leaf-bearing axis, upon which the crowded minute leaves are sessile. In the Mosses they always are so, and they are found, upon examination with a good microscope, to consist as a rule of only one layer of cells, being therefore much simpler in structure than those of the plants we have so far been engaged upon. It is also to be noticed that the leaves of Mosses are without stomata.

340. Observe now that our Moss has no true roots. It is, however, fixed to the soil upon which it grows by numerous root-hairs or *rhizoids.*

341. The slender scape-like stalk which rises above the leaves is technically called the *seta*, or bristle; in the left-hand part of the figure (*c*) the upper end of the seta is covered by a hairy cap, the *calyptra*. In the right-hand portion the calyptra has been removed, disclosing a little pod, variously spoken of as the *theca*, or *urn*, or *capsule*, or *sporangium*. Fig. 241 is an enlarged view. This capsule is closed at the top by a circular lid, the *operculum*, which falls away when the capsule is mature, thus allowing the escape of the *spores*, which are produced in it. The spores are developed upon the surface of a central column which rises from the bottom of the capsule, and which is known as the *columella*. The opening through which the spores escape is called the *stoma*, and a good lens reveals the fact that around the stoma there is a circle (sometimes two) of minute teeth, known collectively as the *peristome*. In the Moss now before us the peristome consists of sixty-four teeth. In other Mosses the number varies, being always, however, some power of 2; either 4, or 8, or 16, or 32, or 64. Occasionally the teeth are altogether absent.

Fig. 239.

Fig. 239.—Two fertile stems of a Moss (*Polytrichum commune*) of the natural size; at *c* the calyptra is seen enveloping the capsule. (Wood and Steele).

342. We shall now consider the mode of reproduction in the Mosses. Let us commence with the spore. This, upon meeting with proper conditions, bursts its outer coat (the *exospore*), and the inner coat (the *endospore*) is then protruded as a slender tube. This continues to grow by repeated division, until at length, in most cases, a tangled thread-like mass of vegetation is produced, to which the name *protonema* has been given. After the lapse of several days minute buds are developed at different points upon the protonema, and these are found to consist of whorls of scaly leaves. This is the beginning of the development of the ordinary Moss-plant. Upon the plants thus arising from the buds are developed antheridia and archegonia, the former in the axils of the leaves forming the rosettes shown in Fig. 240, and the latter at the apex of other stems, as shown in Fig. 239. The antheridia are seen under the microscope to be club-shaped bodies, containing a mass of cells in which the antherozoids are formed. The archegonia are flask-shaped bodies, with a lower expanded portion and a long neck above. Fig. 242 shows the apex of a fertile

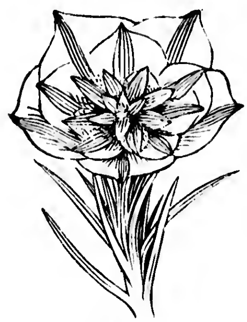


Fig. 240.

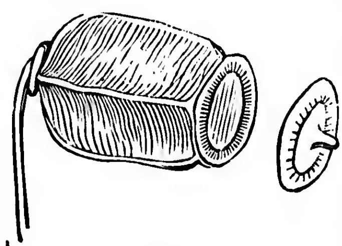


Fig. 241.

Fig. 240.—Apex of sterile stem, showing rosette of perigonial leaves, in the axils of which are the antheridia; greatly enlarged.

Fig. 241.—Enlarged view of capsule, showing peristome and detached operculum. (Wood and Steele.)

stem with several archegonia in the centre, and Fig. 243 shows a single archegonium very highly magnified. The antherozoids upon being set free make their way down the necks of the archegonia, and unite their substance with that of special cells in the lower end (one in each archegonium). These cells, as a consequence of being thus fertilized, become surrounded by a thin coat and immediately begin to grow upwards, developing the slender stalks (setæ) with the capsules at the summit, and surmounted by the calyptra, which is, in fact, nothing but the wall of the archegonium which is torn away at its base and carried upwards. Then the spores are developed around the columella, and the round of life of the plant is completed.

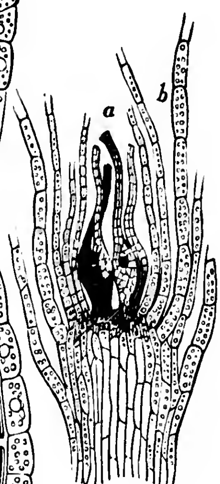


Fig. 242.

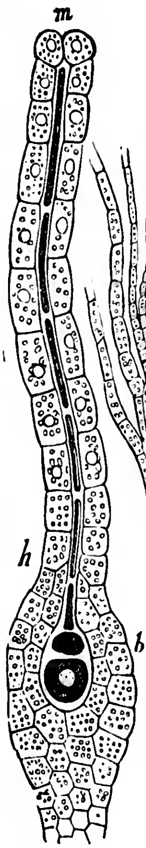


Fig. 243.

As in the Ferns, we have here also exhibited an alternation of generations, the one generation being that arising from the development of the spore and resulting in the production of the antheridia and the archegonia; the other being that arising from the fertilization of the

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Fig. 242.—Enlarged view of apex of the fertile stem of a Moss; *a*, archegonia; *b*, leaves.

Fig. 243.—Very highly magnified view of an archegonium; *b*, the base; *h*, the neck; *m*, the mouth; the germ-cell is seen at the bottom of the flask-shaped cavity. (Sachs.)

special cells in the archegonia, and resulting in the production of spores.

343. **Liverworts.** Figs. 244 and 245 are representations of portions of a very common Liverwort, *Marchantia polymorpha*. It may be found growing along the borders of marshes and in wet places generally, often with intermingled moss. It is of a deep green colour, and usually spreads over a considerable extent of surface. There is no appearance of leaves, the plant-body lying flat upon the surface upon which it grows, and putting forth root-hairs on the under side. From the upper side arise peculiar stalked bodies of two sorts, as shown in the figures; the one consisting of flattened or slightly convex disks, and the other being star-shaped. These stalked bodies contain the reproductive organs. In cavities on the upper surface of the flattened disks are produced the antheridia, from the cells of which are liberated the antherozoids. On the under surface of the rays of the star-shaped bodies are produced clusters of flask-shaped archegonia, each with a germ-cell at its base, and fertilization takes place in the manner already described in the account of the Moss. As a result of fertilization a capsule is developed which produces spores,

Fig. 244.

Fig. 244.—Portion of a Liverwort (*Marchantia polymorpha*), showing the thallus and several stalked disks which bear the antheridia; natural size. (Thomé.)

pretty much as in the Mosses, though in *Marchantia* the stalk of the capsule is very short, and the whole is surrounded by a loose sheath which grows up from the base and at length completely encloses it. The spores on germinating develope into plant-bodies such as we have described, so that the alternation of generations is here also well marked.

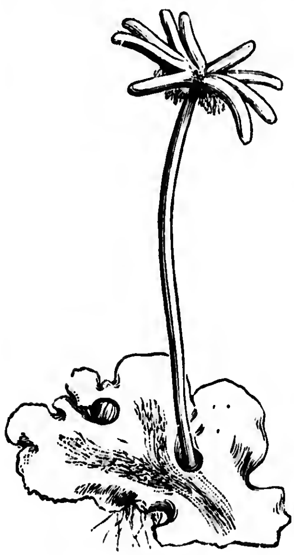
Fig. 245.

344. Other Liverworts more nearly resemble the Mosses in form, having leafy stems, from the summit of which arise slender stalks with capsules at the upper end. These capsules, however, do not open by a stoma, but are four-valved, and at maturity the valves split asunder, allowing the escape of the spores. In the leaves of these latter forms there are no veins of any kind. Forms in which the plant-body is a flat expansion, as in *Marchantia*, are distinguished as *thalloid*, while the leafy forms are said to be *foliose.*

345. It remains to be added that *Marchantia* and other Liverworts reproduce themselves by buds as well as by spores. These buds *(gemmæ)* are formed in little cup-shaped receptacles which appear on the upper surface of the plant-body. They consist of simple masses of tissue, which fall away when fully grown, and immediately develope into new plants.

Fig. 245.—Thallus with star-shaped receptacle bearing archegonia; natural size. (Thomé.)

346. The Mosses and Liverworts constitute a distinct group of plants called **Bryophytes.** It will be evident from the preceding descriptions that in the matter of reproduction they do not differ materially from the Pteridophytes. They are, however, distinctly separated from them by the *simpler organization of their tissues.* The Bryophytes have no true roots, but only root-hairs or rhizoids. The whole plant-body is, as a rule, composed of thin-walled parenchyma, and only in a few cases is there any appearance of a development of a fibro-vascular system, and that only of the vaguest possible kind. There is, however, a well-defined epidermal system, and stomata are not uncommon.

CHAPTER XXIII.

EXAMINATION OF A MUSHROOM—A LICHEN—A CHARA.

347. **Mushroom.** Fig. 246 is a representation of the Common Mushroom of the natural size, while Fig. 247 shows the several stages of its growth. At *A* is seen a matted fibrous mass, which is the underground portion of the plant. It is called the *mycelium;* at several places on it rounded outgrowths of different sizes are visible. These eventually develope into the overground part of the Mushroom. At *II* is shown a vertical section through one of these outgrowths at an early stage; at *l* in this figure you will observe two dark dots; these are the open ends of a channel which forms a complete ring

in the interior. At *III* they are much more distinct, and here is also manifest a difference between the upper and lower sections, which is still more marked at *IV* and *V*. The upper spreading portion is called the *pileus;* at *V* the lower edge of the pileus is still attached by a circular membrane to the stalk. In this stage the membrane is

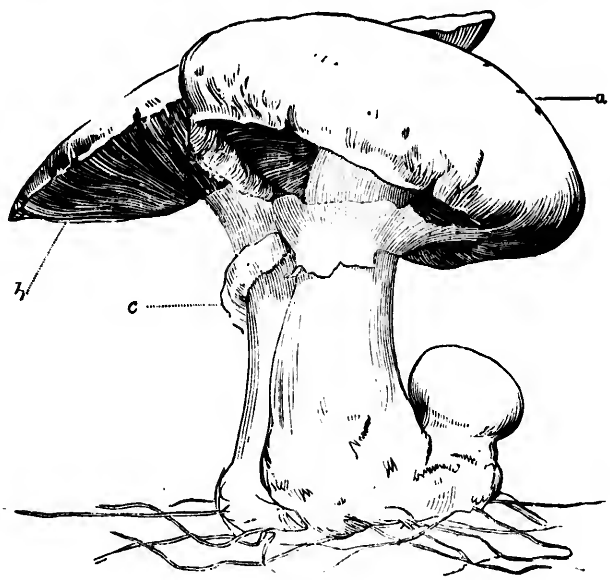

Fig. 246.

called the *veil;* later on, as seen in Fig. 246, it is torn away from the pileus and now forms the *annulus*, or ring, about the stalk. Upon the under side of the pileus are produced a great many vertical, thin plates, called *lamellæ* or *gills.* If we make a vertical section through the pileus so as to cut across a number of the lamellæ, they will

Fig. 246.—The Common Mushroom (*Agaricus campestris*); *a*, the pileus; *b*, the lamellæ; *c*, the annulus. (Thomé.)

present the appearance shown at *A*, Fig. 248, and if we magnify one of these cross-sections it will appear as at *B*,

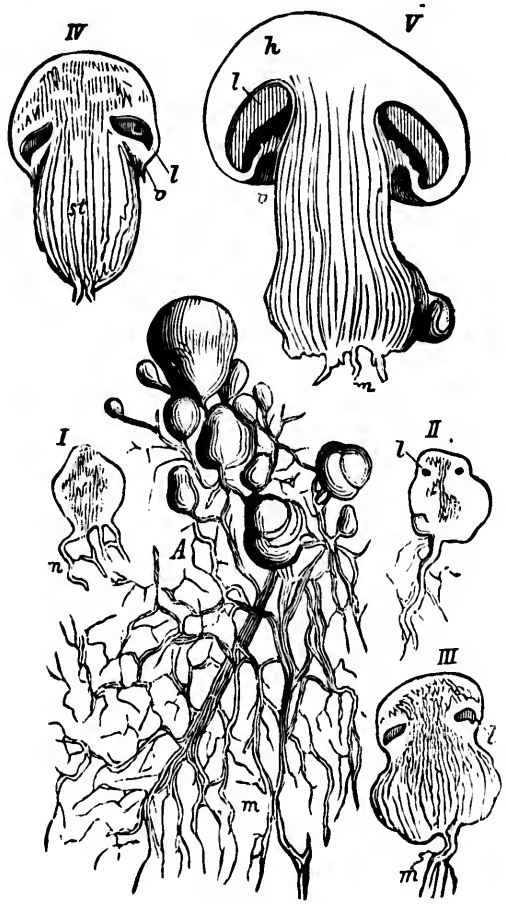

Fig. 247.

where there is seen an outer layer of cells standing on end. The whole of both surfaces of the lamellæ is covered with such cells, and this special layer is the

Fig. 247.—Various stages in the development of a Mushroom. (Sachs.)

hymenium. At *C*, the left hand portion of the figure shows a number of these long cells much more highly

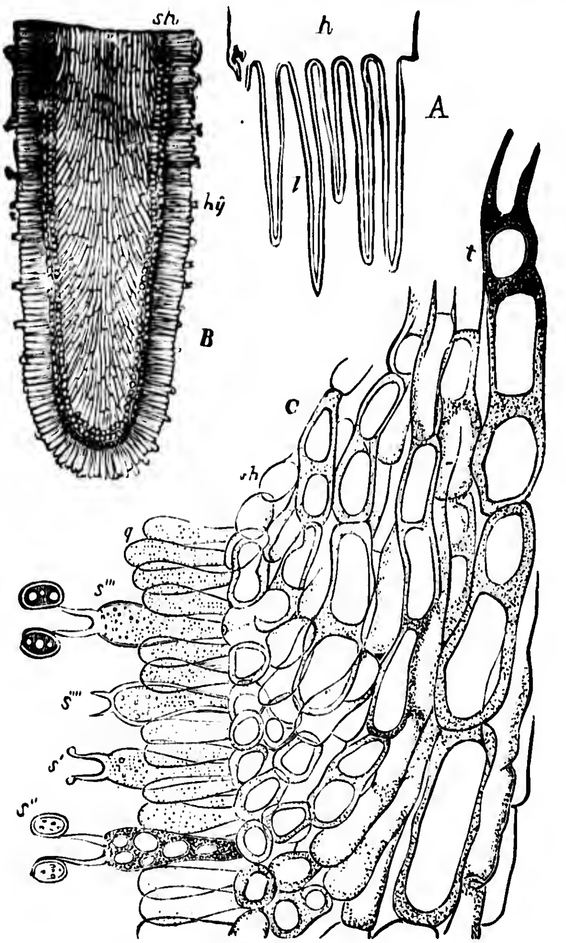

Fig. 248.

magnified, some of them narrowed in at the top so as to form slender points, upon each of which is a rounded body.

Fig. 248.—Greatly enlarged views of sections of the lamellæ of a Mushroom. (Sachs.)

These rounded bodies are the *spores;* the narrowed ends of the cells are called *sterigmata*, and the projecting cells which bear them are specially known as *basidia.* The spores are formed by the simple narrowing in of the outer ends of the basidia.

The mycelium is, therefore, the vegetative part of the Mushroom, while the stalked pileus above the surface is the fructification. The mycelium is developed directly from the spore, but so far there have not been discovered any indications of the interaction of sperm-cells and germ-cells such as characterize the Bryophytes and Pteridophytes.

348. You will note the entire absence of green colouring-matter. The Mushrooms produce no chlorophyll, and, consequently, are incapable of assimilation. They are always found growing upon decaying organic matter, as the leaf-soil of forests and meadows, &c.

349. The Mushrooms are representatives of a large class of plants called **Fungi**, all the members of which are destitute of chlorophyll. The cells of which they are made up are generally in rows so as to form long threads which are known as *hyphæ*, and these may be either loosely interwoven, as in ordinary Moulds, or firmly compacted together, as in the Mushroom.

350. As just mentioned, Mushrooms are saprophytic in their habits; but there are also Fungi which are parasitic, such as Rust and Smut. To the Fungi belong such organisms as the Yeast-plant, and the Bacteria which are found in putrefying matter, and are the cause of, or are associated with, diseases of various kinds.

351. Lichens. These plants may be found growing on the bark of trees, on old fences, on rocks, or on the ground. They differ widely in external appearance, sometimes growing erect and imitating a stem and branches, as in Fig. 249; sometimes forming flat expansions which adhere to the surface upon which they grow, as in Fig. 250. Some species are yellow, others red, others grey. A very common one is that represented in Fig. 250. It may be found upon many tree-trunks, and will be easily recognized by the yellow disks which dot its surface.

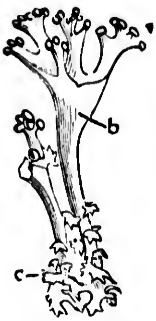

Fig. 249.

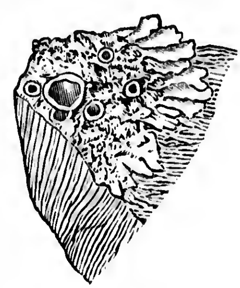
Fig. 250.

352. The flat part of the Lichen is the thallus, or vegetative portion, while the yellow, cup-shaped disks (the *apothecia*) contain the fructification. Fig. 251 shows a section of the apothecium, and also the lobing of the margin of the thallus. Fig. 252 is a very highly magnified view of a section of a thallus, showing it to be largely made up of cells, or *hyphæ*, similar to those of the Mushroom. But in the Lichen there are visible, in addition, large numbers of spherical *green* cells (*g g* in the Fig.) known as *gonidia*, which either occupy well-marked

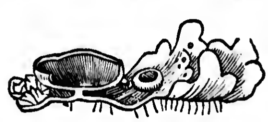
Fig. 251.

Fig. 249.—A fruticose Lichen (*Cladonia digitata*) of the natural size; *b*, the cup; *c*, the thallus; the rounded bodies at the summit are the apothecia. (Thomé.)

Fig. 250.—A foliaceous Lichen growing on a stone; natural size. (Gray.)

Fig. 251.—Section of an apothecium. (Gray.)

layers, as in the present instance, or are scattered through the body of the thallus. The presence of these gonidia may be said to be the distinguishing feature of the Lichens. Their true relation and function were for a long time doubtful, widely different opinions being held, but

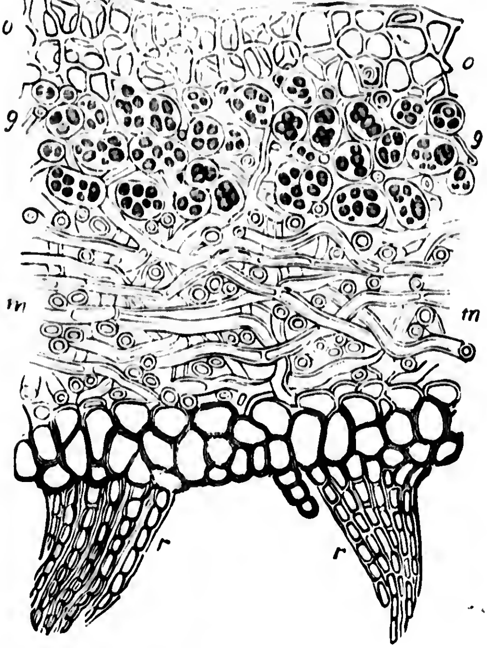

Fig. 252.

it is now generally admitted that the gonidia are themselves *chlorophyll-bearing plants*, and that the remainder of the Lichen is a true Fungus, *parasitic upon the gonidia.*

Fig. 252.—Very highly magnified view of section of the thallus of a Lichen; *r*, rhizoids; *m*, spurious tissue of hyphæ; *g*, green gonidia; *o*, boundary cells of upper side; *u*, boundary cells of under side. (Sachs.)

The question as to the origin of the gonidia is not yet settled.

353. The structure of the apothecium is very well shown in Fig. 253. From the hyphæ are developed large, club-shaped, vertical cells (the *asci*) which penetrate between the narrower vertical branches of the hyphæ (the *paraphyses*). In the asci arise the spores (technically, *ascospores*), usually eight in each, and these when mature are discharged from the asci, and give rise to new plants. The ascospores are formed in the asci by the process known as *free cell-formation* (283). The protoplasm in the asci collects about as many different points as there

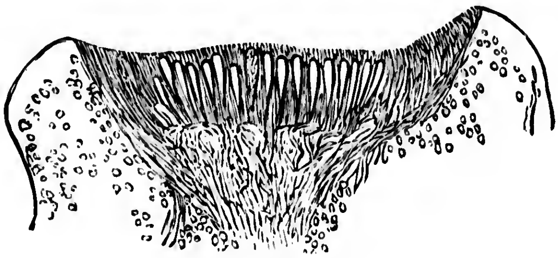

Fig. 253.

are spores to be formed, and a wall is then secreted about each. This mode, which is characteristic of a large number of Fungi, is quite distinct from that which prevails in the Mushrooms, where, as we have seen, the spores are formed by *abstriction.*

354. **Chara.** Fig. 254 represents a Chara of the natural size. It grows almost everywhere in fresh waters, and is quite readily distinguished from other thread-like

Fig. 253.—Very highly magnified view of section o an apothecium, showing the club-shaped asci. (Thomé.)

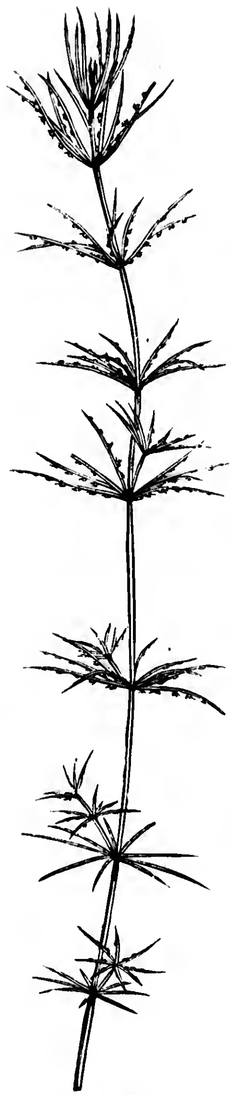

Fig. 254.

aquatics by the whorls of so-called leaves which encircle the stem, and also by the general gritty nature of the plant. A very offensive odour is emitted by the plant in the course of decay. Its green colour shows at once the presence of chlorophyll. On the branches you may observe numbers of minute, more or less rounded, bodies; Fig. 255 is an enlarged view of one of them. Here, at *b*, is shown a large central nucleus (the *nucule*) enclosed in a spiral covering. This spiral consists of five long cells side by side, all of which wind about the central body, and have their ends projecting above it. The nucule is a row of cells of which the highest is the germ-cell, and the whole answers, in fact, to the archegonium of the Bryophytes and Pteridophytes. It is, in this plant, called the *carpogonium*. Just below it is a globular body made up of eight triangular shield-shaped segments arranged about a central cavity. From the inner end of each segment several coiled filaments of many cells each project into the cavity. At maturity the shields separate, and the filaments eventually break up into their

Fig. 254.—*Chara fragilis*; natural size. (Thomé.)

constituent cells, each of which then liberates an antherozoid. The antherozoids make their way down the necks of the carpogonia and fertilize the germ-cells. The spiral cells then harden, and form a firm coat for the spore within. As the plant decays in the autumn, these seed-like *sporocarps*, as they are now called, drop off and fall to the bottom of the water, where they eventually germinate. On germination, they first produce a simple form to which the name *pro-embryo* has been given, and from which arises the plant-body which bears the antheridia and carpogonia.

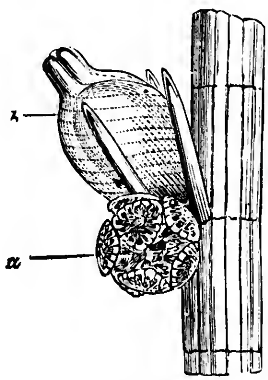

Fig. 255.

There is, therefore, displayed in this case an alternation of generations.

355. Chara belongs to a group of plants known as **Algæ**. They grow either in the water or upon damp surfaces. They differ from the Fungi principally in developing chlorophyll, so that they are able to assimilate. In colour, the Algæ are often green, but in other cases the chlorophyll is obscured by the presence of other colours, such as brown and red. In the lowest forms of both Algæ and Fungi reproduction takes place by simple division of the cells. In higher forms the entire contents of two similar adjacent cells coalesce to form a new one, from which the new plant springs. This is the process of conjugation (284). In still higher forms, as in Chara, reproduction takes place by fertilization.

Fig. 255.—Highly magnified view of part of the fertile thallus of **Chara**. (Thomé.)

356. The Algæ, Fungi, and Lichens together constitute a great group called **Thallophytes**. The Lichens from their peculiar constitution may be regarded as transitional between the Algæ and the Fungi, and by some the Charas are looked upon as links between the Algæ and the Bryophytes.

Some further reference will be made to the Thallophytes in the next chapter, in which is given a brief outline of the classification of plants generally.

CHAPTER XXIV.

CLASSIFICATION OF PLANTS ACCORDING TO THE NATURAL SYSTEM.

357. Hitherto our examination of plants has been confined to a few selected specimens, and we have examined these chiefly in order to become acquainted with some variations in the details of growth, as exemplified by them. Thus we have found plants which agree in exhibiting two cotyledons in the embryo, and others, again, which are monocotyledonous. Some members of the former group were found to exhibit two sets of floral envelopes, other only one, and others, again, were entirely without these organs. And so on through the various details. We now set out with the vegetable world before us—a world populated by forms almost infinite in number and variety. If, therefore, our study of these forms is to be carried on to advantage, we shall have to resolve upon some definite plan or system upon which to proceed; otherwise we shall merely dissipate our energies, and our results will be without meaning. Just as, in our study

of language, we find it convenient to classify words into what we call parts of speech, and to divide and sub-divide these again, in order to draw finer distinctions, so, in our study of plants, it will be necessary to arrange them first of all in comprehensive groups, on the ground of some characteristic possessed by every member of each group. Just as, in Latin, every noun whose genitive case is found to end in *æ* is classed with nouns of the first declension, so in Botany every plant presenting certain peculiarities will be placed in a group along with all the other plants presenting the same peculiarities.

358. Some hints have already been given you as to the kind of resemblances upon which classification is based. For instance, an immense number of plants are found to produce seeds with a dicotyledonous embryo, while an immense number of others have monocotyledonous embryos. This distinction, therefore, is so pronounced, that it forms the basis of a division into two very large groups. Again, a very large number of dicotyledonous plants have their corollas in separate petals; many others have them united, whilst others again have no petals at all. Here, then, is an opportunity to sub-divide the Dicotyledons into polypetalous, gamopetalous, and apetalous groups. And so we go on, always on the plan that the more widely spread a peculiarity is found to be, the more comprehensive must be the group based on that peculiarity; and so it happens, that the smallest groups of all come to depend upon distinctions which are, in many cases, by no means evident, and upon which botanists often find themselves unable to agree.

359. As our divisions and sub-divisions will necessarily be somewhat numerous, we shall have to devise a special

name for each kind of group, in order to avoid confusion of ideas. We shall, then, to begin with, draw a broad line of distinction between those plants which *produce flowers* of some kind, and those which *do not*, and to each of these great groups we shall give the name **Series.** We thus have the **Flowering**, or, to use the Greek term, **Phanerogamous, Series,** and the **Flowerless** or **Cryptogamous Series**; or we may speak of them briefly as **Phanerogams** and **Cryptogams.** Then, leaving the Cryptogams aside for the moment, we may break up the Phanerogams into two great **Classes, Dicotyledons** and **Monocotyledons,** for reasons already explained. By far the greater number of Dicotyledons produce seeds which are enclosed in a pericarp of some kind; but there is a remarkable group of plants (represented in Canada only by the Pines and their immediate relatives) which dispense with the pericarp altogether, and whose seeds are consequently naked. So that we can make two **Sub-classes** of the Dicotyledons on the basis of this difference, and these we shall call the **Angiospermous Sub-class** and the **Gymnospermous** (naked-seeded) **Sub-class.** The first of these may be grouped in three **Divisions,** the *Polypetalous*, *Gamopetalous*, and *Apetalous*, and the **Monocotyledons** also in three, the *Spadiceous*, the *Petaloideous*, and the *Glumaceous*, types of which we have already examined in the Marsh Calla (spadiceous), Trillium (petaloideous), and Timothy (glumaceous), and the distinctions between which are sufficiently obvious.

The **Cryptogams** are divided into three great **Classes,** viz.: **Pteridophytes,** embracing Ferns, Horsetails, and Club-mosses; **Bryophytes,** embracing

Mosses and Liverworts ; and **Thallophytes,** embracing Lichens, Seaweeds (Algæ), and Mushrooms (Fungi).

360. So far, then, our classification is as follows :

Vegetable Kingdom.

- **Series I. Phanerogams.**
  - **Class I.—Dicotyledons** .. .. ..
    - **Sub-class 1**-Angiosperms.
      - *Polypetalous Division.*
      - *Gamopetalous do.*
      - *Apetalous do.*
    - **Sub-class 2**-Gymnosperms
  - **Class II.—Monocotyledons** .. ..
    - *Spadiceous Division.*
    - *Petaloideous do.*
    - *Glumaceous do.*
- **Series II. Cryptogams.**
  - **Class III.—Pteridophytes.**
  - **Class IV.—Bryophytes.**
  - **Class. V.--Thallophytes.**

361. The above is very nearly the arrangement adopted by Gray, but many botanists prefer another arrangement as follows :

Vegetable Kingdom.

- **Group I. Phanerogams.**
  - *A.*—Angiosperms.
    - **Class I.**—*Dicotyledons.*
    - **Class II.**—*Monocotyledons.*
  - *B.*—Gymnosperms.
    - **Class III.**—*Gymnosperms.*
- **Group II. Pteridophytes.**
  - **Class IV.**—*Ferns.*
  - **Class V.**—*Horsetails.*
  - **Class VI.**—*Club-Mosses.*
- **Group III. Bryophytes.**
  - **Class VII.**—*Mosses.*
  - **Class VIII.**—*Liverworts.*
- **Group IV. Thallophytes.**
  - **Class IX.**—*Fungi.*
  - **Class X.**—*Algæ.*

In this arrangement the last three Groups constitute the Cryptogams, and the Gymnosperms are raised to the rank of a sub-division of the Phanerogams, instead of being a sub-division of the Dicotyledons. The **Lichens**, also, are included in the Fungi.

362. The whole question of botanical classification is still in an unsettled state. For further information in regard to the various modes that have been put forward, the student must consult larger works. In the second part of this book, whilst the classification of Gray (who follows Bentham and Hooker) is followed in a general way, those who prefer the second arrangement of the Phanerogams as given above may easily make the requisite change.

363. Each of the *Divisions* is sub-divided into a number of **Families** or **Orders**; each Order into a number of **Genera**; and each Genus into **Species**.

The names of the Orders as a rule have the ending -*aceæ*, as: *Ranunculaceæ*, *Rosaceæ*. These names are adjectives agreeing with the noun *Plantæ* understood, so that they mean "Rosaceous plants," "Ranunculaceous plants," &c.

364. A species is the sum of all the individual plants whose resemblances in all essential respects are so great as to warrant the belief that they have sprung from one common stock. De Candolle has this statement: "We unite under the designation of a *species* all those individuals that mutually bear to each other so close a resemblance as to allow of our supposing that they may have proceeded originally from a single being or a single pair." We may also speak of each one of these individual plants as a species. For example, you may say, after finishing the first lesson of this book, that you have examined *a species of Buttercup*. Mere differences of

colour or size are not sufficient to constitute different species. The Balsams of our gardens, for instance, are of various colours, and the plants vary greatly in size, yet they all belong to one species. These minor differences, which are mainly the result of care and cultivation, give rise to *varieties*. These are of great interest to the horticulturist, but the study of *species* is the great end and aim of the botanist.

365. Those Species which are considered to resemble each other most nearly are grouped into Genera, and the Genera, in like manner, into Orders; but these particular groupings are more or less artificial, and are subject to continual alteration in consequence of our imperfect knowledge. As year by year new facts are brought to light, modifications in arrangement take place. In the Classification of common plants which constitutes the Second Part of this work, the Divisions spoken of above are placed in the order named. In the Polypetalous Division, those Orders are put first which embrace plants with *hypogynous stamens* and *apocarpous pistils*, the parts of the flowers being consequently *separate;* then those with similarly inserted stamens, but *syncarpous pistils;* then those with *perigynous* stamens; and, generally, we proceed from plants whose flowers have all their parts separate to those exhibiting more or less *cohesion* and *adhesion*, and finally to those having one or more parts of the flower wanting.

366. In looking up the name of a plant, it will be your object to determine the *Genus* to which it belongs, and also the *Species*. The name of every plant consists of two parts: its Genus first, and then its Species. The name of

the Genus is a Latin noun, and that of the Species generally a Latin adjective agreeing with the noun. The Buttercup, for example, which we examined at the outset, belongs to the Genus *Ranunculus*. In this Genus are included many Species. The particular one examined by us is known as *acris*; so that the full name of the plant is *Ranunculus acris*. In like manner, the name of the plant popularly called Marsh-Marigold is *Caltha palustris*.

367. The *Key* which is prefixed to the Classification will enable you to determine without much difficulty the *Order* to which a plant belongs, but nothing more. Having satisfied yourselves as to the Order, you must turn to the page on which that Order is described, and, by carefully comparing the descriptions there given with the characters exhibited by your plant, decide upon its Genus, and, in the same manner, upon its Species.

THE HERBARIUM.

368. Those who are anxious to make the most of their botanical studies will find it of great advantage to gather and preserve specimens for reference. A few hints, therefore, on this subject will not be out of place. It will, of course, be an object to collectors to have their specimens exhibit as many of their natural characters as possible, so that, although dried and pressed, there will be no difficulty in recognizing them; and to this end neatness and care are the first requisites.

Specimens should be collected when the plants are in flower, and, if possible, on a dry day, as the flowers are then in better condition than if wet. If the plant is small, the whole of it, root and all, should be taken up; if too large to be treated in this way, a flower and one or two of the leaves (radical as well as cauline, if these be different) may be gathered.

As many of your specimens will be collected at a distance from home, a close tin box, which may be slung over the shoulder by a strap, should be provided, in which the plants may be kept fresh, particularly if a few drops of water be sprinkled upon them. Perhaps a better way, however, is to carry a portfolio of convenient size—say 15 inches by 10 inches—made of two pieces of stout paste board or thin deal, and having a couple of straps with buckles for fastening it together. Between the covers should be placed sheets of blotting-paper or coarse wrapping-paper, as many as will allow the specimens to be separated by at least five or six sheets. The advantage of the portfolio is, that the plants may be placed between the sheets of blotting-paper and subjected to pressure by means of the straps as soon as they are gathered. If carried in a box, they should be transferred to paper as soon as possible. The specimens should be spread out with great care, and the crumpling and doubling of leaves guarded against. The only way to prevent moulding is to place plenty of paper between the plants, and *change the paper frequently;* the frequency depending on the amount of moisture contained in the specimens. From ten days to a fortnight will be found sufficient for the thorough drying of almost any plant you are likely to meet with. Having made a pile of specimens with paper between them, as directed, they should be placed on a table or floor, covered by a flat board, and subjected to pressure by placing weights on the top; twenty bricks or so will answer very well.

369. It is of great importance that *the sheet of paper within which the plant is first placed* should not be interfered with during the drying process. The directions as to frequent changes refer only to the sheets not immediately in contact with the plant. These, to ensure the best results, should be changed once a day for the first few days; less frequently thereafter. Gray recommends ironing with hot irons in order to remove more rapidly the moisture from fleshy leaves, and in any case to warm the driers in the sun before putting them between the plants.

When the specimens are thoroughly dry, the next thing is to mount them, and for this purpose you will require sheets of strong white paper; a good quality of unruled foolscap or cheap drawing paper will be suitable. The most convenient way of attaching the specimen to the paper is to take a sheet of the same size as your paper, lay the specimen carefully in the centre, wrong side up, and gum it thoroughly with a very soft brush. Then take the paper to which the plant is to be attached, and lay it carefully on the specimen. You can then lift paper and specimen together, and, by pressing lightly with a soft cloth, ensure complete adhesion. To render plants with stout stems additionally secure, make a slit with a penknife through the paper immediately underneath the stem; then pass a narrow band of paper round the stem, and thrust both ends of the band through the slit. The ends may then be gummed to the back of the sheet.

The specimen having been duly mounted, its botanical name should be written neatly in the lower right-hand corner, together with the date of its collection and the locality were found. Of course only one Species should be mounted on each sheet; and when a sufficient number have been prepared, the Species of the same Genus should be placed in a sheet of larger and coarser paper than that on which the specimens are mounted, and the name of the Genus should be written outside on the lower corner. Then the Genera of the same Order should be collected in the same manner, and the name of the Order written outside as before. The Orders may then be arranged in accordance with the classification you may be using, and carefully laid away in a dry place. If a cabinet, with shelves or drawers, can be specially devoted to storing the plants, so much the better.

INDEX AND GLOSSARY.

The numbers refer to Sections, unless Figures are specified.

APPENDIX.

Selections from Examination Papers.

UNIVERSITY OF TORONTO.

1. Define suckers, stolons, offsets, runners, tendrils, thorns, and prickles, describing their respective origins and uses, and giving examples of plants in which they occur.

2. What are the functions of leaves ? Describe the different kinds of compound leaves.

3. What is meant by inflorescence ? Describe the different kinds of flower-clusters, giving an example of each.

4. Mention and explain the terms applied to the various modes of insertion of stamens.

5. How are fruits classified ? What are multiple or collective fruits ? Give examples.

6. Relate the differences in structure between endogenous and exogenous stems. Describe their respective modes of growth.

7. What is the food of plants ? how do they obtain it ? and how do they make use of it ?

8. Describe the component parts of a simple flower. How is reproduction effected ?

9. Describe the anatomical structure of a leaf, and the formation and office of leaf-stomata.

10. Explain the consequences of flowering upon the health of a plant, and show how these effects are remedied in different climates. What practical bearing has this upon horticulture ?

11. Trace the development of a carpel from a leaf. Describe the different forms assumed by placentæ in compound ovaries, and explain the origin of these variations.

12. Mention the principal modes in which pollen gains access to the stigma. What are hybrid plants, and how are they perpetuated ?

13. Describe the anatomy of a leaf. What are stomata ?

14. What is the placenta in a seed-vessel ? Describe the different modes of placentation. Show how the varieties of placentation agree with the "altered-leaf theory" of the pistil.

15. Give the characters of the Compositæ. How is the order sub-divided ? Describe the composite flower, and mention some of the common Canadian examples of this order.

16. Give the peculiarities of Endogens in seed-leaf, leaf, and stem. Sub-divide the class. Describe shortly the orders Araceæ and Gramineæ.

17. Describe the wall of a seed-vessel, and notice its varieties of form.

18. What is meant by the dehiscence of a capsule? Show the different modes in which pods dehisce, and give examples of each.

19. Give the characters and orders of Gymnospermous Exogens.

20. Give the characters of Ranunculaceæ. Describe shortly some of the principal plants of the order.

21. Give some account of the *special forms* which the leaves of plants assume.

22. What are stipules? What their size and shape?

23. What is meant by Imperfect, Incomplete, and Unsymmetrical flowers respectively?

24. Describe Papilionaceous and Labiate corollas.

25. Write notes on Abortive Organs, Gymnospermous Pistil, and Pollen Granule.

26. Distinguish between the essential and non-essential materials found in plants, and notice the non-essential.

27. What is vegetable growth? Illustrate by a reference to the pollen granule in its fertilization of the ovary.

28. What is an axil? What is the pappus?

29. What are the cotyledons? What is their function, and what their value in systematic Botany?

30. Distinguish between Epiphytes and Parasites. Describe their respective modes of growth, and give examples of each.

31. What is the difference between roots and subterranean branches? Define rhizoma, tuber, corm, and bulb, giving examples of each. How does a potato differ botanically from a sweet-potato?

32. Describe the calyx and corolla. What modifications of parts take place in double flowers?

33. What is a fruit in Botany? Explain the structure of an apple, grape, almond, strawberry, fig, and pine-apple.

34. What organs appear in the more perfect plants? In what two divisions are they comprised?

35. Weak climbing stems distinguished according to the mode in which they support themselves, the direction of their growth, the nature of their clasping organs.

36. Structure and parts of a leaf: What is most important in their study? Give the leading divisions, and mention what secondary distinctions are required in specific description?

37. Function of the flower: its origin: its essential and accessory parts: name of the circles and their component organs: circumstances which explain the differences among flowers.

38. Parts of the fully formed ovule and distinctions founded on their relative position.

39. Sub-kingdoms and classes of the vegetable kingdom.

40. What is meant by a composite flower? Illustrate your answer by reference to the dandelion, and point out in what respect its flower-head differs from that of the common clover.

41. Define what is meant by the terms *Exogen* and *Endogen*.

42. Explain what is meant by the following: Stamens and petals are, from a morphological point of view, leaves.

What is the morphological nature of onion bulbs, and potato tubers?

43. Name and describe the different parts of stamens and pistils. Why are these two sets of organs called the essential parts of a flower? State what is meant by a staminate flower, and what by a pistillate flower? How is fertilization accomplished in the case of the latter?

44. What is meant by the terms, *berry*, *drupe*, and *pome?* Why cannot a raspberry or a strawberry be termed a true *berry?*

45. Draw outlines of the following forms of leaves: ovate, deltoid, lanceolate, reniform, peltate, sagittate, hastate, cordate, obcordate.

46. Define the following terms: involucre, glume, gynœcium, micropyle, pappus, spadix, tendril, cyme.

SECOND AND THIRD CLASS TEACHERS' CERTIFICATES, PROVINCE OF ONTARIO.

1. Name the parts of the pistil and stamens of a flower and give their uses.

2. What are Perennial plants? Describe their mode of life.

3. "There are two great classes of stems, which differ in the way the woody part is arranged in the cellular tissue." Fully explain this.

4. Describe the functions of leaves. How are leaves classified as to their *veining*.

5. Name and describe the organic constituents of plants.

6. Name the organs of reproduction in plants, and describe their functions.

7. Give, and fully describe, the principal parts of the flower.

8. What are the different parts of a plant? Describe the functions of each part.

9. State all the ways by which an Exogenous stem may be distinguished from an Endogenous.

10. Describe the functions of leaves. What is the cause of their fall in autumn? Draw and describe a maple leaf.

11. Name the different parts of a flower, and describe the use of each part. Draw a diagram showing a stamen and a pistil and the parts of each.

12. What is the fruit? Why do some fruits fall from the stem more easily than others?

13. Of what does the food of plants consist? In what forms and by what organs is it taken up, and how is it assimilated? Name the substances inhaled and those exhaled by plants, and the uses of each in the economy of nature.

14. Describe fully (1) the plant in Vegetation; (2) the plant in Reproduction.

15. Describe Fibrous roots, Fleshy roots, and different kinds of Tap-root.

16. Describe the structure and veining of leaves.

17. "The nourishment which the mother plant provides in the seed is not always stored up in the embryo." Explain and illustrate.

18. Describe the various modes in which Perennials "provide a stock of nourishment to begin the new growth."

19. Describe fully the organs of reproduction in a plant. Describe the process of germination.

20. What are the parts of a flower? Give illustrations by diagram, with a full description.

21. Name and describe the principal sorts of flowers.

22. What elementary substances should the soil contain for the nourishment of plants?

23. How are plants nourished before and after appearing above ground?

24. Tell what you know about the various forms of the calyx and the corolla.

25. Explain the terms Cotyledon, Pinnate, Root-stock, Filament, and Radicle.

26. Explain the terms Papilionaceous, Cruciferous, Silique, and Syngenesious; and in each case name a family in the description of which the term under consideration may be properly applied.

27. Give the characters of the Rose family.

28. Describe the various modes in which biennials store up nourishment during their first season.

29. Explain the meaning of the terms Sepal, Bract, Raceme, and Stipule. Describe minutely the Stamen and the Pistil, and give the names applied to their parts.

30. Are the portions of the onion, the potato, and the turnip which are capable of preservation through the winter, equally entitled to the name of roots? Give reasons for your answer.

31. Describe briefly a vegetable cell in regard to its form, size, contents, &c.

What differences usually exist between cells found in pith and those found in wood?

32. Name two kinds of underground stems.

How do we know that they are not roots?

State any uses of these stems (*a*) to the plant, (*b*) to man.

33. What are the functions of the leaf in plant life?
State any differences between leaves which are surrounded by air and leaves which float upon water.
Give any laws according to which leaves are arranged upon the stem.

34. Give the names and relative positions of the parts of a complete flower.
Can you name a flower which is *perfect* but not *complete?*

35. When a pea is soaked in water it splits into two parts, united by a small ligament, but a grain of corn does not. Explain the meaning of this difference.

36. Is an apple a Botanical fruit? If not, what is it?

37. Name any plants belonging to the following natural orders:—Cruciferæ, Carophyllaceæ, Compositæ, Labiatæ.

38. From what does the root of an exogenous plant originate? What are the chief functions of roots? How may roots be distinguished from underground stems?

39. From what do stems originate? Compare in appearance transverse sections of the stem of an elm and of a stalk of maize. How do these stems differ in their modes of growth?

40. What are the functions of foliage-leaves? Describe briefly the general structure and appearance of the leaf of (*a*) the Sugar Maple (*Acer saccharinum*); (*b*) the Indian Turnip (*Arisæma triphyllum*).

41. Name the parts of a complete flower, and briefly describe the chief modifications due to cohesion, adhesion, and suppression of parts. (Name illustrative examples of each modification you describe.)

42. Contrast a strawberry, a raspberry, and an apple, and compare a gooseberry, a lemon, and a melon.

43. What are the general characters of the Cruciferæ, the Leguminosæ, the Liliaceæ, and the Gramineæ?

44. What are the morphological characters of roots? How do adventitious roots differ from normal roots as respects their origin? Briefly describe the normal mode of growth of the roots of Gymnosperms and Dicotyledons.

45. Describe briefly the structure of the stem of the Sunflower (*Helianthus annuus*). Mention the chief differences in the structure and the mode of growth of the bark in different dicotyledonous trees?

46. What is meant by an inflorescence? Distinguish between definite and indefinite inflorescence, and briefly describe the chief kinds of indefinite inflorescence, giving an example of each.

47. Describe the structure and the process of germination of the following named seeds: bean, buckwheat, marsh-marigold, oat.

48. What are stomata? On what plants and parts of plants are they found? What are their functions?

49. Give the distinguishing characters of the Sapindaceæ, the Rosaceæ, the Coniferæ, and the Iridaceæ. Name a Canadian plant belonging to each of these orders, and mention any uses made of it or of any part of it.

50. Define the following terms: bract, scale, involucre, spathe, scape, pedicel, asepalous, monœcious, monadelphous, perianth, stamen, pistil, pome, thallus, drupe.

51. Describe briefly the structure, the mode of growth, and the use to the plant of roots. Name an example of a plant with aërial roots.

52. Name the enveloping and the essential organs of the flower, and give a morphological comparison of foliage-leaves, floral envelopes, stamens, and carpels.

53. Describe briefly the general process of plant-nutrition, and name the essential elements in the food of plants.

54. Give the chief distinctive characters of the Cruciferæ, the Leguminosæ, the Umbelliferæ, and the Liliaceæ. Name three common examples of each of these families.

55. Describe the modes by which the fertilization of a flower is accomplished.

56. Distinguish between "definite" and "indefinite" inflorescence.

57. Which are the nutritive and which the reproductive organs of plants?

Briefly describe the principal ones of each kind.

58. Describe the structure of a "follicle," a "siliqua" and a "legume."

59. When is a flower said to be "complete," "regular," and "symmetrical?"

60. Fill the accompanying Floral Schedule with an accurate description of the specimen before you, referring it to its proper order, &c.

61. Distinguish between (the series): Phanerogams and Cryptogams. State their divisions and note the distinctions of those of the first (series).

62. What is the foundation of all vegetable tissue? and of its elements which is essential for its growth and development?

63. Describe the functions of the roots, stems, and foliage-leaves of plants. State the kinds and sources of their nourishment. Mention the changes the nutritive elements undergo in their passage through them and the agencies by which these changes are effected.

64. Name, describe, and give the functions of the several parts of a typical flower. State which are essential and why.

65. Give the general characteristics of the Leguminosæ, Rosaceæ and Coniferæ.

66. Refer to their botanical orders, genera, etc.: the plum, pear, orange, pumpkin, cucumber, carrot.

67. Describe the structure and mode of growth of exogenous and endogenous stems.

68. Give the meanings of apocarpous and syncarpous, and name two allied genera which may be distinguished by the difference these terms express.

69. Where, in plants, are stomata most abundant? What is their chief function? Describe chlorophyll and explain its physiological importance.

70. By what means is fertilization effected (1) in Phanerogams, and (2) in Cryptogams?

71. How would you distinguish a root from a stem? Enumerate the most important varieties of roots, giving examples.

72. Make a drawing of the leaf of the sugar maple (*Acer Saccharinum*) and of the beech (*Fagus ferruginea*), and describe them with special reference to form, parts, and venation.

73. Fill the accompanying Floral Schedule with an exact description of the specimen before you. Classify, if you can.

FIRST CLASS CERTIFICATES.

1. What are the cotyledons? Describe their functions, &c. State their value in systematic botany.

2. Describe the difference in structure and modes of growth of exogenous and endogenous stems.

3. Describe the circulation in plants. "In the act of making vegetable matter, plants purify the air for animals." Explain this fully.

4. What are Phænogamous plants? Define Raceme, Corymb, Head, Panicle, Ament.

5. Give the characters of (*a*) the classes Exogens and Endogens; (*b*) the Mint and Lily families.

6. To what family do the Cedar, Clover, Mustard, and Dandelion respectively belong?

7. Why does a botanist consider the tuber of the potato an underground stem.

8. Give the philosophical explanation of the nature of a flower considered as to the origin and correspondence of its different parts.

9. Draw a spathulate, an obcordate, a truncate, a palmately-divided and an odd-pinnate leaf.

10. Explain the constitution of a pome or apple-fruit.

11. What organs appear in the more perfect plants, and in what divisions are they comprised?

12. Give the function of the flower, its origin, and its essential and accessory parts.

13. Describe the nature and chief varieties of roots, and distinguish between them and underground stems.

14. "As to the Apex or Point leaves are Pointed, Acute, Obtuse, Truncate, Retuse, Emarginate, Obcordate, Cuspidate, Mucronate." Sketch these different forms.

15. "There is no separate set of vessels, and no open tubes for the sap to rise through in an unbroken stream, in the way people generally suppose." Comment on this passage.

16. The great series of Flowering Plants is divided into two *classes*. Describe these classes.

17. Give the chief characteristics of the order *Cruciferæ* (Cress Family), and name some common examples of this order.

18. State the difference between definite and indefinite inflorescence, and give examples of the latter.

19. Of what does the food of plants consist? In what form is it found in the soil? How is it introduced into the plant? What inference may be drawn respecting the culture of the plant?

20. Distinguish weak climbing stems according to the mode in which they support themselves, the direction of their growth, and the nature of their clasping organs.

21. Name the three classes of Flowerless Plants, and give an example of each.

22. Explain the terms Spore, Capsule, Bract, Stipule, Albumen, and Epiphyte.

23. What are tendrils, and of what organs are they supposed to be modifications?

24. Give the characters of the Cress Family, and name as many plants belonging to it as you can.

25. Tell what you know about the minute structure and the chemical composition of vegetable tissue.

26. Describe the origin of the different kinds of placentas; and of the different parts of the fruit of the plum, the oak, and the maple.

27. Describe fully the process by which it is supposed that water is carried up from the roots of plants.

28. Give the meaning of the terms *stomate*, *indehiscent*, *thyrse*, *glume*, *pyxis*. Distinguish *epiphytes* from *parasites*.

29. Describe any plant you have examined; if you can, tabulate your description.

30. Name all the families of monopetalous dicotyledons which you remember, and give the characters of any one of them.

31. Describe the following: primordial cell (utricle), protoplasm, cyclosis, mode of plant growth.

32. Describe the process of reproduction in a phanerogamic plant.

33. How are the pulse family—order Leguminosæ—distinguished? Show the utility of the plants of this order.

34. What is Æstivation? Describe the different kinds, and mention a natural order of which each is characteristic.

35. Describe the course of the sap through the root and trunk of an exogenous tree.

36. Enumerate the chief nitrogenous and non-nitrogenous substances which are found in plants.

37. Fill in the accompanying Floral Schedule with a full and accurate description of the specimen under observation.

McGILL UNIVERSITY.

1. Describe the germination of a plant.
2. Explain the differences in the structure of the embryo.
3. Explain the functions of the Root.
4. Describe the structures in a leaf, and explain their action on the air.
5. Mention the several parts of the stamen and the pistil, and explain their uses.
6. Describe an Achene, a Samara, a Drupe, and a Silique.
7. Describe the differences in the stems of Exogens and Endogens, and the relations of these to the other parts of the plant and to classification.
8. Explain the terms Genera, Species, Order.
9. What is an excurrent stem, an axillary bud, bud scales?
10. Explain the terms *primordial utricle*, *parenchyma*, *protoplasm*, as used in Botany.
11. What are the functions of the nucleus in a living cell?
12. Explain the movements of the sap in plants.
13. Describe the appearance under the microscope of *raphides*, *spiral vessels*, and *disc-bearing wood-cells*.
14. Describe the structure of the bark of an Exogen.
15. Describe freely the anatomy of a leaf.
16. Describe shortly the parts and structures denoted by the following terms: *spine*, *aërial root*, *phyllodium*, *cambium*, *stipule*, *rhizoma*.
17. Give examples of *phænogams*, *cryptogams*, *exogens*, and *endogens*, properly arranged.
18. Describe the principal forms of indeterminate inflorescence.
19. In what natural families do we find *siliques*, *didynamous stamens*, *labiate corollas*, or *pappus-bearing achenes*. Describe these structures.
20. State the characters of any Canadian exogenous order, with examples.
21. Describe the cell-walls in a living parenchymatous cell.
22. Describe the fibro-vascular tissues in an Exogenous stem.
23. Describe the appearance of stomata and glandular hairs under the microscope.
24. Define *prosenchyma*, *corm*, *cyclosis*, *thallus*.

25. Explain the sources of the Carbon and Nitrogen of the plant, and the mode of their assimilation.

26. Describe the pericarp, stating its normal structure, and naming some of its modifications.

27. Explain the natural system in Botany, and state the gradation of groups from the species upward, with examples.

ONTARIO COLLEGE OF PHARMACY.

1. What do plants feed upon ?

2. What do you understand by the terms Acaulescent, Apetalous, Suffrutescent, Culm ?

3. Name some of the different forms of Primary, Secondary, and Aërial Roots, giving examples.

4. Explain the following terms descriptive of forms of leaves, giving sketch :— Ovate, Peltate, Crenate, Serrate, Cleft, Entire, Cuspidate, Perfoliate.

5. Explain difference between Determinate and Indeterminate inflorescence, giving three examples of each.

6. What organs are deficient in a sterile and a fertile flower ?

7. Give the parts of a perfect flower, with their relative position.

8. Give the difference between simple and compound Pistil, with examples of each.

9. Name the principal sorts of buds, and explain how the position of these affects the arrangement of branches.

10. Give description of multiple and primary roots, with two examples of same; also explain the difference between these and secondary roots.

11. Name the principal kinds of subterranean stems and branches, and explain how you would distinguish between these and roots.

12. In the classification of plants explain difference between classes and orders: genus and species.

13. Name three principal kinds of simple fruits.

14. When roots stop growing does the absorption of moisture increase or decrease ? Give reason for it.

15. Upon what do plants live ? Indicate how you would prove your answer correct.

16. In what part of the plant, and when, is the work of assimilation carried on ?

17. Name three principal kinds of *determinate*, and some of *indeterminate*, inflorescence; name the essential organs of a flower.

18. In what respects do plants differ from inorganic matter ? And from animals ?

19. Describe a Rhizome, Tuber, Bulb; and say if they belong to the root or stem. Which are Rheum, Jalapa, Sweet Potato, Onion ?

20. Define the difference between natural and special forms of leaves; between simple and compound leaves. Give example of each. Sketch a connate-perfoliate leaf.

21. Mention the parts of an embryo. Of a leaf. Of a pistil. Of a stamen. Of a seed.

22. What is meant by an albuminous seed? By diœcious flowers? By a compound ovary?

23. What is the difference between determinate and indeterminate inflorescence? How do they influence growth of the stem. Give three principal kinds of each.

24. Name the parts of a flower. What office is performed by the ovule? Name two kinds.

25. Name the parts of a vegetable cell. What are spiral ducts?

26. In what parts of the plant is the work of absorption carried on? In what part the work of assimilation? How do the plants purify the air for animals?

27. Explain the natural system of classification in Botany? Name and characterize the classes of plants.

28. Explain the structure and functions of the Leaf, Bud, Root.

29. Give some of the terms used in describing the shape of a simple leaf as concerns (*a*) its general contour, (*b*) its base, (*c*) its margin, (*d*) its apex.

30. Name the organs in a perfect flower; describe fully the structure of the anther and pollen. What is coalescence and adnation of the parts of a flower?

31. Explain the terms Raceme, Pappus, Coma, Rhizome, Pentastichous.

32. State the distinction between Exogens and Endogens.

33. What are cellular structures as distinguished from vascular? What is chlorophyll?

34. Mention the organs of fructification, and explain the process of fertilization in a flowering plant.

35. Explain the structure of a seed, and describe in a few words the process of germination.

36. Define what is meant by the following terms: Morphology, Polycotyledonous, Epiphyte, Peduncle, Stipules.

37. Describe briefly the root, stem, leaf, and flower of the common dandelion, giving the functions or office of each.

38. Name some of the most common forms of leaves, giving a few rough outlines.