ELEMENTARY BOTANY

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ELEMENTARY BOTANY

THEORETICAL AND PRACTICAL

A TEXT-BOOK DESIGNED PRIMARILY FOR STUDENTS OF SCIENCE CLASSES

CONNECTED WITH THE SCIENCE AND ART DEPARTMENT OF

THE COMMITTEE OF COUNCIL ON EDUCATION

BY

HENRY EDMONDS, B. SC. (LOND.)

LECTURER ON NATURAL SCIENCE AT THE BRIGHTON SCHOOL OF SCIENCE AND ART
SCIENCE MASTER AT THE BRIGHTON GRAMMAR SCHOOL, ETC.

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PREFACE.

THE object of this text-book is as far as possible to cover the subject of Elementary Botany as provided in the syllabus of the elementary stage issued by the Science and Art Department, and at the same time to avoid being a mere cram work, but to give a general idea of the fundamental facts and principles of the science.

In many elementary works the greater part of the book is taken up with mere structural details, the Physiology ot the Plants being relegated to a short chapter at the end. I have endeavoured, whilst tracing up the growth and development of the plant from the seed, to treat of the functions of each organ at the same time as its description.

Through the liberality of the publishers the book is well supplied with diagrams. It will not do, however, for the student to trust to these alone. No science can be properly studied from mere book-work, and this is especially true of such a science as Botany, which deals with various forms of natural objects. The student is strongly urged from the first to carefully examine specimens. A sharp penknife and a simple lens, which will only cost a few shillings, are all the apparatus required for dissecting and examining most flowers, and the commonest plants around us will well serve the student's purpose.

For some parts of the subject—as for instance the examination of Cellular Tissues—a microscope is needful. An excellent instrument can be obtained at any of the well-known makers for about five or six pounds.

The student should also especially accustom himself to writing out descriptions of plants according to the model given at the close of the book.

H. EDMONDS.

BRIGHTON: *May* 1882.

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ELEMENTARY BOTANY.

CHAPTER I.

INTRODUCTORY—DEFINITION AND SCOPE OF THE SCIENCE.

BOTANY is the science which deals with those special forms of living organisms known as Plants. This at once raises the question—What do we mean by a plant? The higher forms of animal and vegetable life can be easily distinguished the one from the other; but when we descend to the lower forms we find it most difficult, if not impossible, to draw a line of demarcation between them.

The old distinction between the three kingdoms of nature was a simple one: minerals grow—plants live and grow—animals move, live and grow. Putting aside for the moment the question as to whether minerals really grow, the phenomena of motion cannot be accepted as defining the difference between the two groups of living beings. Many plants, especially amongst the lower forms, are capable of motion at some time or other during their life. As an example, if we examine rain-water that has been standing for some days, we generally find minute green masses floating about in it. These on inspection under a microscope prove to be true plants (*Protococcus pluvialis*), each being a little rounded mass containing green particles. After watching for some time, however, it will be seen that some of these plants change their form, becoming more pear-shaped, at the same time giving off two very minute threads or cilia. These are thrown into rapid motion, propelling the plant through the water in which it floats. In this mode of motion the Protococcus cannot be distinguished from many of the low forms of animal life.

A better distinction is to be found in the food that is assimilated. Plants, like animals, require food; but they, as a rule, possess the power of obtaining it from the mineral kingdom only, whilst animals require for their food either vegetable or animal substances. There are, however, exceptions to this rule, and, as we have said, the two kingdoms appear to merge gradually the one into the other.

Botany, then, being the science which treats of plants, has several branches. *Morphology* deals with the forms of the organs of plants. *Anatomy* treats of their internal structure; and *Histology* of the minute appearance they present under the microscope. *Physiology* deals with the functions of the various organs, and the phenomena attendant upon life. *Classification* has to do with the grouping of plants according to their relation one to another. *Geographical Botany* deals with the distribution of plants in space; and *Palæontological Botany* with their distribution in time. Of these we shall omit the two latter branches in the present work, merely taking up in an elementary form the remaining departments.

CHAPTER II.

FLOWERING AND FLOWERLESS PLANTS—STRUCTURE OF THE SEED.

ALL the higher forms of plant life are distinguished as being able, at some time or other of their existence, to produce *flowers.*

It is this fact which causes the Vegetable Kingdom to be divided into the two sub-kingdoms of Flowering Plants or Phanerogams, and Flowerless Plants or Cryptogams.

In the present work we shall deal entirely with the Phanerogams.

The point in which all of these plants agree is that they spring originally from seeds. To understand a seed thoroughly, it is well to commence with a large specimen, as, for instance, a Broad Bean, Haricot, or a Pea.

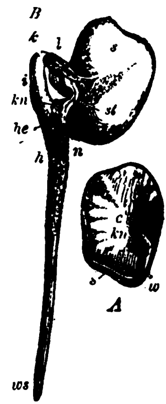


FIG. 1. — *Vicia Faba.* *A*, seed, with one cotyledon removed; *c*, remaining cotyledon; *kn*, the plumule; *w*, the radicle; *s*, the spermoderm. *B*, germinating seed: *s*, spermoderm, a portion torn away at *l*; *n*, hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary portion of axis, *i*; *he*, short hypocotyledonary portion of axis; *h*, main root; *ws*, its apex; *kn*, bud in axil of one of the cotyledons. (After Sachs.)

If we examine a Broad Bean carefully, we notice that it has an elongated shape. At one end there is a scar or mark. This is the point by which the seed is attached to the fruit, and is known as the *hilum*. At one end of this there is a minute hole. This can be readily seen by allowing the bean to soak in hot water for a short time, then on taking it out and squeezing it a drop of water is seen to escape through the aperture. This hole, which leads into the interior of the seed, is called the *micropyle*.

Next, taking a sharp pen-knife, we find that we can peel the skin from off the seed, leaving a whitish fleshy mass within. This skin is really, however, double, as can easily be proved by peeling from the interior a thin pellicle.

These coats are collectively known as *spermoderm*; the outer being called the *testa*, and the inner the *tegmen*.

The mass within the spermoderm forms the nucleus of the seed. In the case of the Broad Bean this nucleus is entirely made up of the young plant or embryo. At one end there is a pointed portion which is directed towards the micropyle. This is destined on germination to be prolonged to form the root, and is known as the *radicle* (fig. 1).

The great mass of the nucleus is made up of two fleshy lobes, which can easily be separated from one another —the *cotyledons*; and between these at the top of the radicle there is a little portion curved over and divided at the end in a plume-like manner. This, which is known as the *plumule*, will, under favourable circumstances, grow into the stem and leaves of the future plant.

In some seeds, as, for instance, those of the varieties of

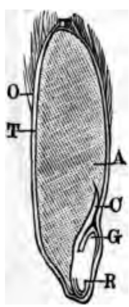


Fig. 2.—Longitudinal section of a seed of Oat: A, endosperm; C, the single cotyledon; G, plumule; R, radicle; T, testa; O, hairs.

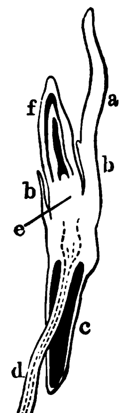


Fig. 3. — Germination of the Oat: *a*, cotyledon; *e*, axis of the embryo; *d*, radicle; *f*, plumule.

corn and grass, there is in the nucleus a substance, *albumen*, in addition to the embryo of the plant (fig. 2). This albumen may originate from two different parts of the ovule or unripe seed, and hence is known either as *endosperm* or *perisperm*. This will be more apparent when we have dealt with the growth of the ovule.

The albumen differs in its characteristics in various plants. In cereals it is *mealy* or *farinaceous*; in the Barberry and Heartsease it is *fleshy*; in the Poppy and Cocoanut it is *oily*; in the Mallow, *mucilaginous*; in the Vegetable Ivory and Coffee, *horny*.

Seeds containing albumen are spoken of as *albuminous*, whilst those destitute of it are *exalbuminous*.

We may tabulate the structure of the most perfect seed as follows:—

Spermoderm { Testa, Tegmen }

Nucleus . { Albumen; Embryo { Radicle, Plumule, Cotyledons. } }

There is another point in which seeds differ. On examining a grain of Wheat, or of an allied cereal, we find that there is only one cotyledon present, instead of, as in the case of the Bean, two. Several plants resemble the Bean in having two cotyledons present in their embryos; whilst others, like Oats, have but one. This causes the division of the sub-kingdom of Flowering Plants into two divisions: *Dicotyledons* include those Phanerogams with two (or in some Conifers more) cotyledons; whilst *Monocotyledons* are those with only one. As we proceed further we shall find that there are other differences between these two great classes.

CHAPTER III.

CELL STRUCTURE.

THE substance of the Bean-seed is not homogeneous. The whole of the various organs of plants are made up of a large number of component parts—cells—so minute as a rule as to be invisible separately to the naked eye. If a little brewer's Yeast be examined under a hand magnifying glass, it is seen to present a granular appearance. If it be more highly magnified, it is found to consist of a large number of minute rounded particles (fig. 4); these are separate cells. We recognise in them the outer pellicle or cell wall and the cell contents.

The *cell wall* may be absent during a portion of the cell's existence; it is simply inert, not-living matter; but in

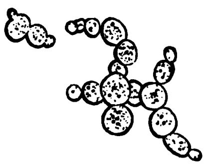


FIG. 4.—Beer-Yeast (*Saccharomyces* (*Torula*) *Cerevisiæ*).

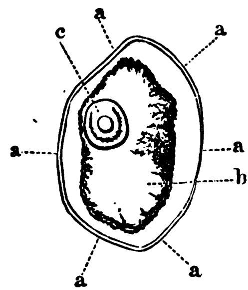


FIG. 5.—A cell from the root of the Lizard Orchis (*Orchis hircina*): *a*, the cell-wall, consisting of cellulose; *b*, the protoplasm contracted by alcohol; *c*, the nucleus with a nucleolus.

the Vegetable Kingdom it is always sooner or later produced. The principal substance contained in it is *cellulose*, a compound of carbon, hydrogen, and oxygen, having the chemical composition $C_6H_{10}O_5$.

Cellulose is not coloured blue by means of iodine alone, although it is so changed by the action of iodine and sulphuric acid, thus being distinguishable from starch, which has precisely the same chemical composition, but is turned blue by iodine. Schultz's solution[1] will also stain it.

Cellulose is insoluble in water, both cold and boiling; also in alcohol, ether, and dilute acids. If it be treated with cold concentrated sulphuric acid, it is converted first into

[1] Schultz's solution.—Dissolve zinc in hydrochloric acid; permit the solution to evaporate in contact with metallic zinc until it has attained a *syrupy* consistence. Saturate the syrup with potassic iodide, and then add enough iodine to make a dark sherry-coloured solution. The object to be stained must be placed in a little water, and then some of the above solution added.

dextrine or British gum, which is the same composition as cellulose, and then into grape sugar, $C_6H_{12}O_6$. It is found almost pure in Cotton wool, but generally the cell wall contains mineral ash and water in addition.

In the older cells of the plant the cellulose is often converted into other but allied substances.

The *cell contents* are very various; we will note some of the principal :—

Protoplasm.—It is of this substance that the whole of the young cell is at first made up. It is very complex in its chemical constitution, but always contains nitrogen. Iodine colours it brown, and concentrated sulphuric acid rose-red; whilst it is also stained by magenta. It is soft and jelly-like in consistency, never truly fluid. At times it is homogeneous and transparent, more often it is granular. It forms the vital portion of the cell and possesses considerable power of movement. It readily absorbs water, which, however, forms drops or vacuoles in its interior.

The movements of protoplasm may be grouped under two heads :—

1. Movements of protoplasmic masses destitute of a cell wall.

a. Swimming by means of cilia, as in the case of Protococcus (page 2).

b. Amœbiform movements, where a naked mass of protoplasm emits irregular projections (*pseudopodia*) at various parts of its surface; the rest of the mass flowing after the processes. This is seen in the remarkable animal, the Amœba or Proteus animalcule, and is met with in some of the lower forms of plant life.

2. Movements of protoplasm within the cell wall.

In many cases the protoplasm contained within the cellulose wall shows a tendency to rotate or circulate in various directions through the cell, often carrying with it substances which may be imbedded in it. This is especially well seen in the cells of many water plants, *Chlorophyll* is the substance to whose presence the green colour of plants is due. It occurs (in the higher plants) in the form of granules imbedded in the protoplasm of various parts of the plant. These granules really consist of two parts—a colourless more or less solid portion, which is formed out of the protoplasm and builds up the chlorophyll granules; and a green colouring matter diffused through and colouring it. The exact chemical composition is not yet known, but there appears to be two separate colouring matters, the one yellow, phylloxanthin, and the other blue, phyllocyanin, which by their union give the green tint.

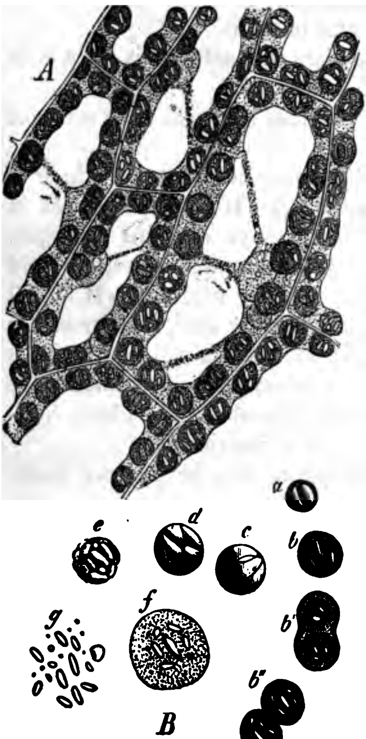


FIG. 6.—Chlorophyll granules in cells of leaf of *Funaria hygrometrica*. *A*, granules of chlorophyll, with contained starch grains imbedded in the protoplasm of the cells. *B*, separated chlorophyll granules containing starch: *a*, *b*, young granules; *b'*, *b''*, chlorophyll granules dividing; *c*, *d*, *e*, old chlorophyll granules; *f*, granule swollen up by action of water; *g*, starch granules remaining after chlorophyll destroyed by action of water. (After Sachs.)

The colouring matter of the chlorophyll is soluble in alcohol, ether, chloroform, benzine, and essential oils and fats.

The chlorophyll granules are produced in the protoplasm under the influence of light, except in the case of the germinating seeds of some Conifers and the fronds of Ferns, in which cases high temperature alone appears to be necessary for their formation.

If a growing plant be placed in perfect darkness no chlorophyll will be formed; the leaves and other organs which would naturally have a green colour present a pale and sickly appearance. Such organs are said to be *etiolated.* An example is to be found in the leaf-stalks of Celery. In the natural state they are green, but when cultivated, earth is heaped up so as to remove them from the influence of the light. The result of this is to produce the white leaf-stalk of the edible varieties, this change of colour being accompanied by change of flavour.

Chlorophyll plays a most important part in the plant economy, which we shall notice when we treat later on of the food supply of the plant.

Starch has the same chemical composition as cellulose $C_6H_{10}O_5$. It differs, however, in many of its properties.

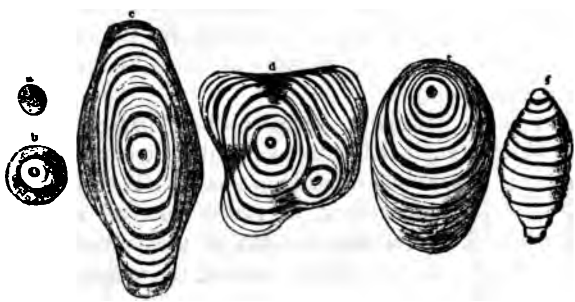


FIG. 7.—Various forms of starch grain from the Potato.

It is insoluble in cold water, but swells up very strongly on the addition of boiling water, forming a paste. It is readily turned a dark blue by the addition of iodine. As this blue colour, however, is removed by heat, the starch requires to be cold, or nearly so, for its production. Exposed to heat for some time, or to dilute sulphuric acid for a shorter period, it is converted into dextrine or British gum.

Starch occurs in the plant in the form of granules varying in their size. Amongst the smaller are those of Rice starch, which are frequently under $\frac{1}{5000}$ of an inch in diameter, whilst those of the 'Tous-les-mois' are often as much as $\frac{1}{300}$ of an inch in length. In external form they vary

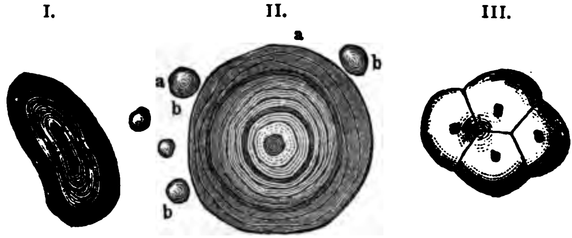


FIG. 8.—I. Starch grain from the Scarlet Runner. II. *a*, *b*, Starch grains from Rye. III. Starch grain from the stem of the Sarsaparilla (*Smilax Sarsaparilla*).

very much, but they usually present a central portion, the hilum, or nucleus, round which the starch substance is arranged in concentric layers. Probably this striated appearance is due to a varying quantity of water in the different parts of the granule.

The starch substance seems to be separable into two parts, which are allied if not identical in composition, but which differ in properties. The one, known as *farinose* or *starch cellulose*, appears to form the skeleton of the granule, and is either stained brown by iodine, or, as in some cases, remains unstained; whilst the other part, *granulose*, which forms 94 to 96 per cent. of the granule, is coloured blue.

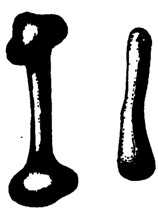


FIG. 9. — Starch grains from the latex of *Euphorbia splendens.*

Granulose is readily soluble in saliva, and is thus separated from the skeleton. The same change takes place by the action of *diastase*, a substance occurring in germinating seeds, *whereby the starch* stored up in the seed as a food supply *is rendered soluble.*

Starch granules, like those of chlorophyll, require *light* for their formation; the quantity needed, however, is greater than that for the production of the green colouring matter. The gránules are at first formed within those of the chloro-

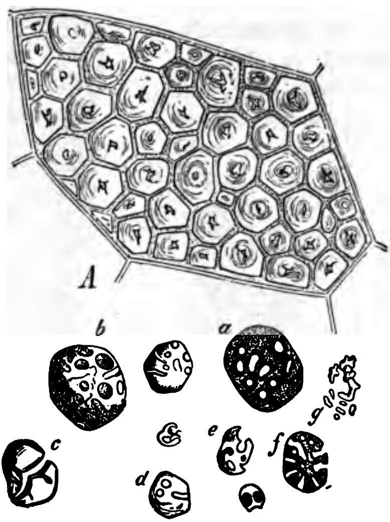


FIG. 10.—Cell of endosperm of *Zea Mais*, Maize. Thin plates of protoplasm separating the polygonal starch grains. *a–g*, Granules from germinating seed of Maize becoming dissolved and disintegrated. (After Sachs.)

phyll, then in the dark they are converted into soluble substances which are transferred to other parts of the plant, where they are again fixed as reserve food materials in the form of starch.

Cell Sap.—In the young cell the whole of the wall with the protoplasm and other contents is saturated with a watery fluid containing various mineral and other substances in solution. This constitutes the cell sap. As the cell increases in age this sap collects in drops (*vacuoli*), which gradually run together until the whole of the interior of the cell is filled with sap, presenting the appearance of being surrounded by two coats—viz. within, the layer of protoplasm; and without, the cell wall. This sap is most important, as it contains much of the food material of the plant.

Raphides or Crystals.—Very often some of the mineral substances contained in the sap become crystallised out, and make their appearance either within the cell or in the wall.

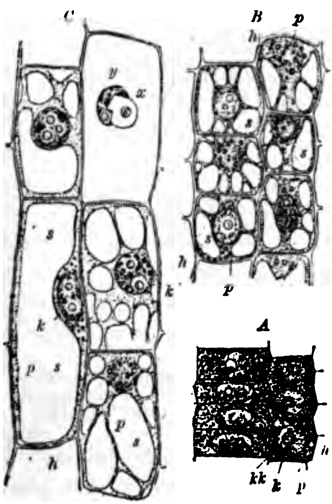


FIG. 11.—Cells from the root of *Fritillaria imperialis.* *A*, very young cell from near apex. *B*, from 2 mm. above the apex. *C*, from about 8 mm. above the apex: *h*, cell-wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleoli; *s*, vacuoles and cell-sap cavity. (After Sachs.)

FIG. 12.—Crystals of calcium oxalate in the cell wall. *Welwitschia mirabilis.* (After Sachs.)

In some plants the amount of these crystals is very great. In the Old-Man Cactus, as much as 80 per cent. of the dried tissue consists of them. Professor Bailey found in a square inch of Locust-bark no thicker than writing paper, as many as a million and a half of these crystals. The root of Turkey Rhubarb contains so many as to give a gritty character to it when chewed. As a rule the raphides are found in cells where there are no other granular con-

FIG. 13.—Cell from the stem of *Aloë retusa*, with raphides.

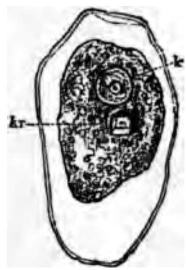


FIG. 14.—Crystalloid, *kr*, in a parenchymatous cell of the Potato-tuber; *k*, nucleus.

tents, but this is not universal. In chemical composition they consist of phosphate of lime, or more often of oxalate of lime. Carbonate or sulphate of lime is sometimes met with. In shape they are either cubical, octohedral, or needle-like (hence the name of *raphides*, from the Greek name for a needle).

Crystalloids.—In some cells, especially those of fatty seeds like the Brazil-nut, bodies are found which are crystal-like in appearance, but instead of being mineral in composition, consist of proteinaceous or nitrogenous material closely allied to protoplasm. They are insoluble in water, but break up in a peculiar manner so as to appear to be composed of several layers.

Aleurone Grains.—Are minute rounded grains found in the cells of many seeds just before ripening. They often contain crystalloids. They are soluble in caustic potash.

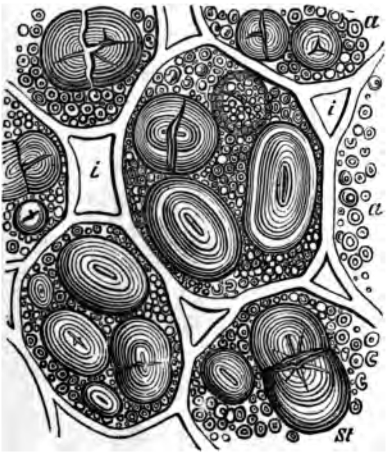


FIG. 15.—Cells of cotyledon of *Pisum sativum*, Pea. *St*, Starch granules with central hilum and concentric striæ ; *a*, granules of aleurone ; *i*, intercellular spaces. (After Sachs.)

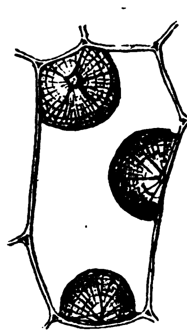


FIG. 16.—Sphere crystals of inuline in a parenchymatous cell from a tuber of the Dahlia preserved in alcohol, after addition of nitric acid.

They are often oily, and appear to be used as food reservoirs by the plant.

Inuline.—Is a peculiar substance found in the roots of Compositæ, and now and then in stems. It is very closely related to starch and sugar, and in the living plant is only found in solution in the sap ; but by the addition of alcohol or glycerine it separates out, either in a frothy condition or as beautiful spherical masses known as *sphere crystals.*

CHAPTER IV.

CELL GROWTH, SHAPE, FORMATION, AND TISSUES.

CELLS grow by the process of *intussusception.* This is a term which requires some amount of explanation. We must look upon the cell wall as consisting, not of a continuous homogeneous layer of cellulose, but of an immense number of isolated, minute, solid particles or molecules, which are comparatively speaking unalterable.

Between these it is supposed that water percolates so that each molecule is surrounded by a layer of liquid. The neighbouring molecules may vary in size, so that, if the aqueous envelope remains the same, larger molecules will form a denser, smaller, a less dense, substance.

This hypothesis (for it is but an hypothesis, as the molecules are too minute to be perceived even by the strongest lens) was first suggested by Nägeli, and it is supposed that these molecules are held in their places by three forces, viz.: 1. The *cohesion* of the particles of which each individual molecule is made up. 2. The *mutual attraction* which exists between the adjacent molecules and which gives them a tendency to approach one another. 3. The *attraction* of their surfaces *for* the *watery envelope* which counteracts this tendency.

When fresh food material is brought to the cell, the new molecules are intercalated between those already existing there, and thus they cause an increase in the size of the cell wall. Such a process of increase by means of intussusception is very characteristic of the growth of organic beings, and is totally different from the manner in which minerals increase in size. If a crystal say of alum be suspended in a *vessel containing* a strong solution of the same substance, it enlarges by a process of *accretion*, that is, a series of fresh layers form upon its exterior.

I. II. III.

FIG. 17.—I. Spherical cell from the flesh of the Peach. II. Ellipsoidal cell from the flesh of the Peach. III. Hour-glass-shaped cell from the flesh of the Peach.

Growth by intussusception often produces a change in the shape of the cell. The normal form is more or less spherical; this, however, is rarely preserved except in the case of unicellular plants. If the wall grows more vigorously at the two extremities than at the sides, the cell will become *oval* or *elliptical* (fig. 17), then *elongated* (fig. 19), and lastly *fusiform* or *spindle-shaped* (fig. 18).

I. II.

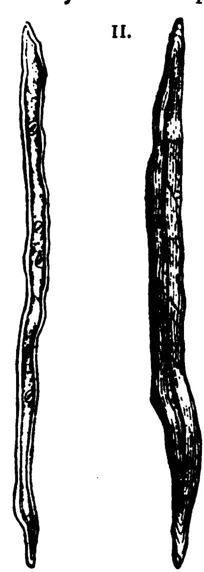


FIG. 18.—I. Fusiform cell from the wood of the Spruce Fir, with bordered pits. II. Fusiform bast-fibre of the Larch.

On the other hand, if a very vigorous growth takes place at certain parts whilst the rest of the cell wall is but slightly developed, several protuberances will be produced upon the surface, and a *stellate* or *star-shaped* cell is formed (fig. 20).

Another cause modifying the shape of individual cells is to be found in their mutual pressure the one upon the other

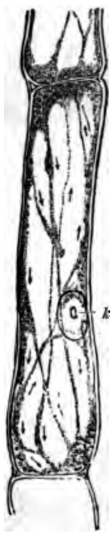


FIG. 19.—Circulation of protoplasm in an elongated cell of the Celandine: *k*, the nucleus with a nucleolus. The arrows indicate the direction of the currents.

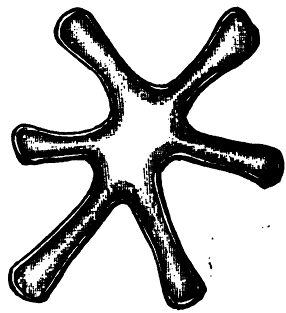


FIG. 20.—Stellate cell from the horizontal septum of the air-passages of the Flowering Rush (*Butomus umbellatus*).

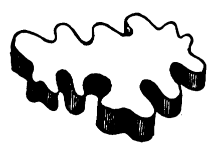


FIG. 21.—Tabular cell from the epidermis of *Callitriche*.

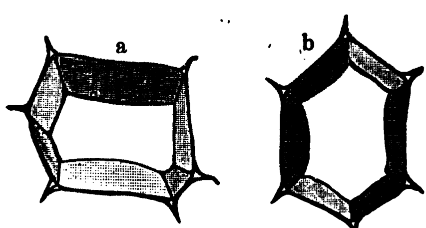


FIG. 22.—Polyhedral cell from the pith of *Acacia lophantha*; *a*, seen in transverse; *b*, in longitudinal section.

during growth. By this means they may become flattened or *tabular* (*fig.* 21), or polyhedral (fig. 22).

Other forms of cells are shown in figs. 23, 24, and 25.

At first the cell wall appears as a thin layer of cellulose perfectly permeable to liquids. In some cells but little

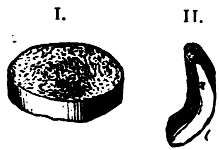


Fig. 23.—I. Disc-shaped cell: a unicellular Alga, *Coscinodiscus*. II. Crescent-shaped cell of a stoma (guard-cell).

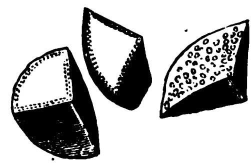


Fig. 24.—Tetrahedral cells: spore of a Fern in various positions.

thickening takes place during growth; in many others, however, very soon layers of secondary deposit are formed lining their interior surfaces. At first these layers are complete and continuous like the original coat, but soon they are

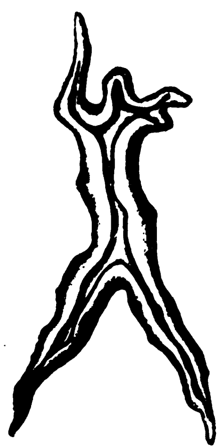


Fig. 25.—Branched bast-cell of the Larch.

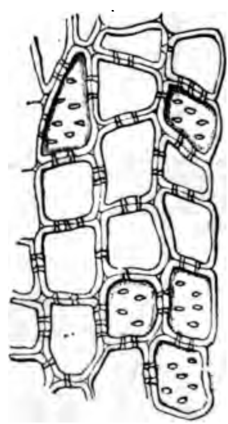


Fig. 26.—Moderately thickened pitted parenchyma from the pith of the Beech.

developed but slightly or not at all at certain points, thus causing perforations in their substance. As the holes thus produced in the contiguous layers correspond with one another, canals are gradually formed leading towards the centre of the cell cavity.

Such cells, when seen under a microscope transmit the

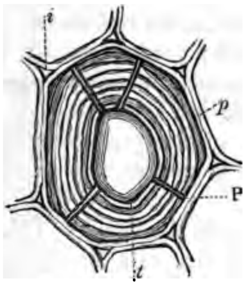


FIG. 27.—Transverse section of a cell of the pith of *Clematis vitalba* : *p*, primary cell-wall ; *t*, innermost thickening layer ; P, pore-canal ; *i*, intercellular space.

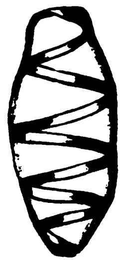


FIG. 28.—A spiral cell from a Cactus *Opuntia Tuna*, with strongly thickened spiral band.

light differently through their pore canals and through the thickened walls, and hence they present a pitted or dotted

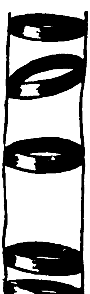


FIG. 29.—Annular cell from *Arundo donax*, with strongly thickened rings placed at different distances and different angles.

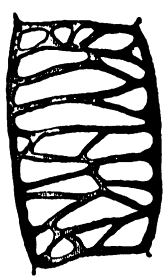


FIG. 30.—Reticulately thickened cell of the Touch-me-not (*Impatiens noli-me-tangere*).

appearance as though pierced by a number of holes (fig. 26). These cells are known as *pitted* or *dotted cells*.

In other cases the secondary deposit takes the form of a spiral band round the wall, thus producing a *spiral* cell (fig. 28). Or else it is deposited as separate rings, when an *annular* cell is formed (fig. 29). When the thickening is arranged in an irregular manner, producing a perfect network over the wall, the cell is said to be *reticulated.*

Very often there is in the cell a gradual passage from a spiral to an annular or reticulated marking (fig. 31). At other times there is a spiral or reticulate marking in addition to the pits or dots. Such cells as these are known as tracheïdes (fig. 32).

Fig. 33 shows another form of thickening known as *scalariform* or ladder-like. In this

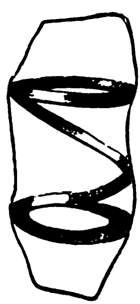


FIG. 31.—Annular cell from an *Opuntia* with rings passing over into a spiral band.

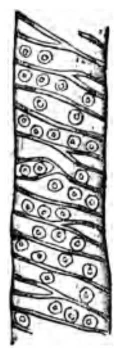


FIG. 32.—Piece of a reticulately pitted tracheïde from the Lime (*Tilia grandifolia*).

FIG. 33.—Scalariform cell from the underground stem of the Brake (*Pteris aquilina*).

case the secondary deposit is arranged in transverse layers like the rungs of a ladder. Such cells are well seen in the stems of Ferns.

A very important form of pitted cell is met with especially in the wood of the Fir trees and their allies. In these cases the pit is *funnel-shaped*, being wide on the outside and gradually tapering till it forms a tube or pore canal leading into the centre of the cell.

On examining these cells by means of a microscope, they present the appearance of a central pit surrounded by a border, and they are called *cells with bordered pits.* This appearance is caused by a varying amount of light being transmitted through the central pore which forms the pit, and the funnel-shaped upper portion which forms the border.

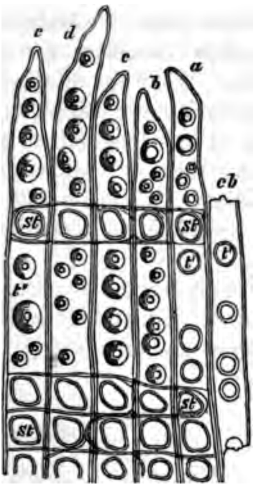


Fig. 34.—Longitudinal section of wood of *Pinus sylvestris.* Bordered pits, *t t' t''*, increasing in age; *a–e*, wood cells, *e* eldest, *a* youngest; *cb*, wood cell of cambium; *st*, large pits, where medullary rays touch wood cells. (After Sachs.)

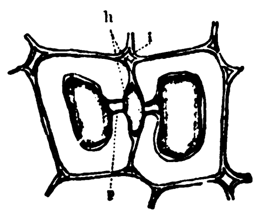


Fig. 35.—Two cells from the wood of the Scotch Fir in transverse section, each with a pore, *p*, widened at its base. By the disappearance of the original cell-wall the two widenings have united to form the 'border,' *h*; *i*, intercellular space.

Very often the cell wall between the two 'borders' becomes absorbed, in which case a complete passage is made between the two cells.

Besides these appearances due to secondary deposit, there is, especially in older cells, a striation or stratification of the cell wall, which appears to be due to the varying amount of water in the different parts of the wall.

Another important change in the history of the cell is the formation of *vessels* or cell fusion.

Vessels are formed by the union of several cells (vascular cells), the walls between them being either partially or entirely absorbed.

When several cells standing one over another have the walls separating them simply perforated in a sieve-like manner, *sieve tubes* or *bast vessels* are formed. These are found in various parts of plants, and contain nutritive materials necessary for the nourishment of the plant. When the disappearance of the separating walls is more complete, so that the cells form more or less long tubes, true vessels are produced, and these are known, according to the nature of their component cells, as pitted, spiral, annular, reticulate, or scalariform vessels

These true vessels usually possess a considerable quantity of secondary deposit, and are seldom branched. As a rule they contain nothing but

I.

II.

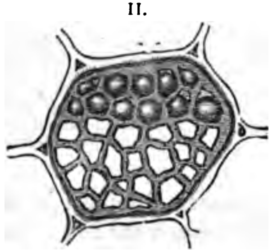


FIG. 36.—I. Sieve tube from the White Bryony (*Bryonia dioica*), the horizontal partition walls with peculiar thickenings. II. Transverse section of a sieve-disc, the upper part represented with the thickening substance, which *takes the form of wart-like* elevations; the *lower part without it.*

I. II.

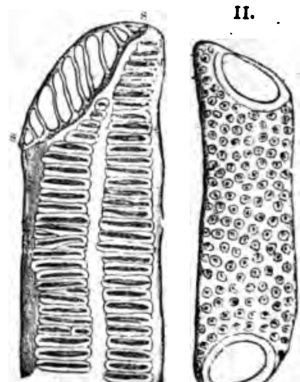


FIG. 37.—I. Portion of a scalariform vessel from the Brake (*Pteris aquilina*): *s*, *s*, the transverse division wall broken through in a reticulate manner. II. Pitted vascular cell from the stem of a Grass, *Phragmites communis*, with numerous small bordered pits.

air; but in the early spring, when the stem is gorged with sap, they are often partly filled with liquid.

Bast tubes or *bast fibres* are generally more pointed and sometimes branching (fig. 25). The coalescence between the component parts is so complete that the separate cells cannot be distinguished when the fibres are examined by means of the microscope. Bast fibres do not often com-

FIG. 38.—Fusiform bast fibre of the Larch.

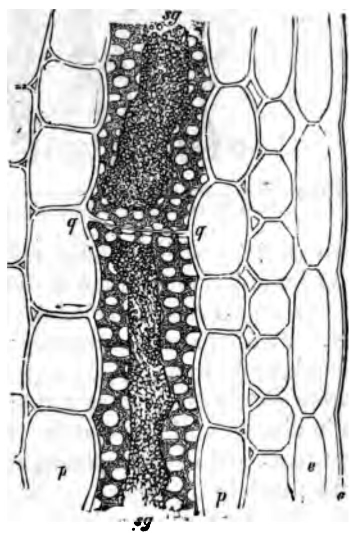


FIG. 39.—Vesicular vessel in longitudinal section of scale of bulb of Onion (*Allium Cepa*): *e*, epidermis with cuticle (*c*); *p*, parenchyma; *sg*, coagulated contents, contracted to show the porous walls. (After Sachs.)

municate directly with one another; when they do so it is by means of their lateral branches.

Very closely related to the sieve tubes mentioned above, especially in containing like them nutrient fluids, are *vesicular vessels* and *laticiferous vessels*. The former consist of elongated cells containing a milky juice and bundles of needle-shaped crystals.

Laticiferous vessels are tubes more or less branching, often forming a complete network, and containing a fluid

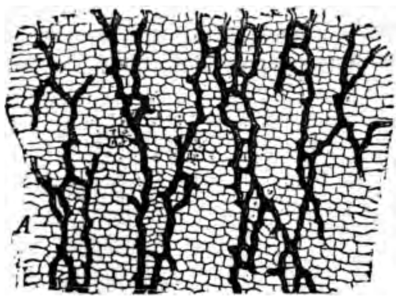


FIG. 40.—Transverse section of phloëm of root of *Scorzonera hispanica*, showing branching and anastomosing laticiferous vessels.

known as *latex*, which is often milky, sometimes coloured, and varies in its composition in different plants.

Cells do not grow indefinitely; the size of the adult cell varies. *Prosenchymatous cells* vary from $\frac{1}{40}$ to $\frac{1}{12}$ of an inch in length, and from $\frac{1}{1500}$ to $\frac{1}{3000}$ of an inch in diameter. *Parenchymatous cells* vary as a rule from $\frac{1}{250}$ to $\frac{1}{1200}$ of an inch in diameter, whilst some in the pith of plants, in succulent parts, and in water plants, are as much as $\frac{1}{50}$ or even $\frac{1}{30}$ of an inch in diameter.

As the plant increases in size, fresh cells are produced, being formed out of those already existing. This process is known as *cell formation.* There are several modes by which this takes place, but in the formation of the vegetative cells of higher plants it is always by means of *cell division.* Vitally active cells always contain a portion of the protoplasm more or less distinctly separated from the general mass, known as the nucleus, and which often contains small granules or nucleoli. When cell division is about to take place, two nuclei are formed either by the division of the original one, or by its disappearance, and the formation of two fresh ones.

The whole mass of the protoplasm now aggregates around these nuclei, and a cell wall is formed between the masses thus produced, growing inwards from the circumference to the centre, thus dividing the mother cell into two daughter cells, each of which may grow to the size of the mother cell, and itself undergo division. The formation of reproductive cells we shall have to notice later on.

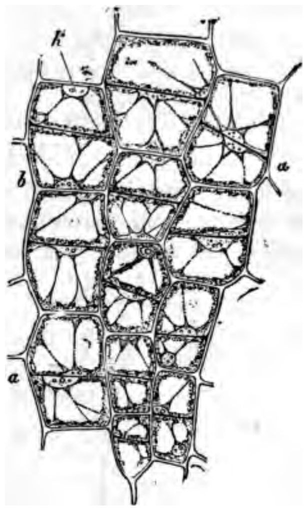


FIG. 41. — Cells of stem of *Vicia Faba.* Meristem cells in process of division: *k*, nucleus; dividing, *a*; fully divided, *b*. (After Prantl.)

Except in a few cases, cells do not remain through life individually separate, but are united together to form 'tissues.' These may be grouped according to either their *function* or their *structure.* Under the former method of division we have two kinds, viz. *meristem*, which is a tissue where the cells remain vitally active and capable of division, and *permanent tissue*, where the cells are no longer able to divide. If we arrange them according to their structure, we distinguish those tissues which consist of elongated cells overlapping one another, and which are known as *prosenchyma*, and those which are formed of shorter cells placed end to end, or *parenchyma.* These two forms of tissues, however, pass the one into the other by endless gradations.

Sometimes the term *sclerenchyma* is used to denote either prosenchymatous or parenchymatous tissues, where the walls of the cells have become very thick and hard, and often dark coloured.

CHAPTER V.

GERMINATION, ROOT GROWTH, STRUCTURE, AND FUNCTIONS.

IF a living seed be placed in the soil and be supplied with moisture and warmth, and exposed to fresh air, germination will ensue. The range of temperature between

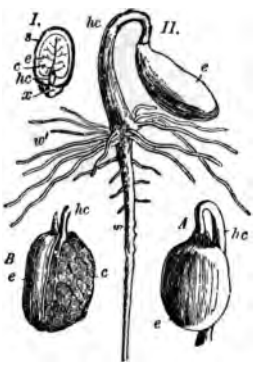


FIG. 42.—*Ricinus communis.* *I*, longitudinal section of ripe seed. *II*, germinating seed, the cotyledons still within the spermoderm, shown more distinctly in *A* and *B*: *s*, spermoderm; *e*, endosperm; *c*, cotyledon; *hc*, hypocotyledonary portion of axis; *w*, primary root; *w'*, lateral rootlets; *x*, the caruncle (or aril), a peculiar appendage to the seeds of *Euphorbiaceæ*. (After Sachs.)

FIG. 43.—Germinating seed of cabbage: *b*, axis; *c*, *d*, the two cotyledons which have risen above the soil, the testa *a* not being yet completely thrown off.

which this is possible varies with different plants, but it may be stated generally as being between 5° or 6° C. and 40° C.

Either the roots at once lengthen and grow out through *the micropyle, or,* which is more often the case, the lower part of the cotyledon, known as the *hypocotyledonary* portion of the stem, becomes elongated, pushing the end of the root before it out of the seed.

If we sow in some soil, specimens of the following seeds—Broad Bean, Acorn, Cress, Cabbage, Castor Oil, Pine, Date, and Wheat—and watch the germination as it takes place, we shall find that there is a great difference with regard to the growth and development of the cotyledon during the process.

In *exalbuminous* seeds, where the cotyledons are thick and fleshy, as in the Bean (fig. 1) and Acorn, they remain within the seed during germination, finally perishing after the food-material contained in them has been used up for the growth of the embryo. In the case of the Cress and Cabbage we have an *exalbuminous* seed where the cotyledons are thin, and here they rise out of the soil to form the first leaves, carrying the testa with them (fig. 43). The Castor-oil plant has an *albuminous* seed; in this case the cotyledons are not liberated until after the *endosperm* has been all absorbed (fig. 42). In the case of the Pine we have an analogous growth (fig. 44), the cotyledons (which are numerous) appearing above ground after the absorption of the albumen, the peculiarity here being the development of *chlorophyll* in the cotyledons before they rise above the surface. All these are *dicotyledonous* seeds. The remaining two illustrate the germination of *monocotyledons*. In the Date Palm (fig. 45), the lower part of the cotyledon lengthens, pushing the root and plumule out of the seed, whilst the rest of it remains in contact with the albumen absorbing it.

In the Wheat (fig. 46), the cotyledon is developed to form a plate where it is in contact with the endosperm, and is known as the *scutellum*. This serves the purpose of absorbing the albumen. In this case there is at once a growth of the root causing a rupture of the sheath surrounding it, which remains attached to the axis forming the *coleorhiza* (fig. 47). In some few monocotyledonous plants where there are exalbuminous seeds (as in the natural orders Naiadaceæ, Alismaceæ, etc.), the cotyledon

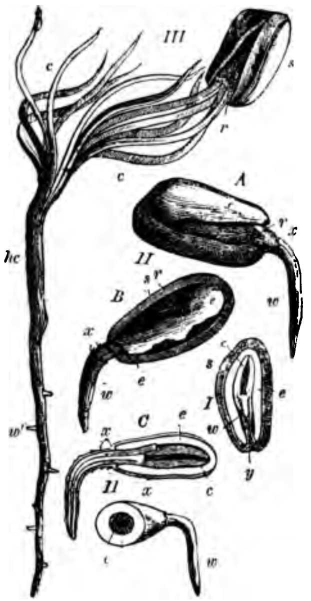


FIG. 44.—Seeds of *Pinus Pinea* in different stages of germination. *I*, ripe seed in longitudinal section: *s*, spermoderm; *e*, endosperm; *w*, radicle of embryo; *c*, the cotyledons; *y*, the micropyle end of seed, with the rootlet directed towards it. *II*, germination commencing, *A*; spermoderm, *s*, ruptured, and rootlet, *w*, protruding; *r*, red membrane inside spermoderm; *x*, ruptured embryo sac; *B*, portion of spermoderm removed; *e*, endosperm; *C*, longitudinal section; *c*, cotyledons; *D*, transverse section. *III*, germination complete, the cotyledons, *c*, unfolding, and the hypocotyledonary part of stem, *hc*, elongated, the main root, *w*, developing lateral rootlets, *w'*. (After Sachs.)

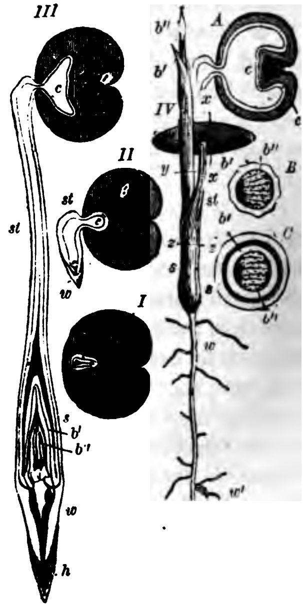


FIG. 45.—Germination of *Phœnix dactylifera*. *I*, transverse section of seed before germination. *II*, *III*, *IV*, different stages of germination. *A*, transverse section of seed at *x*, *x*, in *IV*; *B*, at *x y*; *C*, at *z z*. The following letters refer to all the figures: —*e*, endosperm; *s*, sheath of cotyledon; *st*, its stalk; *c*, apex, forming an organ of absorption by which the endosperm is entirely removed, the growing end ocupying the place of the absorbed endosperm; *w*, primary root; *w'*, secondary root; *b'*, *b*, leaves succeeding the cotyledon; *b''*, the first foliage leaf; *h*, pileorhiza. In *B*, *C*, the folded lamina is seen cut across. (After Sachs.)

is freed from the integuments, and is raised up through the soil.

When the cotyledons remain beneath the soil they are said to be *hypogeal*, when they rise above *epigeal*.

There is also a great difference between dicotyledons and monocotyledons with regard to the formation of the young root. In dicotyledons the radicle is directly prolonged, and no branching takes place until after the young root has left

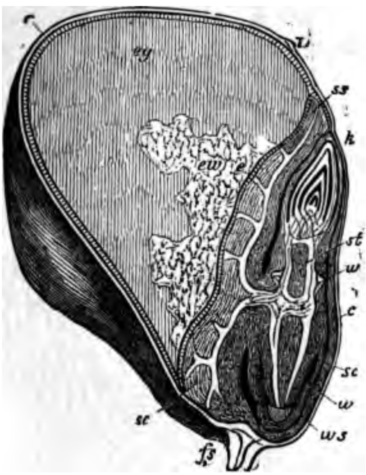


FIG. 46.—Longitudinal section of fruit of *Zea Mais*. *c*, pericarp; *n*, remains of the stigma; *fs*, base of the fruit; *eg*, hard yellowish part of endosperm; *ew*, white softer portion of endosperm; *sc*, scutellum (cotyledon) of embryo; *ss*, its apex; *e*, its epidermis; *k*, plumule; *w* (below), the main root; *ws*, sheath covering main root; *w* (above), lateral rootlets springing from the first internode of the stem, *st*. (After Sachs.)

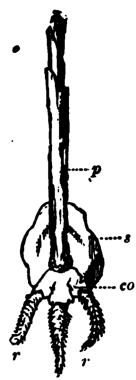


FIG. 47.—Germinating embryo of Oat (the endosperm removed). *p*, the plumule; *s*, the scutellum; *r*, *r*, the rootlets; *co*, the coleorhiza.

the seed (fig. 48), so that the first root is a direct prolongation of the radicle, and is known as a *normal* root. Such a mode of root development is called *exorhizal*. In monocotyledons, on the other hand, there is a branching within the seed (fig. 47), and the radicle is not directly produced. Such roots are known as *adventitious*, and the growth is said to be *endorhizal*.

The term *adventitious* is applied to all roots which are not developed by the direct growth of the radicle, hence in dicotyledons adventitious roots may be developed later on

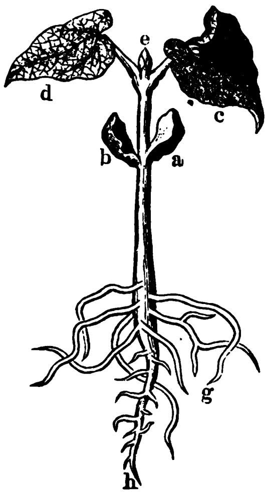


FIG. 48.—Germinating Bean : *a*, *b*, cotyledons ; *c*, *d*, leaves ; *e*, terminal bud ; *h*, primary root ; *g*, lateral roots.

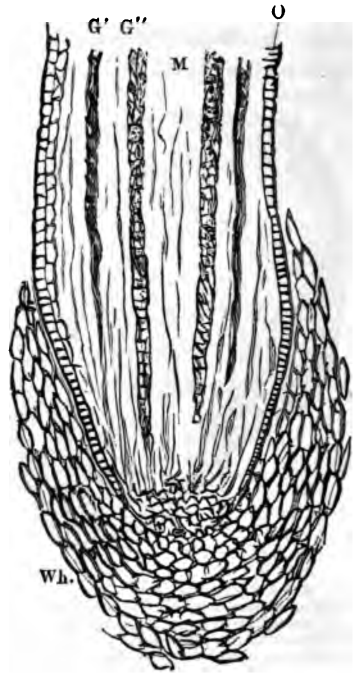


FIG. 49.—Longitudinal section through the apex of a root of *Aspidistra elatior* : *wh*, root-cap ; M, pith ; O, epidermis ; G′, narrow spiral vessels ; G″, broad reticulate vessels.

from various parts of the plants (as from stem, as seen in the Ivy, etc.), so that it is only the first-formed roots which are always normal in this group.

ROOT STRUCTURE.

Even whilst the radicle is within the seed a change of *shape and condition* has come over some of the cells, which, however, is more apparent after the young root has commenced to grow (fig. 49). The outer layer of cells become more or less flattened, forming a complete protective coat known as the *epidermis*. At the extremity the cells are thickened in such a manner as to produce what is known as the root-cap or *pileorhiza*, which is intended to protect the growing extremity of the root during its prolongation. Just behind the root-cap there is a mass of meristem tissue, which forms the growing point of the root. This by the constant subdivision of its cells produces on its outer sides additions

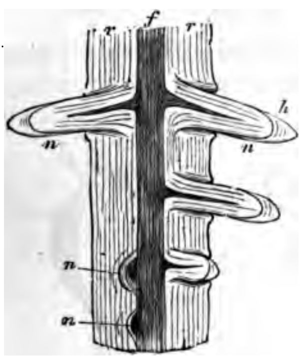


Fig. 50.—Longitudinal section of main root of *Vicia Faba*. *r*, *r*, cortex of main root ; *f*, fibro-vascular bundles ; *n*, *n*, lateral rootlets developing from pericambium, and breaking through cortical tissue ; *h*, pileorhiza of side rootlets. (After Prantl.)

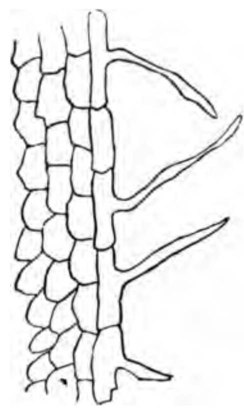


Fig. 51.—Epidermis of root with hairs.

to the root-cap, thus making up for portions that have become worn off by the growth of the root, whilst on its inner side it forms fresh tissue, thus causing the root to increase in length. Roots, then, increase in length only by growth near the apex. The upper part of the root is made up of permanent tissue, consisting principally of a mass of parenchymatous cells forming the ground tissue, and in this there are developed, more or less completely, bundles of prosenchymatous cells and vessels, forming what are known as fibro-vascular bundles, running from the base of the root towards the apex.

On their exterior there is often meristem produced, forming a layer called *pericambium*, and from which the branches are developed.

These latter commence as outgrowths from the pericambium and push their way through the adjacent tissue, repeating the structure of the original root (fig. 50).

The cells of the epidermis often possess prolongations or hairs (*trichomes*), which tend to increase the amount of surface in contact with the soil (fig. 51).

FORMS OF ROOTS.

There are certain terms which are used in the description of the form of the root. When it is broad at its base and tapers

FIG. 52.—Fusiform root of the Carrot.

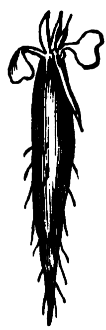


FIG. 53.—Fusiform root of the Radish.

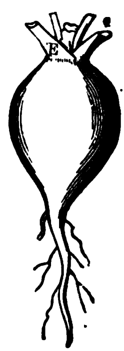


FIG. 54.—Napiform root of the Radish.

towards the apex, as in the Carrot (fig. 52) or Monkshood, it is *conical.* When it is broadest in the centre and tapers towards the two ends, as in the Radish (fig. 53), it is *fusiform*, or spindle-shaped. When it has become somewhat globular with a tapering extremity, as in the Turnip (fig. 54), or some varieties of Radish, it is said to be *napiform*; whilst the term *placentiform* is applied to it if the tapering apex be absent, as in the Sow-bread. If a number of slender branches be given off, as in the Grass (fig. 55), the root is *fibrous*. When some of these fibres become swollen in an

FIG. 55.—Fibrous root of a Grass.

FIG. 56.—Double tuber, *a*, *b*, of *Orchis Morio*.

egg-shaped manner, as in *Orchis Morio* (fig. 56), the term *tuberculated* is employed; whilst if the tuber is divided so

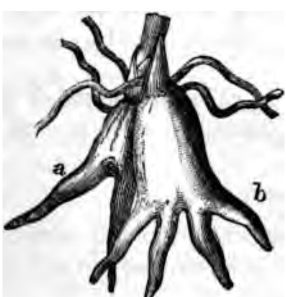


FIG. 57.—Double palmate tuber, *a*, *b*, of *Orchis odoratissima*.

FIG. 58.—Tuberous fasciculated root of the Dahlia.

as somewhat to resemble the fingers of a hand outstretched, as in *Orchis odoratissima* (fig. 57), it is called *palmate*.

The term *fasciculated*, or tufted, is used where there are a number of tubercules or fleshy branches arranged in a bunch, as in the Dahlia (fig. 58).

When the fibres are enlarged only at their extremities, as in the Dropwort (fig. 59), the root is *nodulose* or knotted;

FIG. 59.—Nodulose root of *Spiræa filipendula.*

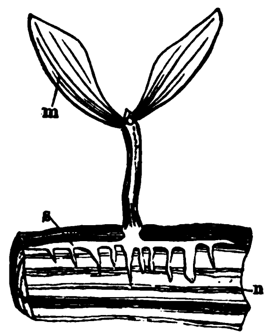


FIG. 60.—*n*, a piece of branch of an Apple tree cut through lengthwise, into which a young Mistletoe plant, *m*, has driven its sucking roots, *s*.

whilst if there be several swellings arranged like beads on a necklace, as in *Pelargonium triste*, it is said to be *moniliform*, or necklace-shaped.

In Ipecacuanha the root is called *annulated*, it being marked with several ring-like expansions upon its surface.

ROOT FUNCTIONS.

1. The root is a great organ of support, tending to hold the plant fixed in the soil or other situation in which it may be growing.

2. It is an organ for the absorption of food.

This raises three questions, viz.: the source of the food, the nature of the food, and the manner of its introduction into the plant.

A. *The source of the food.*—The roots, as a rule, enter the ground, and hence receive the plant-nourishment from that source. In the case of some aerial plants the roots absorb the food with the moisture present in the air, whilst in the case of many parasites, as the Mistletoe (fig. 60), the sucking roots penetrate into the stem of the plant upon which it grows, thus obtaining their nourishment second-hand.

B. *Nature of the food.*—A chemical analysis of the substance of a plant shows it to be composed of the following elements :—

Carbon, C.	Phosphorus, P.	Potassium, K.
Hydrogen, H.	(Silicon, Si.)	Calcium, Ca.
Oxygen, O.	(Chlorine, Cl.)	Magnesium, Mg.
Nitrogen, N.		Iron, Fe.
Sulphur, S.		(Sodium, Na.)

The five placed in the first column are sometimes called the organic elements, as they are required for the building up of the protoplasm and cellulose. Those placed in brackets are not so necessary or so universally met with as the rest.

Since then the plant body is built up of these elements it is evident that they must enter into the composition of its food. They are not, however, absorbed in their elementary condition, being obtained from various compounds which contain them.

Carbon is obtained by green plants from carbon dioxide, called also carbonic anhydride, and formerly known as carbonic acid gas, CO_2, a gaseous compound of carbon and oxygen ; perhaps partly by means of the roots ; but especially, as we shall see later on, through the pores of the leaves, these pores performing the part of both lungs and mouths for the plant. Carbon is one of the most important substances present, building up portions of all the plant-tissues, and usually *forming one-half of* the dried plant by weight.

Hydrogen, another element present in every organic compound, is obtained from water, H_2O, which is taken up in large quantities by the roots, and also from ammonia, NH_3.

Oxygen.—The sources of this element are to some extent the two compounds H_2O and CO_2 already noted, and also the various oxygen salts of the metals, such as sulphates, phosphates, nitrates, &c. Besides this, the free oxygen of the atmosphere enters the plant, combining with the tissues, as we shall have to notice further on under the head of respiration.

Nitrogen, which is an essential element of protoplasm, the albuminoids, and allied bodies, is obtained from ammonia, NH_3, and nitric acid, HNO_3, which latter, with the metals, forms the salts known as nitrates. It must be borne in mind that, although nitrogen exists to a very large extent in the air in a free or uncombined state, yet that plants are only able to absorb it from its compounds.

Sulphur is taken up as sulphates, that is, salts of sulphuric acid H_2SO_4; probably chiefly calcium sulphate or gypsum, $CaSO_4$. This element also is required for the protoplasm and albuminoids.

Phosphorus is obtained from phosphates, principally calcium phosphate, $Ca_3 2PO_4$.

Silicon is taken in as silica, SiO_2, which is often largely present in the soil; whilst the sources of *chlorine* are the chlorides of the various metals, especially of sodium, the chloride of which is common salt. The metals mentioned above are all obtained as salts combined with the acids we have noticed.

c. *Method of introduction of the food substances into the plant.*

Before any food can be absorbed it is necessary for it to *be in a state of solution.* The water present in the soil dissolves up the various food materials, and thus brings them into a fit state to be taken.

The outside surface of the root is entire, not perforated by holes, hence the solution of food has to be absorbed into the cells of the plant itself. This is accomplished by means of the process of *osmosis*. If two liquids be separated by a membrane permeable to both, they will flow through it and intermingle.

This can be very easily demonstrated by means of a simple experiment. If a vessel be closed below by a piece of bladder, whilst a tube be tightly fastened in the neck (fig. 61), and if a concentrated solution of cupric sulphate be placed in the vessel so that it stands a short way up the tube, and then the whole apparatus be plunged into a vessel of water as shown in the diagram, the two liquids will interchange, some of the cupric sulphate passing through the bladder into the outer water, whilst some of the latter enters the vessel. The two liquids do not, however, flow with equal rapidity. The law in all such cases is that the denser liquid flows more slowly than the less concentrated. As a result more water will enter the vessel than copper solution will leave, and therefore the liquid will rise in the glass tube. The passage inwards is called *endosmose*, whilst that outwards is termed *exosmose*. Sugar syrup may be used in the above experiment instead of cupric sulphate.

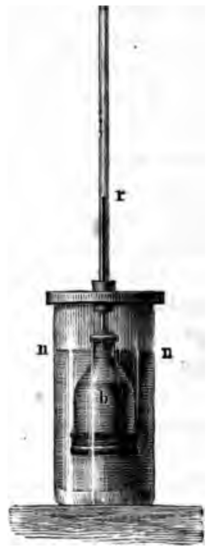


FIG. 61.—Apparatus for measuring osmose: *b*, a vessel filled with cupric sulphate closed below by a permeable membrane, and placed in a vessel of water. As the water passes through the bladder to mingle with the cupric sulphate, the level of the fluid will rise in the tube *r* in connection with the vessel *b*, but will fall at *n*, in the outer vessel.

Let us apply this process to the root. Within the cells there is the sap, without there is the water with mineral salts *in solution; we have* here two liquids of different densities separated by a permeable membrane, the cell wall. As a consequence osmosis ensues, some of the external water passing into the cell, and some of the sap being excreted into the soil. As, however, the sap is much denser than the water without, the flow of this latter is more rapid. By the same means the food material thus absorbed is transferred up the root from cell to cell towards the stem. The sap is densest in the upper cells owing to the evaporation which is going on, and hence the flow is maintained. This passage of food takes place especially by means of the prosenchymatous cells or fibres, whilst absorption goes on most actively in those cells which are near the growing point and by means of the hairs.

The various food materials are not, however, taken up indiscriminately by the plants. It is found that if plants be grown in water containing equal amounts of the salts necessary for food, that the quantities removed are very different.

There is what is known as *selective power*, each plant removing from the soil those substances which are more especially necessary for its life, leaving other foods behind. Thus, leguminous plants remove especially lime salts; potatoes and turnips, compounds of potash; cereals and grasses, silica, and so on.

If the same plant be grown year after year in the same soil it gradually impoverishes the ground, whilst food materials needful for other plants will be accumulated. Hence is brought about what is known as rotation of crops, that is, growing a well-chosen selection of plants in succeeding years in the same soil. Thus one year there might be a crop of leguminous plants, to be followed the next year by cereals, and the third year by, say, potatoes, and thus the ground would be more evenly exhausted. At the same time various manures are employed to supply the place of the different materials removed from the soil.

3. It is also, as we have seen, an organ of excretion; *some of the sap, by* osmosis, passes out into the soil, whilst the food enters the root. This is most important, as the sap is found to possess, as a rule, an acid reaction (that is, it turns vegetable blues, such as litmus, red), and hence it aids the root by dissolving up some of the materials present in the soil. Many of these substances, which are very needful for the food of the plant, are insoluble in water, but the acid sap dissolves them readily.

This can be easily shown by means of an experiment. Take a piece of perfectly smooth marble and cover it with sand to the depth of about a quarter of an inch; sow in this some seeds of mustard or cress, and place in a position favourable for germination. When the young plants have grown for a short time, clear the whole off, and it will be found that the rootlets will have eaten their way into the marble, dissolving up the substance, and forming minute grooves where they had been.

This explains how it is that we sometimes see large trees with their roots sunk into the solid rock. They have sprung up in that position from seeds, and as the roots have grown the acid sap has gradually eaten a passage for them until they have attained their present firm condition. Added to this, the root exerts a mechanical force, splitting the rock in the direction of pre-existing grooves, and thus helping to form a passage for their growth. On the high road between Buxton and Longner, at a village called Sterndale, several large trees are close to the roadside, growing through immense blocks of limestone, which blocks have been split by the expansive force of the tree.

4. The preceding functions belong more or less to all roots; there is, however, a fourth, which is only occasionally seen. In some cases the root acts as a storehouse of food.

Let us take the case of a biennial plant, such as a Turnip. During the first year there are no flowers, but plenty of leaves. Food materials are absorbed and converted by means of the leaves into starch and other substances, which are stored up in the root, which latter becomes swollen. The next year the plant flowers and fruits, and this reserve of food is used up during the process, so that by the end of the second year the root has become shrivelled and fibrous.

CHAPTER VI.

DEVELOPMENT OF THE PLUMULE; FORMATION, STRUCTURE, AND FUNCTIONS OF THE STEM.

WHILST the radicle grows downwards to form the root of the plant, the plumule is elevated above the soil, and produces the stem, bearing leaves and other appendages.

Popularly the stem is looked upon as differing from the root in growing above the ground, but botanically there is a wider difference. Underground portions of many plants, as the Onion and Potato, which are generally called roots, are in reality stems.

The characters of stems as distinguished from roots are as follows :—

1. Their growing points are not covered with a root-cap, but are surrounded by young leaves (buds).

2. They have developed upon them appendages, variously modified, but which differ in structure from the stems themselves; whilst roots simply branch, the branches being repetitions of the structure of the original root.

3. Whilst, as we have seen, the branches of the root have their origin in the deep-seated layers of the pericambium (endogenous growth), the branches and appendages of stems take their rise from more superficial layers (exogenous growth).

If we make a transverse section across the young stem during the first year of its growth, we find that there is a great difference in the appearance it presents in the two great groups of Dicotyledons and Monocotyledons.

Fig. 62 shows the section of a portion of a young dicotyledonous stem. On the exterior there is an epidermis of flattened cells.

At first this is like the epidermis of the root, consisting of a number of similar cells, always completely in contact; but after a while some of these become separated from one

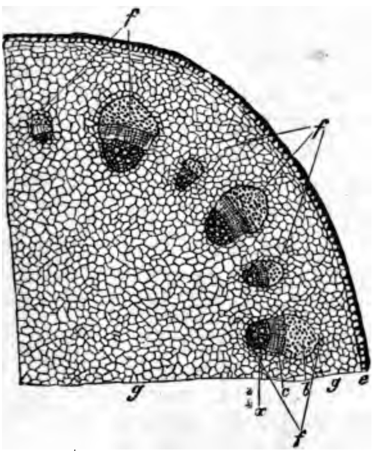


FIG. 62.—Transverse section of petiole of *Helleborus*, showing the three systems of tissues: *e*, epidermal; *f*, fibro-vascular; *x*, xylem; *c*, *b*, phloëm—*c*, soft bast; *b*, bast fibres; *g*, ground or fundamental tissue. (After Prantl.)

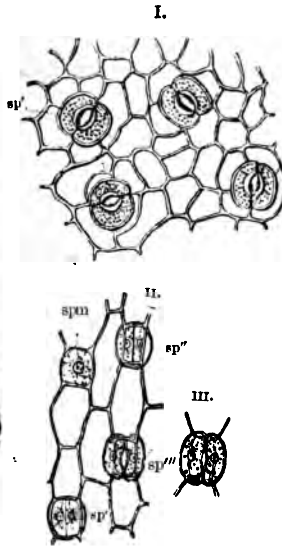


FIG. 63.—I. Horizontal section through the epidermis of the under side of the leaf of *Euonymus japonicus*, looked at from below: *sp*, stomata. II. Course of development of the stoma of *Arthropodium cirrhatum*: *spm*, mother cell ready for division; *sp'*, *sp''*, *sp'''*, successive stages of division. III. Mature stoma.

another, leaving an opening or *stoma* (plural, *stomata*) between them (fig. 63).

These stomata are always surrounded by two or four cells which are generally smaller than the epidermal cells, are crescent-shaped, and contain chlorophyll. These are *known as stomatal* or *guard cells.*

More towards the interior of the stem there are developed some bundles of cells (fig. 62). At first these bundles consist of meristem tissue, known as ***procambium***, forming a string of similar and growing cells. Very soon, however, the greater part of this passes into the form of permanent tissue, which is separated into an outer or ***phloëm***

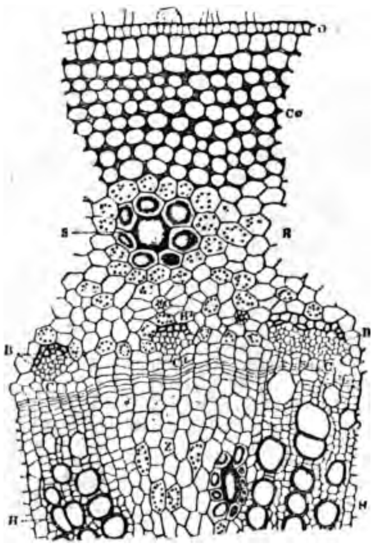


FIG. 64.—Transverse section through a young internode of ***Bœhmeria argentea***: O, epidermis; CO, outer cortex (collenchyma); R, inner cortex; S, intercellular space; C, cambium of the vascular bundle; C′, cambium of the thickening ring; B, bast portion; H, xylem portion of the vascular bundle; B′, the bast formed from the intermediate cambium; Z, medullary ray.

and an inner or *xylem* portion, leaving a band of meristem (*cambium*) between them (fig. 64).

The bundles, which now consist of fibres and vessels, with a few parenchymatous cells, are spoken of as fibro-vascular bundles. In many cases the fibres and vessels *become very much* hardened by the thickening of the *secondary deposit*, and the fibro-vascular bundles can then be easily separated from the surrounding portions of the stem. In other cases there is very little hardening in the bundles, and they cannot be thus separated.

The rest of the stem in its young state is made up of parenchymatous cells, forming what is known as *fundamental* or *ground tissue*, which is divided into three parts—a portion in the centre of the stem, the pith or *medulla*; a ring underlying the epidermis from which the *cortex* or bark is developed; and, lastly, masses of cells which separate the fibro-vascular bundles and unite these two portions, the *medullary rays*.

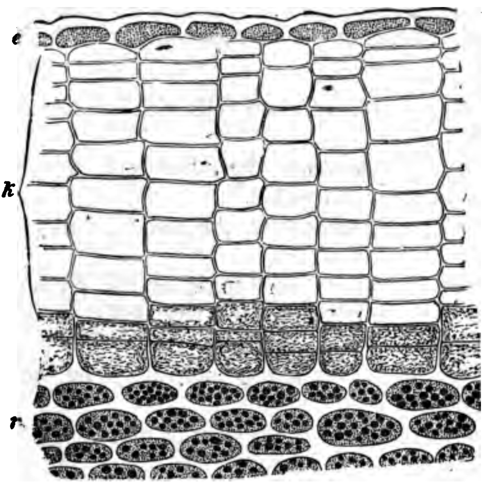


FIG. 65.—Transverse section of one-year-old stem of *Ailanthus glandulosus*: *e*, epidermis withered; *k*, cork cells, formed by the inner cells with protoplasm, the cork cambium or phellogen; *r*, inner green cells, the phelloderma. (After Prantl.)

The next change is in the cells which lie between the fibro-vascular bundles and the epidermis. Here are produced flattened cells filled with air, possessing flexible and elastic walls forming a close tissue without interspaces. These are *cork cells*. They are rarely (as in the Willow) developed from the epidermis itself; sometimes (as in the Poplar) from the cells immediately beneath it, more often from the more deeply lying cells.

On the inner side there is developed a ring of meristem, known as *phellogen* or cork cambium, whilst within this there is a layer of cells containing chlorophyll, the *phelloderma* or green layer. Sooner or later all the cells outside the cork tissue dry up and shrivel, forming the outermost layer of the bark.

The dicotyledonous stem now consists of the following parts :—

1. *A ring of epidermis* and cells with it becoming dried and dead.

2. *A ring of cork tissue*, the outer bark or epiphlœum, with the cork cambium within.

3. *A ring of phelloderma*, the middle bark or mesophlœum.

4. *A ring of phloëm*, interrupted by the passage of the medullary rays, and forming the bast, liber, inner bark or endophlœum.

5. *A ring of cambium*, also interrupted by the passage of the medullary rays.

6. *An interrupted ring* of xylem or wood.

7. *A central pith* or medulla.

8. *The medullary rays*, uniting the pith with the middle bark. (See fig. 64.)

In the monocotyledonous stem (fig. 66) there is quite a different arrangement. On the exterior there is no differentiated bark; within, no separation into pith and medullary rays; but a number of bundles of procambium scattered amongst the general ground or fundamental tissue. These bundles differ in their development as well as in their arrangement from those of the dicotyledonous stem. Instead of leaving a layer of vitally active cambium, they are entirely converted into xylem and phloëm:

Dicotyledonous bundles which contain cambium are spoken of as *open*, whilst those bundles which are destitute of this formative tissue, as those of monocotyledons, are known as closed.

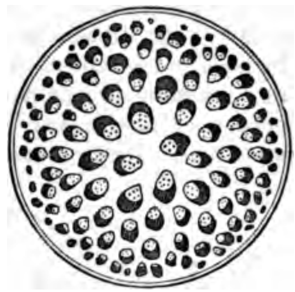


FIG. 66.—Diagrammatic representation of the distribution of the fibro-vascular bundles in the transverse section of a Palm stem.

We must now note a little more fully the structure and functions of the various parts of the dicotyledonous stem.

1. The *medulla* or *pith* consists entirely of parenchymatous cells, generally dodecahedral in shape, and it forms a cylindrical axis at or towards the centre of the stem. In the earlier stages the cells usually contain a little chlorophyll, and are filled with nutrient substances; later on they become dry and colourless, and filled with air, and no longer serve any purpose in the life of the plant, so that the stem may be hollowed, all the pith having disappeared, and yet the plant may be living vigorously.

The amount of pith varies much in different plants. In hard-wooded plants, as the Ebony, it is very small; whilst in soft-wooded plants, as the Elder, it is much larger. Again, we often find in many rapidly growing herbaceous plants, as the Hemlock, the pith not being able to keep up in growth with the other parts, has left the stem hollow, with a rugged attachment of pith at the sides, whilst in the Walnut and Jessamine it has become broken up into thin discs (*discoid* pith).

2 Surrounding the pith there is a layer of spiral vessels (the *medullary sheath*), which is in reality the commencement of the wood or xylem. The function of these vessels, as indeed of all true vessels, is to serve as air carriers. Like the wood, cambium, and liber, the medullary sheath is pierced by the medullary rays.

3. Outside the medullary sheath comes the xylem or wood, arranged in the form of concentric rings. These rings are formed as follows. During the first year the cambium cells by their division have caused the wood and liber to increase in thickness. During the winter the cambium remains dormant, but as soon as spring returns the cells once more become vitally active, and form a fresh ring of wood on its interior *outside* the old xylem, and a fresh ring

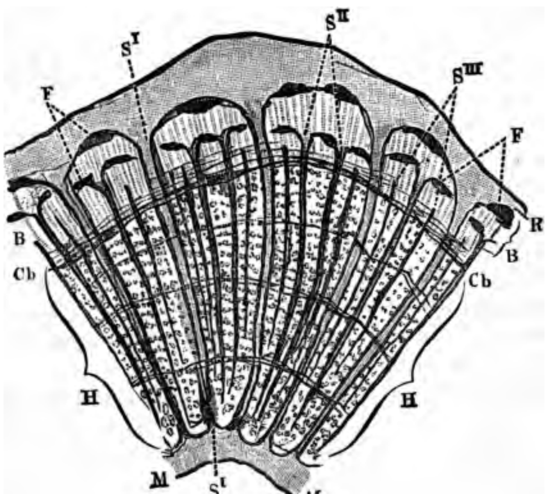


FIG. 67.—Portion of the transverse section through a shoot of Ivy four years old: R, cortex; B, bast bundles; H, wood, in which the four annual rings are distinctly visible; M, pith; s′, medullary rays; F, bast fibres; *cb*, cambium; s″, primary; s‴, secondary bundles.

of liber on its exterior *inside* the old phloëm. Thus year by year fresh rings of wood and liber are formed (fig. 67), the oldest wood being towards the centre of the tree, whilst the oldest bark is towards the exterior. Growth such as this is sometimes spoken of as *exogenous*, and dicotyledonous plants were formerly termed *exogens*. It is, however, only the wood which is exogenous in growth; the liber is endogenous.

As fresh rings of wood are as a rule formed every year, the age of a tree can generally be approximately ascertained by counting the number of the rings. The annual rings of various trees differ very much in the extent of their thickness, much depending not only on the nature of the plant itself, but also on its age and the atmospheric conditions of the climate. Also in the same plant the rings are not of equal thickness all round, so that the pith instead of being geometrically in the centre of the tree is generally more or less excentric.

When these wood rings are fully developed they consist of three elements, viz. :—

a. Wood fibres or wood prosenchyma.

b. Vessels, either spiral, annular, pitted, etc.

c. A variable quantity of wood parenchyma.

These three elements are variously arranged, and any one of them may be absent. Generally there is plenty of secondary deposit, so that the cells have become hard. The inner wood is, as we have seen, the oldest, and hence the hardest, and is often coloured by the secondary deposit having colouring matter. This is especially well seen in such wood as Ebony, Mahogany, Rosewood, etc. In other cases, as in the Poplar and Willow, the old wood is nearly as colourless as that of the exterior. This inner wood is known as the *duramen* or heart-wood.

The xylem on the exterior, which is younger, is permeated with sap, and is known as the *alburnum* or sap-wood.

The heart-wood is principally useful in supporting the plant, so that it may be absent as well as the pith without interfering with the vital activities of the tree.

In the sap-wood the vessels are air carriers, whilst the fibres are sap distributors carrying a current of sap from the root up towards the leaves.

4. Outside the xylem there is the interrupted ring of *cambium consisting* of prosenchymatous cells dormant

during the winter, and in full activity on the return of spring. After the first year cambium is formed between

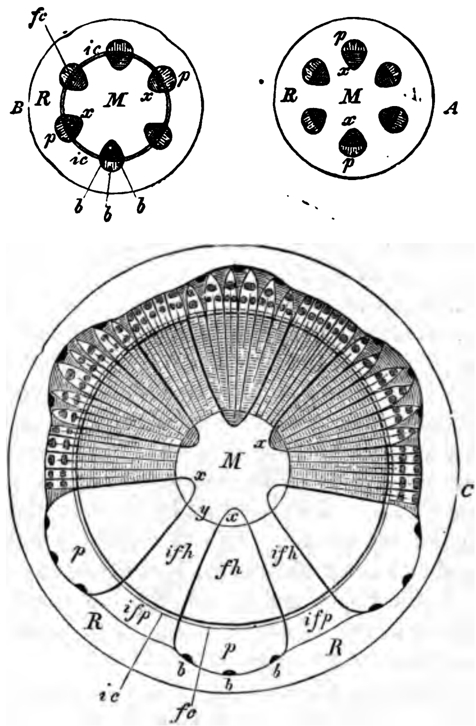


FIG. 68.—Diagrammatic view of the structure of a dicotyledonous stem with circumferential growth, as seen in transverse section. *A*—M, R, ground tissue forming pith (M) and cortex (R), the external ring representing the epidermis. Six fibro-vascular bundles separate,—*x* the xylem, and *p* the phloëm of each bundle. *B*—older stem: the bundles now united by cambium ring of fascicular (*fc*) and interfascicular (*ic*) cambium; *b*, *b*, the primary bast fibres of the phloëm. *C*—still older stem. By the activity of the cambium new wood and bast have been formed. *fh*, wood formed by fascicular cambium; *ifh*, wood formed by interfascicular cambium; *ifp*, interfascicular phloëm; *x*, *y*, medullary sheath. The shaded upper part shows medullary rays. (After Sachs.)

the fibro-vascular bundles (*interfascicular cambium*), thus *making the cambium* ring complete (see figs. 64 and 68, B).

By means of this interfascicular cambium, not only are the medullary rays lengthened as the stem increases in thickness, but also fresh phloëm and xylem are produced between the original bundles.

5. Outside the cambium there is the interrupted ring of phloëm, liber or inner bark. Like the wood this consists of three elements, viz. :—

a. The bast vessels or sieve tubes (fig. 36).

b. Bast fibres (fig. 38).

c. Bast parenchyma or soft bast.

The separate annual layers of the liber cannot, as a rule, be so readily distinguished as those of the wood, they being much thinner and compressed together by the growth in thickness of the tree. In some cases, however, the liber can be separated into thin plate-like layers.

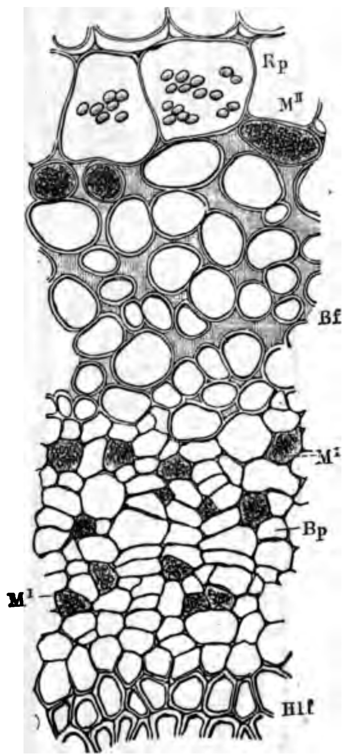


FIG. 69.—Part of a transverse section through the bast of the Wild Lettuce (*Lactuca scariola*): B*f*, bast fibres; B*p*, bast parenchyma; M'', outer, M', inner, laticiferous vessels; R*p*, cortical parenchyma; H*lf*, wood-fibres.

A good example of this is to be seen in the Lace-bark tree (*Lagetta lintearia*) of Jamaica, where the inner bark separates into thin sheets having the appearance of lace, the holes in it being the perforations for the passage of the medullary rays.

The fibres of the bast act as sap circulators bringing down the elaborated sap from the leaves.

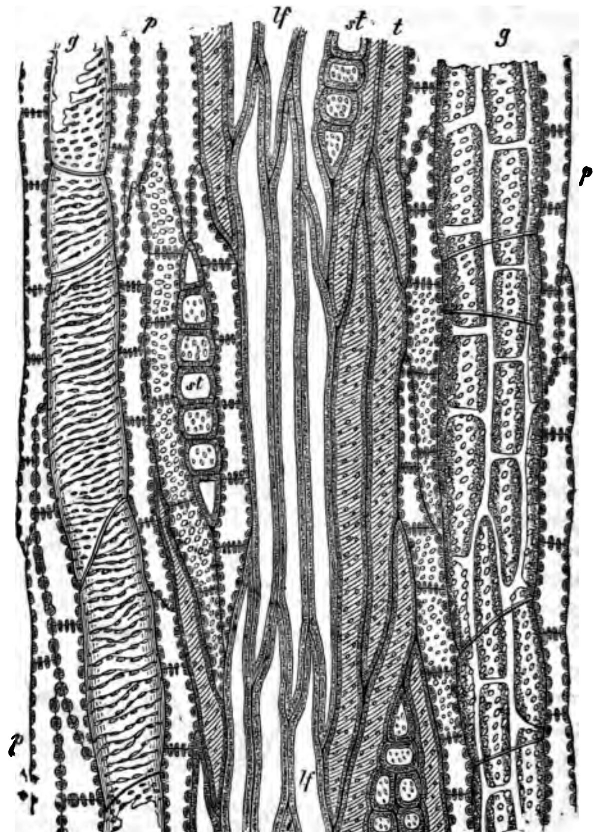


FIG. 70.—Longitudinal tangential section of stem of *Ailanthus*, showing secondary xylem of fibro-vascular bundles: *g*, *g*, wood vessels; *p*, wood parenchyma; *t*, *lf*, wood prosenchyma of two varieties; *t*, tracheïdes, with pitted and spiral markings, and *lf*, libriform or bast-like wood fibres; *st*, medullary rays cut across. (After Sachs.)

6. The *green layer*, or *phelloderm* consists of chloro-*phyll-containing* cells often intermixed with laticiferous *vessels.*

7. The *outer* or *cork layer* with its formative phellogen immediately beneath it. These two last layers form a protective coat to the exterior of the stem. After a short time the cells generally become dead, and very often peel off under the expanding influence of the growth of the stem.

This, as is seen in the Elm or Cork Oak, gives a rugged appearance to the bark. In other cases, as in the Beech, owing to its capability of distension, the bark presents a smooth appearance.

8. The *medullary rays* uniting the pith with the middle bark, and separating the fibro-vascular bundles. They are generally made up of flattened, six-sided cells, arranged like bricks in a wall (*muriform parenchyma*).

The rays are rarely continuous from the top to the bottom of the stem, being separated by the fibro-vascular bundles (*st*, fig. 70).

The medullary rays form what is known as the 'silver grain' of the cabinet makers. The use of the rays is to distribute the elaborated sap from the liber through the other parts of the stem.

STRUCTURE AND FUNCTIONS OF THE PARTS OF A MONOCOTYLEDONOUS STEM.

Even in their external form monocotyledonous stems present a different appearance to the dicotyledonous stems described. In this country we possess no indigenous monocotyledonous tree (the Butcher's Broom is the only indigenous shrub), but the exotic Palms (fig. 71), instead of having tapering stems like our forest trees, possess them of much the same diameter from top to bottom.

Within there is no separation into pith or bark. On the exterior there is an epidermis and a cortex, or false rind made up of the ends of the fibro-vascular bundles. These bundles enter the stem from the bases of the leaves being continuous with the bundles present in them. At first they are narrow. They grow inwards, and then pass

FIG. 71.—*Livistonia australis*, a Fan Palm.

down the interior of the stem, gradually increasing in diameter. At length, having attained their largest size, they begin to curve outward again, thinning as they do till they end at the exterior (fig. 72).

The bundles are closed, containing no cambium, hence after their formation they cannot increase in size. A section across the stem will show the younger bundles

FIG. 72.—Course of the vascular bundles of *Iris* in longitudinal section (diagrammatic).

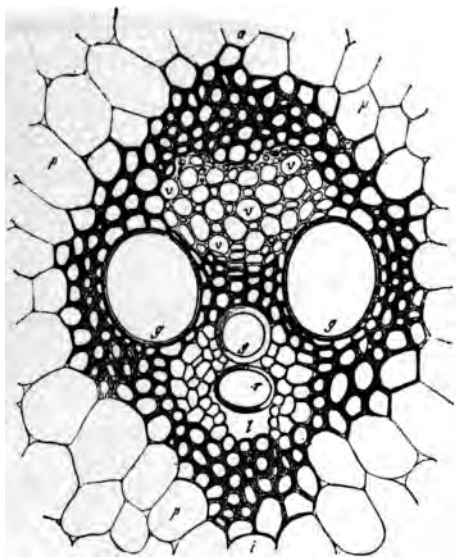


FIG. 73.—Transverse section of fibro-vascular bundle of *Zea Mais*: *p*, thin-walled parenchyma of ground tissue of, *a*, outer and, *i*, inner part of stem, with thick-walled prosenchymatous ground tissue internal to it; *g*, *g*, large pitted vessels; *s*, spiral vessel; *r*, isolated ring of annular vessel; *l*, air cavity; *v*, *v*, cambiform tissue or soft bast. (After Sachs.)

within and the older ones without. Such a mode of growth is often termed endogenous, but it must be borne in mind that is only at a part of their passage that this is true, as at the commencement and end they grow outwards.

In annual and herbaceous monocotyledons the ground *tissue is soft* and delicate; but in trees, as Palms, it is much hardened by secondary deposit, forming *woody parenchyma.*

It follows from this structure that it is impossible for such a stem to increase in thickness after the outer rind has become thoroughly hardened.

In some Monocotyledons of the Lily tribe, as the Aloe

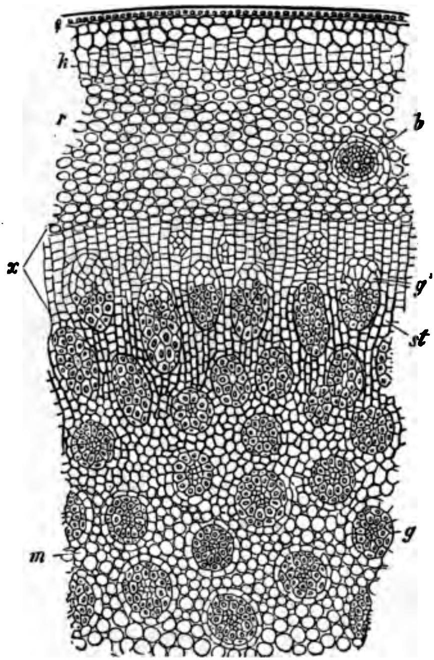


FIG. 74.—Transverse section of stem of *Dracæna*, near apex: *e*, epidermis; *k*, cork; *r*, cortical portion of ground tissue; *b*, fibro-vascular bundle to leaf; *m*, ground tissue of centre of stem; *g*, fibro-vascular bundles; *x*, meristem zone, developing new fibro-vascular bundles (*g'*) and new ground tissue (*st*). (After Sachs.)

and Dragon-tree (fig. 74), there is a provision for the exogenous formation of new bundles, but in a different manner to that which takes place in Dicotyledons.

A layer of meristem is formed in the outer part of the ground tissue, by means of which the stem is increased in thickness, and in which new fibro-vascular bundles are formed.

In Monocotyledons the sap rises to the leaves through the xylem of the bundles and descends through the phloëm, and apparently partly by the parenchymatous tissue.

EXTERNAL FORMS OF STEMS.

A section of the stem usually shows it to be more or less cylindrical in shape; at other times it is angular, being either triangular, square, five-ribbed, etc. (fig. 75).

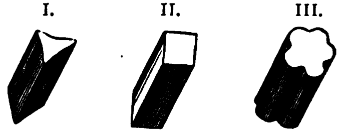


FIG. 75.—I. Section of triangular stem. II. Section of square stem. III. Section of five-ribbed stem.

When the stem is herbaceous, and dies down annually, it is called a *caulis*; when woody and perennial, a *trunk*; and when jointed, as in Grasses, a *culm*.

Generally stems are able to support themselves in an upright position, and are *erect*; if they trail on the ground they are *prostrate*; if, whilst thus reclining, they rise towards their extremities, they are *decumbent*; or if they gradually rise from near the base, *ascending*.

Some stems are *climbing*, attaching themselves to some object of support either by rootlets (as in the Ivy), or by tendrils (as in the Passion Flower and Sweet Pea). At other times they are *twining* around the object of support (as in the Bindweed and Hop, fig. 76).

There are certain terms which are applied to various forms of stems, some of which describe the aerial, or above ground, and others the subterranean stems.

1. *Aerial Stems.*

a. The Runner.—This is well seen in the Strawberry, where a branch springing from a plant creeps along the ground (often with a modified leaf or scale upon it), and

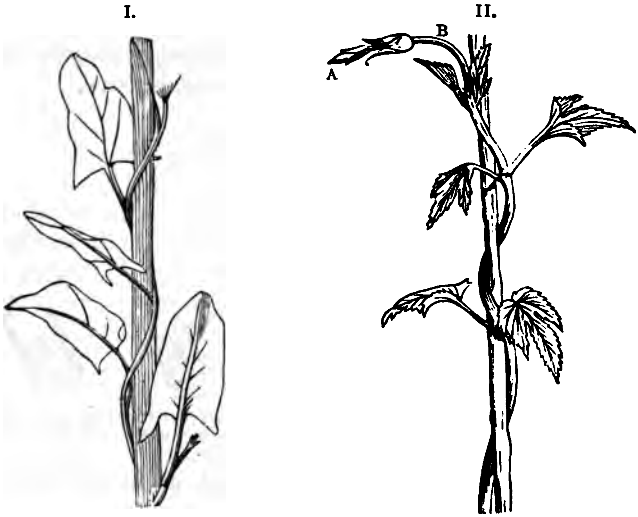


FIG. 76.—I. Stem of *Convolvulus arvensis* twining to the left. II. Stem of Hop twining to the right.

ultimately strikes in the soil, producing leaves and roots, and forming a new plant (fig. 77).

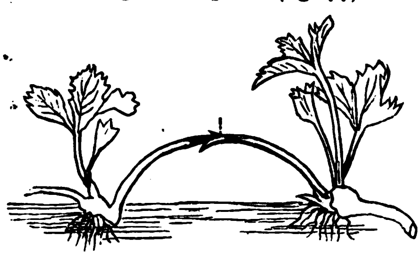


FIG. 77.—Runner of Strawberry (*Fragaria vesca*).

FIG. 78.—The offset of the House Leek (*Sempervivum*).

b. The offset, seen in the House Leek, much resembling *the runner, but* shorter and thicker (fig. 78).

c. The *stolon*, as in the Gooseberry and Currant, is really a branch given off above the ground striking into the earth and giving off roots and leaves, forming a fresh plant. This is often imitated by gardeners in the process of layering, when they bend down a branch into the soil, thus causing it to take root and produce a fresh plant.

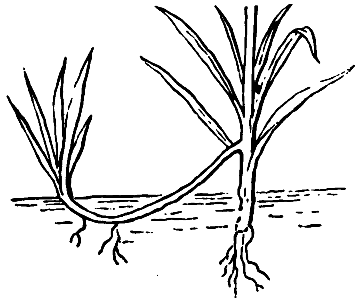


FIG. 79.—Stolon.

d. The Sucker.—This differs from the last in being a branch springing from beneath the soil, and after proceeding for a short time in a horizontal direction, giving off roots as it does so, turns up and grows out of the ground, forming a new plant. The Rose and Mint are examples.

FIG 80.—Sucker.

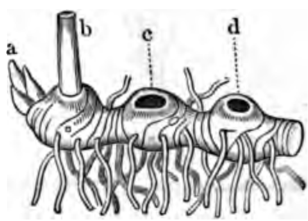


FIG. 81.—Rhizome of Solomon's Seal (*Convallaria Polygonatum*): *a*, terminal bud from which is developed the next year's stem; *b*, this year's stem; *c*, *d*, scars of the stems of previous years

2. *Subterranean Stems.*

e. The *rhizome* or *rootstock* is a thickened stem creeping either at the surface of the soil or just below it, giving off leaves from the upper surface, and roots from the lower. As the leaves fall off year by year, they leave scars marking where they had been. These, together with other subterranean stems, are popularly termed roots, but are distinguished from true roots in the manner already indicated. Examples are to be found in the Iris, Sweet Flag, Ginger, Solomon's Seal, etc.

f. The *soboles* or *creeping stem* is thinner than the rhizome, but otherwise resembles it. It is met with in the Sand Sedge and Couch Grass. In the former plant it is often

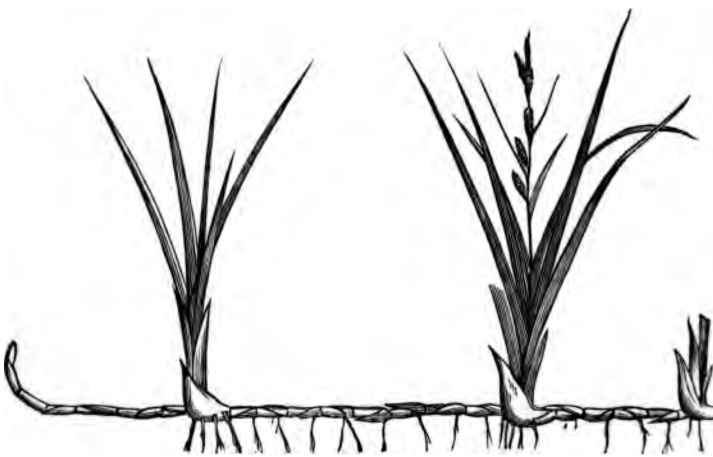


FIG. 82.—Creeping rhizome of *Carex*.

of great use in binding together the loose sands of the sea shore, whilst in the latter it is a pest to the farmer.

g. The *tuber* is an underground stem or branch, which is much swollen by the deposition of a large quantity of starch and other food materials. It possesses leaves which are more or less modified. In the Potato (which is a good example of the tuber) the eyes are the modified leaf buds. It is a well-known fact that if the aerial branches of a Potato plant be earthed, their growth will be arrested and tubers will be formed.

Other examples of tubers are to be seen in the Jerusalem Artichoke and in the Pig Nut.

The two following modifications of stem are only to be met with amongst monocotyledonous plants.

h. The *bulb* consists of a more or less flattened disc-like stem, giving off roots below, and scale-like leaves, together with stem and flowers, above.

The scale-like leaves have the power of developing in

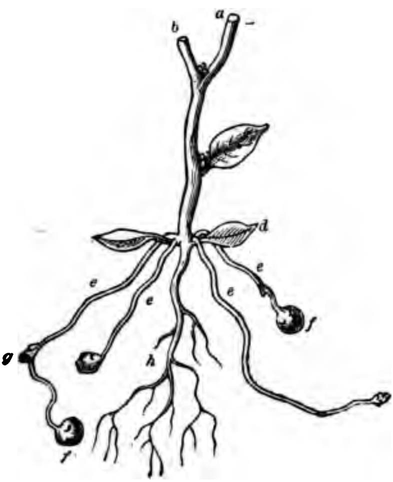


FIG. 83.—A six-weeks-old Potato plant, developed from the seed, the upper branches, *a*, *b*, being cut off: *d*, cotyledons; in the axils of the cotyledons are developed the underground branches, *e*, *e*, which penetrate into the ground and form tubers, *f*, *g*, at their apex or in the axils of small leaves. The tubers are formed only on the branches which are produced in the axils of the cotyledons, never on the true roots, *h*.

FIG. 84.—Single tuber of the Pig Nut (*Carum bulbocastanum*).

their axils smaller bulbs or buds known as *cloves* or *bulbils* (*a*, fig. 85). There are two forms of bulb. When the inner scales are fleshy, and are covered by thin membranous ones, the bulb is said to be *tunicated*, as in the Onion. If there be no outer tunic, as in the Lily, the bulb is said to be *scaly* or *naked* *i.* The *corm* differs from the bulb in being much more solid, consisting of a larger disc and fewer scale-leaves.

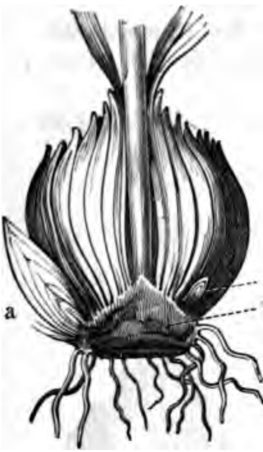


FIG. 85.—Scaly (squamose) bulb of the Onion: *b*, plate or disc; *a*, bulbils.

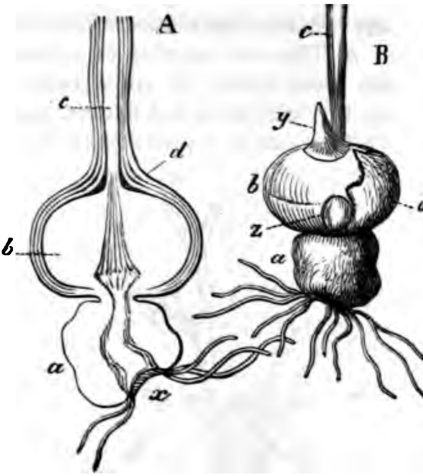


FIG. 86.—Corm of *Gladiolus segetum*. A, longitudinal section: *a*, last year's, *b*, this year's bulb; *c*, scape; *d*, scales; *x*, roots; B, after removal of the enveloping scales: *y*, bud, which will develop into next year's bud; *z*, bulbil.

Examples are to be met with in the Gladiolus, Snowdrop, Crocus, Colchicum, etc.

CHAPTER VII.

BUDS AND RAMIFICATION.

BRANCHES of the stem first make their appearance as ***buds***. These as a rule do not appear indiscriminately but at certain definite parts of the plant, viz., at the extremities of the *stem and branches*, when they are called ***terminal buds***; and *in the axils of the* leaves, that is to say, the angle formed between the leaf and the stem, when they are termed ***axillary buds.***

If they grow from any other part of the plant they are said to be ***adventitious.***

At first the bud consists entirely of parenchymatous tissue connected with the parenchyma of the stem. There

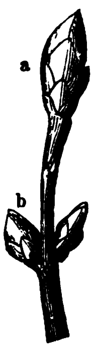


FIG. 87.—*a*, terminal bud; *b*, axillary bud, the leaf in the axil of which it was produced having been removed.

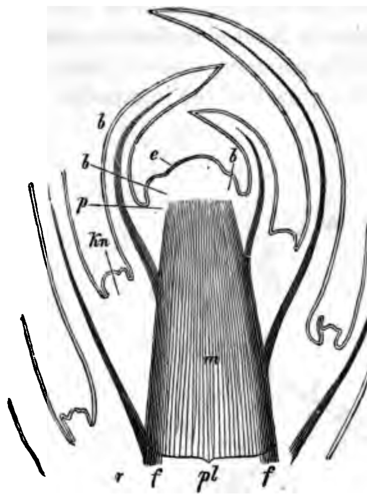


FIG. 88.—Diagram of a longitudinal section of the apex of the stem of a dicotyledonous plant: *m*, pith; *f*, fibro-vascular bundles, both developed from the pleurome (*pl*), the bundles sending branches to the leaves; *r*, cortical tissue; *e*, epidermis; *b*, *b*, young leaves, two showing their origin from protomeristem (*p*); *kn*, axillary bud. (After Prantl.)

is a central conical mass around which, after a while, vessels and wood cells are developed, outside these, parenchymatous tissue which forms bark, and which is covered with little scales of parenchyma variously overlapping one another, forming the rudimentary leaves.

The portions of the young stem to which these leaves are attached are known as ***nodes***, whilst the stem between the *nodes forms the* ***internodes.***

In cold and temperate climates, where the buds remain dormant during the winter, unfolding during the following spring, the outer surface is protected by modified scales, which sometimes, as in the Horsechestnut and Poplar, possess resinous secretions, and at other times, as in Willows, are covered with hairs. These scales protect the young bud from the cold and frosts of the winter, and fall off when it begins to develop in the following spring.

The commencement of the development of the bud is by the growth of the internodes by which the young leaves

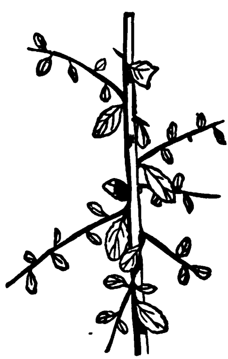


FIG. 89.—Branch spines of the Sloe (*Prunus spinosa*).

FIG. 90.—Prickles of the Rose.

become gradually separated from one another and the branch is formed.

If all the normal buds of the plant were developed, the branching would follow regularly the arrangement of the leaves.

This uniformity is often interfered with: 1st, by the non-development of buds; 2nd, by the formation of adventitious buds.

Sometimes many of the buds remain entirely undeveloped. At other times, instead of being developed into leaf-bearing branches, they form subsidiary organs.

1. *Spines* are often modified branches. They are met with in the Sloe or Blackthorn. At times they are small and destitute of leaves; often they bear leaves, and under cultivation they become developed into leaf-bearing branches. Thus, whilst the Sloe is spiny, the cultivated Plum bears only leafy branches.

There is a great difference between spines (as in the Sloe and Locust Tree) and prickles (as in the Rose and Bramble). In the former case the spines are modified branches, and as such are connected with the internal parts of the stem; in the latter case the prickles are simply hairs of the epidermis which have become hardened by the deposition of secondary deposit.

2. *Tendrils.*—Sometimes the buds become developed as tendrils or cirrhi, as in the Grape Vine, enabling the plant to hold on to the object of support.

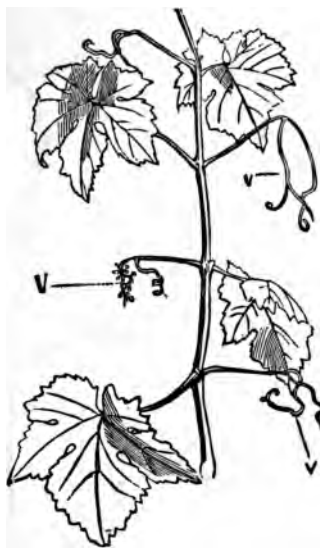


FIG. 91.—Stem tendrils of the Grape-vine: *v*, in the normal state; V, bearing a bunch of grapes.

Both spines and tendrils *may* be modifications of parts of leaves. The spines of the Barberry, and of some species of Acacia (fig. 126), and the tendrils of the Sweet Pea (fig. 92), are examples.

We can tell, however, which they are by their position. If they are in the axils of leaves they are modified branches; if upon the stem or forming part of the leaf they are modified leaves.

In some cases adventitious buds are formed beneath the *bark, and are not* developed externally. In such cases they produce considerable variations in the figure and grain of the wood. Bird's-eye Maple is a very good example of this.

Buds are often capable of being removed from one plant and made to grow upon another of the same family. Upon

FIG. 92.—Sweet Pea (*Lathyrus odoratus*).

this fact depend the important operations of ***grafting*** and ***budding***.

In grafting, a branch of a superior variety, possessing ***buds, is taken*** and implanted on a wild stock (fig. 93). The formative cambium round the wound grows, forming a protective succulent cushion of tissue known as a *callus* (fig. 94). The graft grows independently of the stock, receiving, however, its nourishment through it.

In budding, a bud, together with the surrounding bark, is removed from a superior variety, and a T-shaped incision

FIG. 93.—Grafting: *d*, the stock to which the graft is attached.

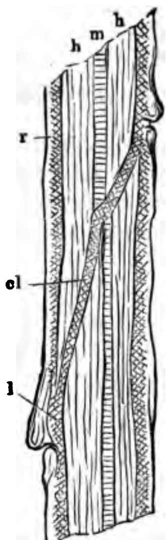


FIG. 94.—Diagrammatic representation of a longitudinal section through a graft: *cl*, the callus; *r*, bark; *m*, pith.

is made in the stock, beneath which the bark of the bud is inserted, the whole being bound round to protect it from the action of the atmosphere (fig. 95).

The bud grows in the same way as the graft.

The terms vernation and *præfoliation* are employed to express the way in which the young leaves are arranged in the bud. We have two things to notice, viz., 1st, the

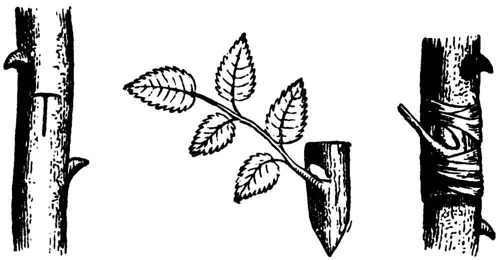


FIG. 95.—The various elements in the process of budding.

arrangement of each individual leaf; 2nd, the disposition of the several leaves in the bud.

1. *The arrangement of the separate leaves.*—In the buds of the Firs they are *flat.* In other cases they are variously

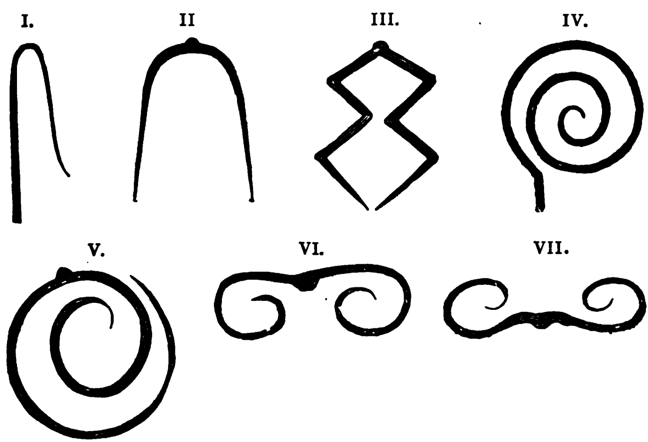


FIG. 96.—Various methods of leaf-folding in buds.

bent. If the apex approaches the base, as in the Tulip-tree *(fig. 96, I.), it is reclinate.* If the two edges meet together leaving the midrib in the centre, as in the Oak and Magnolia (II.), it is *conduplicate.* If each side be folded several times like a fan, as in the Ladies' Mantle, Beech, Sycamore, and Vine (III.), it is *plicate.* When the apex of the leaf is rolled up towards the base, as in the Sundews, Ferns, and Cycads (IV.), it is *circinate.* When the leaf is rolled on itself, one margin being rolled towards the midrib, and the other margin rolled over it, as in the Apricot and Banana (V.), the folding is *convolute.* When the two margins are rolled towards the midrib on the under side of the leaf, as in the Dock and Rosemary (VI.), it is *revolute.* When the margins are rolled in the opposite way, that is, towards the upper surface of the leaf, as in the Violet and Water Lily (VII.), it is *involute.*

(The diagrams of vernation are often at first hard to understand, unless we remember they represent *sections* cut

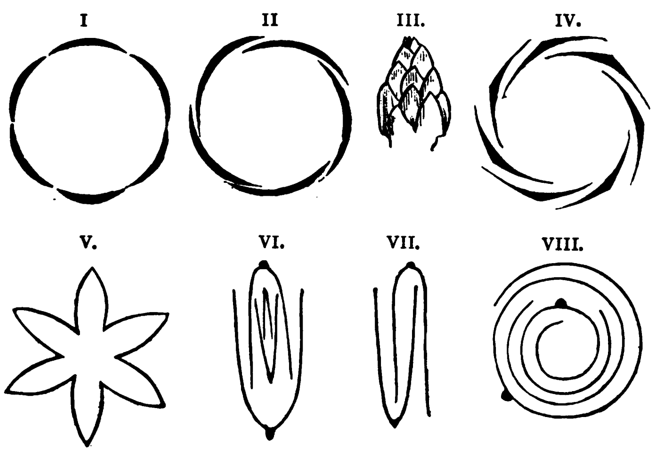


FIG. 97.—Forms of leaf-arrangement in bud.

across the leaves. A good plan is to cut out a large leaf in paper and to bend it in the forms described, after which an examination should be made of actual specimens.)

2. *The disposition of the several leaves in the bud.*—In this case the leaves are either flat, or only slightly convex, or they are bent or rolled.

(*a*) *Leaves flat or only slightly convex.*—The vernation is *valvate* (fig. 97, I.), when the leaves are placed in the same level and simply touch one another by their edges. If they are placed at different levels and overlap one another like tiles of a roof, as in the Lilac (II. and III.), it is *imbricate.* When the overlapping is carried further (as in fig. IV.), it is said to be *spiral* or *twisted.*

(*b*) *The separate leaves bent or rolled.*—When, as in the Columbine, involute leaves touch by their edges without overlapping (V.), the vernation is *induplicate.* When, as in the Privet, conduplicate leaves are bent around one another (VI.), it is *equitant*, whilst when, as in the Sage, they are only half folded over one another (VII.), they are *obvolute* or *half equitant.*

When, as in the Apricot, a convolute leaf has another rolled outside it (VIII.), the vernation is *supervolute.*

CHAPTER VIII.

STRUCTURE AND FUNCTIONS OF LEAVES.

WHEN a leaf is perfectly complete, it consists of three parts:—
1. The flat expanded portion which is popularly called the leaf. This is the *lamina*, or *blade.* 2. The stalk, which attaches this to the stem, the *petiole* or *leaf-stalk.* 3. The little leaf-like projections at the point of union between the petiole and the stem, the *stipules.*

In very many cases, however, there is only one or two of these parts present. If the petiole be absent, the leaf is said to be *sessile*; if the stipules, *exstipulate.*

The Wallflower and Shepherd's Purse (fig. 99) are examples of plants with leaves which consist of lamina only.

In some of the leaves of the Australian Acacias (fig. 100), we have only the petiole developed. It grows in a flattened leaf-like expansion known as a *phyllode* (fig. 100, *a*, *b*).

FIG. 98.—Oval leaf of the Apple, with two free stipules.

FIG. 99.—Sessile leaves of Shepherd's Purse (*Capsella bursa-pastoris*).

In the *Lathyrus Aphaca* (fig. 101) the stipules are the only parts which are developed in a leaf-like manner, the lamina and petiole being converted into a tendril.

In structure the leaf consists of parenchyma, which is intimately connected with the outer parenchyma of the stem, and prosenchyma forming the veins, and which is in like manner connected with the xylem and phloëm.

In a *vertical* section through the leaf we find the following parts (fig. 102) :—

1. A flattened *epidermis* coating the upper (*b*) and under

FIG. 100.—Leaf of *Acacia melanoxylon*, showing phyllodes *a*, *b*.

FIG. 101.—*Lathyrus Aphaca*: *r*, tendril; *b*, *flower*; *f*, fruit: *n*, stipule.

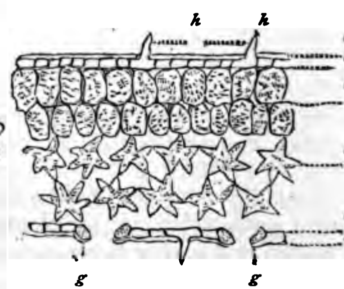


FIG. 102.—Diagrammatic section of leaf: *a*, cuticle of upper, *f*, of lower side; *b*, epidermis of upper, *e*, of lower side; *c*, cells of upper side; *d*, stellate cells of lower side; *g*, *g*, stomata; *h*, *h*, hairs.

(*e*) sides. As a rule, the under surface possesses a greater umber of stomata than does the upper.

Professor Bentley gives the following table of the number of stomata found in a square inch of the two surfaces respectively of the various plants.

	Upper Surface.	Under Surface.
Mezereon	None	4,000
Pæony	"	13,790
Vine	"	13,600
Olive	"	57,600
Holly	"	63,600
Laurustinus	"	90,000
Cherry Laurel	"	90,000
Lilac	"	160,000
Hydrangea	"	160,000
Mistletoe	200	200
Tradescentia	2,000	2,000
House Leek	10,710	6,000
Garden Flag	11,572	11,572
Aloe	25,000	20,000
Yucca	40,000	40,000
Clove Pink	38,500	38,500

Besides stomata, the epidermis is very frequently provided with hairs of various kinds.

These are simply prolongations of the epidermal cells sometimes unicellular (fig. 103, I.), sometimes multicellular (fig. 103, II.).

They vary much in their shape, sometimes being simple and at other times branched.

An interesting modification is seen in glandular hairs which contain various secretions; of these stinging hairs, as are found in the stinging-nettle, are good examples. In this case there is a little bag at the base of the hollow hair, containing an acrid fluid, and surrounded by a number of elastic cells. The point of the hair is sharp, and is protected by a little cap. When the nettle is touched lightly, the cap is broken off, the point of the hair pierces the skin, and a

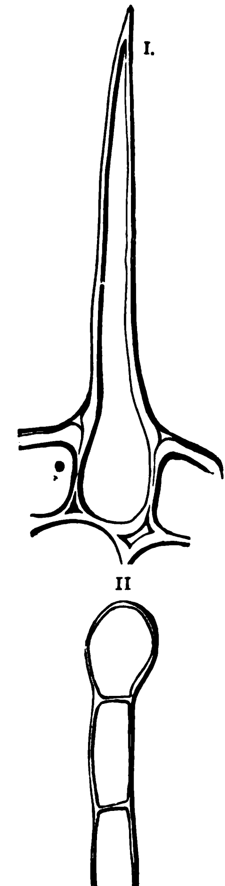


FIG. 103.—Simple hairs: I. Unicellular hair from the leaf of a Pelargonium. II. Multicellula hair from the stem of *Geranium pratense.*

FIG. 104.—Stinging hair of the Nettle (*Urtica dioica*); the corroding fluid flows out of the hair when the vitreous knob-shaped apex is broken off.

of the stinging juice is forced into the blood. If the nettle be grasped firmly the sting is broken lower down, and hence there is no sharp point to pierce the skin, and the juice is simply poured out upon the exterior.

2. The surface of the epidermis is generally covered with a thin structureless layer, the *cuticle* (fig. 102, *a* and *f*).

FIG. 105.—Reticulately veined leaf of *Acer acutifolium.*

3. The parenchyma of the interior of the leaf consists of cells containing chlorophyll.

There is a difference, however, in their arrangement in the different parts of the leaf. Towards the upper surface the cells are packed closely together (*c*, fig. 102), whilst towards the under surface we find examples of stellate parenchyma, *leaving air spaces* between the cells (*d*, fig. 102). This is *the cause of the* fact that in most leaves the under surface is lighter in colour than the upper, as there is less chlorophyll packed there.

The upper parts of the veins are in direct communication with the wood of the stem, whilst the lower parts are connected with the liber. At the edges of the leaves there is a passage between the upper and lower sides, so that the sap which passes up the wood flows out through the upper part of the veins, back through the under surface to the liber, and so down the stem.

There is a great difference in the *venation* or arrangement of the veins of the leaves in the two great groups of flowering plants.

In Dicotyledons the smaller veins run together, forming a complete network known as *reticulate venation* (fig. 105).

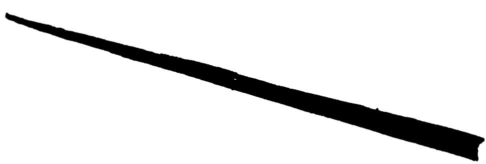


FIG. 106.—Parallel venation.

In Monocotyledons, as a rule, there is no network formed between the principal veins, and the venation is said to be *parallel* (fig. 106). (Some Monocotyledons, however, as the Aroids, have net-veined leaves.)

There are varieties of both net-veined and parallel-veined leaves.

If we take the net-veined leaves, we find that there is either a single principal vein or midrib, as in the Guelder Rose (fig. 107), when the leaf is said to be *unicostate*, or there are several principal veins, as in the Maple (fig. 105), when the leaf is *multicostate*.

Again, amongst unicostate leaves in some cases the *smaller veins* curve towards the apex (fig. 107), when we may term the leaf *curve-veined*; in other cases they run more at right angles from the midrib to the margin (fig. 108), when it is said to be *feather-veined.*

There are also two varieties of the multicostate leaves. In some cases, as in the Maple (fig. 105), the diverging ribs never meet again. The venation of the leaf is then said to be *diverging* or *palmate.* In other cases, as in the Cinnamon

FIG. 107. — Dentate ovate leaf of the Guelder Rose, with unicostate venation (*Viburnum Opulus*).

FIG. 108.—Runcinate leaf of the Dandelion, feather-veined.

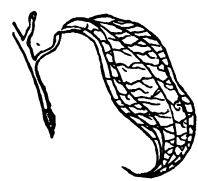


FIG. 109.—Converging veined leaf of Cinnamon.

(fig. 109), they meet again at the apex, and the leaf is *converging veined.*

Of the parallel-veined leaves there are three varieties. When, as in the Grass (fig. 106), the veins all run from the base to the apex, it is *straight veined.* When, as in the Banana, there is a central midrib, and the side veins run off to the margin, it is *transverse veined.* When, as in the

Fan Palm (fig. 71), there are several veins diverging from a common centre, it is *radiating veined.*

We may tabulate these forms of venation as follows :—

Reticulate-veined Leaves

Unicostate		Multicostate	
Curved veined	Feather veined	Diverging veined	Converging veined

Parallel-veined Leaves

Straight veined	Transverse veined	Radiating veined

In describing leaves, besides the venation, we have to take into account the following points :—1. Composition ; 2. Margin ; 3. Incision ; 4. Apex ; 5. General Outline.

1. *Composition.*—Leaves are either *simple* or *compound.* In simple leaves, as in the Apple (fig. 98), there is only a single lamina ; in compound leaves, as the Acacia (fig. 100), the lamina is divided into a number of leaflets articulated to the common petiole.

2. *Margin.*—The condition of this depends upon the extent to which the parenchyma is developed between the veins. The margin may be *entire*, as in Grasses. More often there are indentations.

If the teeth thus formed are rounded (fig. 110), the margin is *crenate.* If they are sharp, and point straight outwards (fig. 107), it is *dentate.* If sharp and pointing towards the apex, like teeth of a saw (fig. 98), *serrate.*

Sometimes the teeth are themselves divided, and we get *bicrenate*, *duplico-dentate*, and *biserrate* margins.

If the margin of the leaf be covered with numerous hairs (fig. 111), it is *ciliate.* If there be alternate concavities and convexities larger than crenated indentations, the margin is *sinuate* (fig. 112).

When the teeth are very long and sharp, the margin is *spiny* (fig. 113), and when the margin is very irregular, as in the garden Endive and curled Dock, it is *crisped.*

3. *Incision.*—We apply this term if the margin be more deeply indented than in the instances already described. If the indentations reach to midway between the margin and the midrib or petiole, we speak of them as *fissures*, and

FIG. 110.—Lyrate-crenate leaf of the White Mustard (*Brassica alba*).

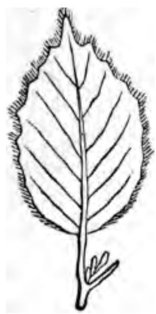


FIG. 111.—Ciliate leaf of the Beech.

FIG. 112.—Sinuate leaf of the Oak.

the portions of leaf between them as *lobes*, and the leaf is said to be *bi-*, *tri-*, etc., *-fid.* If the divisions go nearly to the base, or midrib, they are *partitions*, and the leaf is *bi-*, *tri-*, etc., *-partite.* If quite down to the midrib or base *segments*, the leaf is *bi-*, *tri-*, etc., *-sected.* (For further remarks on this point see under the head of Outline.)

FIG. 113.—Spiny leaf of the Holly.

4. *Apex.*—If the apex of the leaf be rounded (fig. 112), it is *obtuse* or *blunt.* If it be sharp pointed (fig. 107), it is *acute*, and if it gradually tapers to a point (fig. 114), it is *acuminate.* When there is a rounded head, and a broad shallow notch in it, the apex is retuse, and

when the notch is more triangular (fig. 115), it is *emarginate.* When the apex is very abrupt as though cut off, it is said to be *truncate.*

When the apex is flattened and has a sharp point projecting (fig. 116), it is called *mucronate.*

5. *General Outline.*—Various terms are employed for the description of the general outline.

If, as in the Grasses (fig. 106), the two margins of the

FIG. 114.—Acuminate leaf of the Pellitory (*Parietaria*).

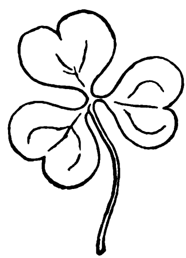


FIG. 115.—Leaf of *Oxalis micrantha*, with three obcordate leaflets.

FIG. 116. — Mucronate leaflet of the Lucerne.

lamina are nearly parallel and the lamina itself is narrow, the leaf is *linear.*

If the leaf be sharp pointed and needle-like, as in many Conifers (fig. 117), it is *acerose.* When the leaf is somewhat broad in the centre, and tapers towards the two extremities, as in the Privet, it is *lanceolate* (fig. 118). If more rounded at the extremities and broader in the centre, it is *oval*, or *elliptical* (fig. 98), and *oblong*, when rather longer. When, as in the Guelder Rose (fig. 107), the leaf is broad and rounded at the base, tapering to a point at the apex, it is *ovate* or egg-shaped ; and if the reverse, *obovate* or inversely egg-shaped.

When the leaf is nearly round (fig. 119) it is *orbicular*, or *subrotund*. When, as in the case of the Lamium (fig.

FIG. 117.—*Pinus sylvestris*, the Scotch Fir, with acerose leaves.

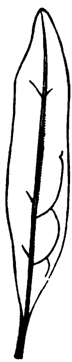


FIG. 118.—Lanceolate leaf of the Privet.

120), the leaf is somewhat hollowed out at the base, and pointed at the apex, so as to be roughly like a heart in a

FIG. 119.—Orbicular leaf of *Malva rotundifolia*.

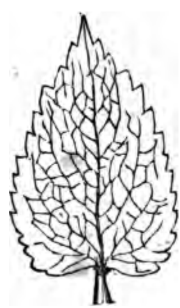


FIG. 120.—Cordate leaf of *Lamium*.

pack of playing cards, it is *cordate* or heart-shaped, and when the reverse (fig. 115), *obcordate*.

If the apex is rounded, instead of pointed, whilst the base is hollowed, as in the Ground Ivy (fig. 121), the outline is *reniform* or kidney-shaped.

When the apex is rounded, and the leaf gradually tapers to the base (fig. 122), it is *spathulate* or spoon-shaped; or if it is more

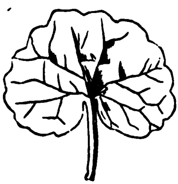


FIG. 121.—Reniform leaf of the Ground Ivy (*Nepeta Glechoma*).

FIG. 122.—Spathulate leaf of the Ox-eye Daisy (*Chrysanthemum leucanthemum*).

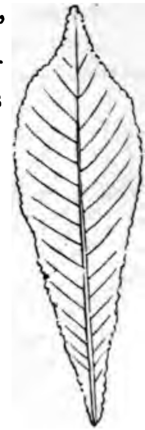


FIG. 123. — Cuneate leaflet from the leaf of the Horsechestnut.

tapering, as in the leaflets of the Horsechestnut (fig. 123), the outline is said to be *cuneate* or wedge-shaped.

When the leaf is somewhat of the form of an arrow-head (fig. 124), it is called *sagittate* or arrow-shaped; or if the barbs of the arrow point out more at a right-angle to the blade, the leaf is *hastate* or halbert-shaped (fig. 125).

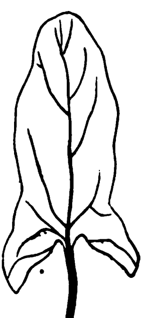


FIG. 124.—Sagittate leaf of *Convolvulus arvensis*.

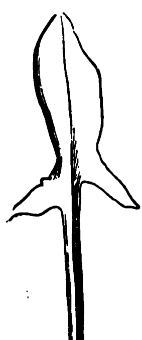


FIG. 125.—Hastate leaf of *Rumex acetosa*.

There are also several terms which are applied to the outlines of compound and much divided leaves. Thus, if a compound leaf has two leaflets it is *binate*; if three, *ternate* (fig. 115).

A *quadrifoliate* leaf has four, a *quinate* five, a *septenate* seven, and a *multifoliate* leaf more than seven leaflets springing from a common point. When the leaflets are arranged on either side of the central stalk, like barbs on a feather, the leaf is said to be *pinnate*. Of these leaves there are two varieties, viz., *imparipinnate*, or unequally

FIG. 127.—Paripinnate leaf of *Lathyrus macrorhizus* (with auriculate or ear-shaped stipules), the rachis ending in a point.

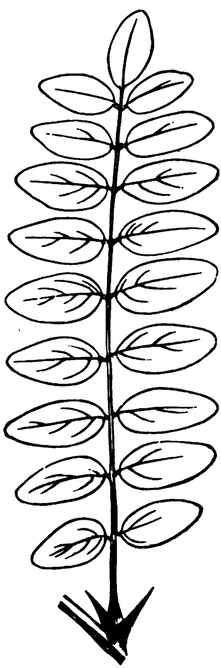


FIG. 126.—Imparipinnate leaf of the 'Acacia' (*Robinia Pseudacacia*), with opposite leaflets (and spinous stipules).

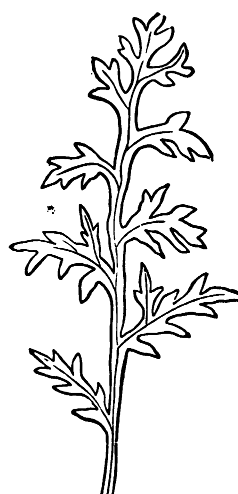


FIG. 128.—Pinnatisect leaf of the common Poppy (*Papaver Rhœas*).

pinnate, when there is an odd lobe at the extremity (fig. 126), and *paripinnate*, or equally pinnate, when the number of lobes present is even (fig. 127).

When a simple leaf is divided in a pinnate manner, it is

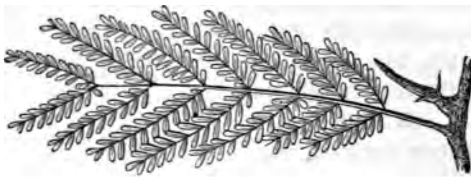


FIG. 129.—Bipinnate leaf of *Gleditschia triacanthos.*

pinnatifid, *pinnatipartite*, or *pinnatisected* (fig. 128), according to the depth of the incisions. When a pinna-

FIG. 130.—Tripinnate leaf of *Thalictrum.*

tifid leaf has its terminal lobe large and rounded, and the side lobes gradually getting smaller towards the base (fig.

110), it is *lyrate*; whilst if the terminal lobe is triangular, and the lobes are also angular (fig. 108), it is *runcinate.*

When each of the pinnæ of a pinnate leaf is itself pinnate, the leaf is said to be *bipinnate.* If the division be carried a step further, it is *tripinnate* (fig. 130).

When the divisions of the leaf spread out like the fingers

FIG. 131.—Palminerved leaf of *Geranium pratense* (nature-printed).

FIG. 132.—Palmatisect leaf of the Monkshood (*Aconitum*).

of a hand, the leaf is *palmate* (fig. 131), *palmatifid* (fig. 105), *palmatipartite* and *palmatisected* (fig. 132).

When a palmatisected leaf is itself cut up into segments, it is *dissected* or *laciniate* (fig. 133).

Sometimes the lateral lobes of a palmate leaf are themselves divided, giving the whole somewhat the appearance of a bird's foot (fig. 134). The leaf is then *pedate.*

There are certain terms which are applied to the attachment of the leaves to the stem. Thus when placed one above the other upon opposite sides of the stem, they are *alternate.* If placed in pairs on opposite sides, they are *opposite.* If the alternate pairs of opposite leaves are placed at right angles to one another (fig. 135), they are *decussate.* When there are more than two leaves forming a whorl round the stem (fig. 136), they are said to be verticillate. When two opposite leaves have their bases so united as to form apparently but one (fig. 137), often thus producing a cup, as

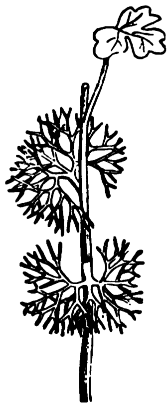


FIG. 133.—Heteromorphic leaves of the Water Crowfoot (*Ranunculus aquatilis*); the floating leaves trilobed, the submerged leaves laciniate.

FIG. 134.—Pedate leaf of the Christmas Rose (*Helleborus niger.*)

FIG. 135.—Decussate leaves of the Scarlet Pimpernel (*Anagallis arvensis*), with axillary flowers.]

in the Teasel, they are *connate*. If the base of the leaf, whether *petiole*, lamina, or stipules, embraces the stem, the leaf is *amplexicaul*, the part surrounding the stem being called the *vagina* or *sheath*.

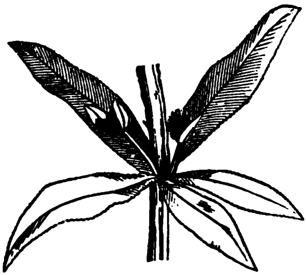


FIG. 136.—Verticillate leaves of the Madder (*Rubia tinctorum*).

FIG. 137.—Connate leaves of the Honeysuckle.

FIG. 138.—Perfoliate leaf of *Bupleurum rotundifolium*.

FIG. 139.—Decurrent leaf of *Symphytum officinale*, the stem hence becoming winged on one side

If the stem grows through the leaf, the latter is said to be *perfoliate* (fig. 138), whilst, if any part of the leaf adheres to the stem, causing the latter to be winged (fig. 139), the leaf is said to be *decurrent.*

If the leaves grow from the point of junction of the root and stem, or if the stem be so reduced as to be almost obliterated, they are said to be *radical.* Leaves growing from the main stem are called *cauline*, and those from the branches, *ramal.*

FUNCTIONS OF THE LEAVES.

1. *To absorb food for the plant.*—We have already seen how the roots take up from the soil the various substances needed for the life of the plant. One very important substance, however, is not taken up by the roots of green plants, and this is carbon.

This element exists in the atmosphere in the form of carbon dioxide or carbonic acid gas, a compound of carbon and oxygen, CO_2. It is produced wherever breathing, burning, and decay of organic bodies are taking place.

The composition of a thousand parts, by volume, of atmospheric air is as follows :—

Nitrogen	779·50.
Oxygen	206·10.
Water (variable)	14·00.
Carbon dioxide	·40.
Various gases	traces.
	1,000·00.

That is to say that a thousand cubic feet of air contain not quite half a cubic foot of carbonic acid. Small as this quantity may appear to be, it is the source of the carbon of the plant.

The carbon dioxide enters with the other constituents of the air by means of the stomata into the interior of the leaf, there to serve for the nourishment of the plant.

2. *To assimilate the food absorbed.*—The food materials which are taken up by the root are not changed as they are carried up the wood. The sap becomes thicker by evaporation, but when it enters the leaves it still contains simply mineral substances. In the leaves, however, it is brought into contact with the carbon dioxide, and a marvellous change takes place. In the presence of the chlorophyll and under the action of light, the carbonic acid gas is decomposed : its oxygen is restored to the atmosphere, whilst the carbon is chemically united with the water and the mineral substances, to build up new and organic compounds. These changes will only take place in the light, and go on in all the green parts of the plants. It is owing to this that the amount of carbonic acid in the atmosphere is kept down, and the air purified and rendered fit for man to breathe ; hence the importance of open spaces with trees in the midst of our cities.

One of the first substances formed is generally oxalic acid, which unites with the lime of the sulphate of lime, setting free the sulphur which is required for the manufacture of the various albuminoids. Other organic substances soon follow, and the food which passes down the liber is in a fit state to be absorbed by the plant.

(It is generally stated that the presence of chlorophyll is necessary to the decomposition of carbon dioxide. Recent observations, however, have raised the suggestion that chlorophyll may be the *result*, not the *cause*, of the decomposition. The question needs further investigation, but the presence of chlorophyll and the decomposition of carbonic acid always go together.)

A very important point to remember is that the plant does not absorb free nitrogen from the atmosphere. All the nitrogen required by the plant is taken in either as ammonia or nitrates.

3. *As a breathing organ.*—Plants, like animals, carry on a process of respiration, *i.e.* they take in atmospheric oxy-

gen which combines with the carbon and hydrogen of the tissues forming carbon dioxide and water, which are restored to the air. The respiration, however, of plants, is much less than that of animals; it differs in its amount in various plants, and in the different parts of the same plant. The more energetic the growth, the greater the amount of respiration: hence it is especially well seen in quickly germinating seeds, and unfolding leaf and flower buds.

The oxygen passes into the interior of the plant by means of the stomata, and by the same openings the carbonic acid gas is passed out into the atmosphere. This change goes on continually, irrespective of the presence or absence of light. During the daytime the feeding by the decomposition of carbon dioxide and assimilation of the carbon is so greatly in excess of the respiratory act that it completely overshadows it, and apparently nothing is going on but the decomposition of the carbonic acid; but in the night time, when, owing to the absence of the light, no assimilation is taking place, the breathing can be perceived.

4. *As an organ of transpiration.*—A large portion of the water which is taken in by the roots of the plant escapes by the leaves. By means of this evaporation the sap becomes thickened as it ascends the stem. The transpiration takes place by means of the epidermis, and especially through the stomata. The amount which is evaporated depends upon certain conditions, viz. :—

a. The state of the atmosphere. All other things being equal, more moisture will be given off in dry than in moist atmosphere.

b. The amount of light. The greater the light, the greater the transpiration.

c. The structure of the epidermis. In many succulent plants the epidermis is very thick, thus preventing an excess of evaporation.

d. There is a greater evaporation from the lower than the upper sides of the leaves.

The amount of water transpired is often very great, as is shown by experiments which were first performed by Hales in 1724. A Sunflower plant, 3½ feet high, weighing 3 lbs., and with a surface of 5,616 square inches, exhaled a pint of water a day; a Cabbage plant with 2,736 square inches, 19 fluid ounces; a Lemon tree with 2,557 square inches, 6 fluid ounces.

The action of Wardian cases depends upon this continual evaporation. By this means the water which evaporates collects on the glass, and running down once more, waters the plants.

The transpiration of plants also plays an important part in determining the humidity of the atmosphere where they grow. We always find that if there are forests of trees the atmosphere in the neighbourhood is moist; whilst, on the other hand, there have been numerous cases where the clearing of a tract of country has materially interfered with the rainfall, producing droughts.

5. *As organs of circulation.*—From the fact of transpiration follows the next, that the leaves tend to produce a flow of sap upwards. As evaporation takes place there is a continual flow of the crude sap up the wood to take its place: the greater the evaporation the more rapid the sap circulation.

The foregoing functions are performed by all leaves; the following, however, are exceptional.

6. *In some cases the leaves act as carnivorous organs.*—Some plants seem to possess the power of absorbing their nitrogen by means of organic compounds containing it. Good examples are to be seen in Venus's Fly-trap (fig. 140), and the Sundews of our own country. If we examine the leaves of either of these plants, we find that their upper surfaces are covered with glandular hairs which, when touched, exude a few drops of a sticky liquid which adheres to the fingers, and will be drawn out into a fine thread.

If an insect settles upon the leaf it becomes arrested, and gradually the leaf folds over, enclosing it. It thus remains closed for a short time, and on opening again there is found

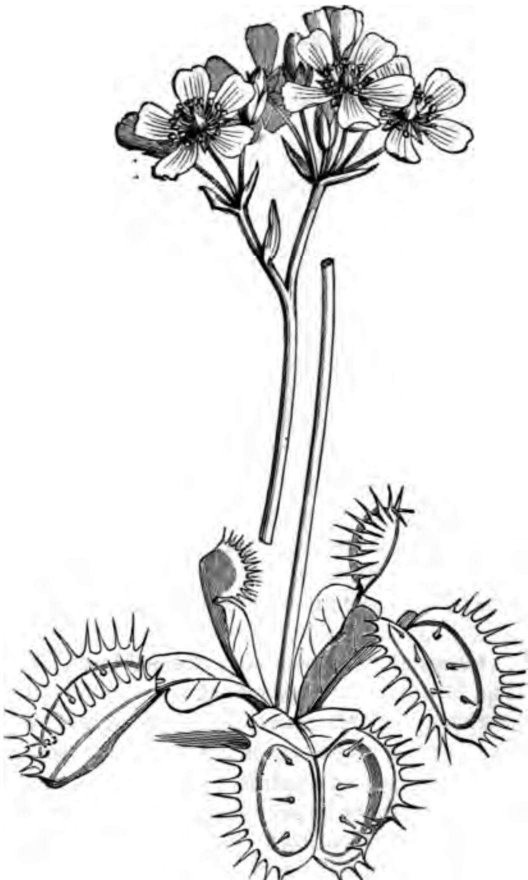


FIG. 140.—Venus's Fly-trap (*Dionæa muscipula*).

merely the outer shell of the insect, all the nutritive part having been absorbed by the plant. The leaf seems to contain a substance analogous to, if not identical with, the pepsine of the animal stomach, which possesses the power of rendering nitrogenous substances soluble. Other carnivorous plants have the same power of absorbing organic food materials by their leaves in various ways.

7. *In some cases the leaves act as organs of support.*—We have already seen that parts of the leaf may be converted into tendrils (figs. 92 and 101), thus twining round the organ of support and sustaining the stem. In the Tropæolum the leaf-stalk itself twines and supports the plant.

CHAPTER IX.

BRACTS AND INFLORESCENCE.

THE term *bract* is employed for those leaves in whose axils flower buds instead of leaf buds arise, or for any appendage growing upon the flower-stalk below the flower.

FIG. 141.—Capitulum of Marigold, with imbricate involucre.

In some cases, as in the White Dead-nettle, bracts cannot be distinguished, except by their position, from the true leaves of the plant; in other cases, whilst still leaf-like, they differ in shape from the other leaves of the same plant. In all these cases the bracts are said to be foliaceous or leafy bracts.

Sometimes the bracts are coloured, being then often mistaken for the true flowers, as in the Hydrangea, and in some species of *Euphorbia*. In other cases the bracts are small and scale-like.

When several bracts surround a single flower as in the Pink, or a head of flowers as in the Marigold (fig. 141), they form an *involucre.*

When a single bract is enlarged and ensheaths a single flower whilst in the young state as in the Narcissus and Snow-flake, or a head of flowers as in the Cuckoo-pint or Palm, it is called a *spathe.*

When bracts are scaly they are said to be *squamous,* and the special scaly bracts which enclose the flowers of the Grass and Sedge tribes are *pales* and *glumes.*

FIG. 142.—Simple raceme of *Antirrhinum majus.*

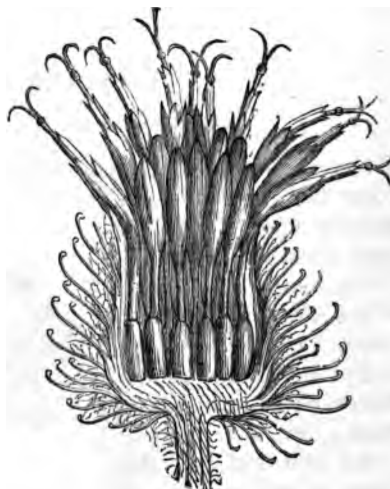


FIG. 143.—Longitudinal section through the capitulum of the Burdock (*Arctium Lappa*).

If the bracts fall before, or soon after the flower opens, they are *deciduous* ; whilst if they remain (sometimes even to the ripening of the fruit), *persistent.*

If bracts be present, the plant is said to be *bracteate* ; if absent, *ebracteate.*

The term inflorescence is employed to describe the arrangement of the flowers upon the stem. In some cases, as in the Tulip, there is a single flower at the top of the stalk, no others being formed below. The inflorescence is then said to be single-flowered. More often there are several flowers variously arranged. Inflorescences are divided under two heads.

If we examine such a bunch of flowers as the Snapdragon (fig. 142), or Wallflower, or Stock, we find that the oldest flowers are towards the base, the younger ones being towards the apex. Such an inflorescence is said to be *indefinite.* Sometimes in the indefinite inflorescences, as in the Burdock (fig. 143), or Thistle, or Dandelion, the flowers instead of being arranged one above another are side by side. In this case the younger flowers are towards the centre, and the older ones around them, and hence the indefinite inflorescence is also spoken of as *centripetal*, or centre-seeking. In the Pink, on the other hand (fig. 144), the stalk is capped by a flower which is the first to open, the younger ones budding below it. This is termed *definite inflorescence*, or (since, when the flowers are on the same level, the older ones will be towards the centre, and the younger ones outside) *centrifugal.*

FIG. 144.—*Dianthus Caryophyllus*: portion of plant with definite inflorescence.

Of each of these forms there are several varieties.

Indefinite or Centripetal Inflorescence.—In the case of the indefinite inflorescence the axis may either be lengthened as in the Snapdragon, or arrested as in the Burdock and Dandelion ; and in either case the flowers may be sessile or stalked.

A *spike* is an indefinite inflorescence with lengthened

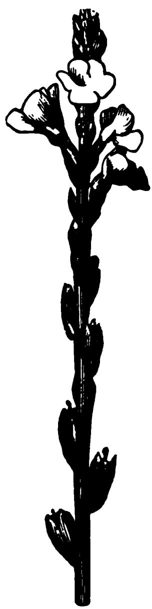


FIG. 145.—Simple spike of *Verbena officinalis.*

FIG. 146.—Simple raceme of the Currant.

axis and sessile flowers, as in the Verbena (fig. 145), Plantain, or Wheat.

A *raceme* is an indefinite inflorescence with a lengthened axis and stalked flowers, as in the Snapdragon (fig. 142) and Currant (fig. 146).

A *capitulum* is an indefinite inflorescence with shortened axis and sessile flowers, as in the Marigold (fig. 141), Burdock (fig. 143), and Dandelion.

An *umbel* is an indefinite inflorescence with shortened axis and stalked flowers, as in the Cherry (fig. 147). If each branch of the umbel be itself branched, the compound umbel is produced, as in the Fool's Parsley (fig. 148). Generally the capitulum and umbel are surrounded by an involucre of

FIG. 147.—Simple umbel of the Cherry.

FIG. 148.—Compound umbel of Fool's Parsley (*Æthusa Cynapium*); common involucre wanting; involucels of three leaves each.

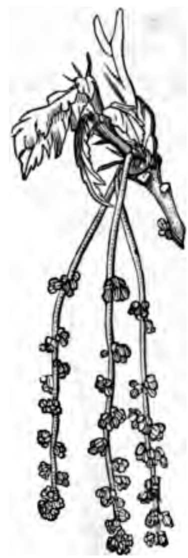


FIG. 149.—Catkin or amentum of the Oak.

bracts, and sometimes the secondary branches of the compound umbel have a special involucre which is called the involucel.

Special names are given to varieties of some of these forms.

VARIETIES OF SPIKE.

A *catkin* or *amentum* is a deciduous spike of unisexual flowers, as in the Oak (fig. 149), Hazel, or Willow.

A *spadix* is a fleshy spike bearing several unisexual flowers, the whole enveloped in a spathe, as in the Arum (fig. 150).

A *strobilus* is a spike of unisexual flowers with membranous bracts, as in the Hop.

A *cone* is a spike of unisexual flowers with lignified bracts, as in the Fir (fig. 151).

VARIETIES OF RACEME.

A *orymb* is a raceme where the stalks or pedicels are of different lengths, the lower ones being the longest, so that

FIG. 150.—Spadix of Arum : *a*, barren stamens ; *b*, stamens ; *c*, pistils.

FIG. 151.—Cone of the Scotch Fir.

the flowers form a flat-topped head, as in the Hawthorn and some species of Cerasus.

A panicle is a compound raceme, that is, one where each *branch is itself* branched, as in some Yuccas.

A *thyrsus* is a panicle with very short pedicels, as in the Horsechestnut and Lilac.

VARIETY OF CAPITULUM.

The *hypanthodium* has the end of the stalk hollowed out, the flowers growing within, as in the Fig (fig. 152).

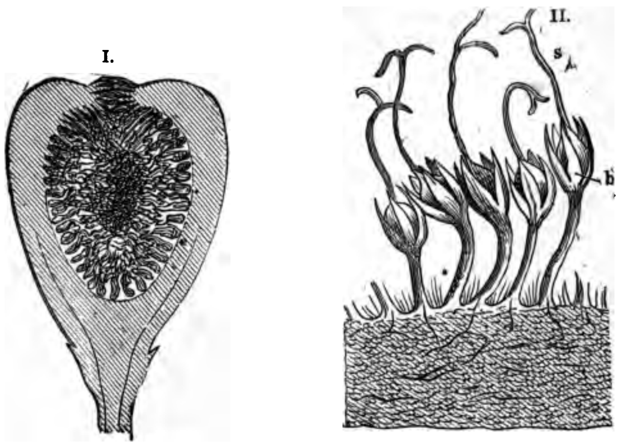


FIG. 152.—I. Longitudinal section through the hypanthodium of a Fig, exposing the flowers in its interior. II. A piece with five female flowers : *s*, pistil ; *b*, perianth.

We may tabulate the forms of indefinite inflorescence as follows :—

Indefinite Inflorescence.

	With lengthened axis.		With shortened axis.	
	With sessile *flowers.*	With stalked *flowers.*	With sessile *flowers.*	With stalked *flowers.*
	SPIKE.	RACEME.	CAPITULUM.	UMBEL.
Varieties.	Amentum.	Corymb.	Hypanthodium.	Compound umbel.
	Spadix.	Panicle.		
	Strobilus.	Thyrsus.		
	Cone.			

Definite or Centripetal Inflorescence.—The general name for these is *Cyme.* We cannot well tabulate them in the same way that we do the indefinite. In many cases we employ the name of the indefinite inflorescence as an adjective to qualify the term *cyme.* Thus we have a *spiked cyme* in Sedum, *racemose cyme* in Campanulas, *panicled cyme* in Privet, *corymbose cyme* in Laurustinus, etc.

The *dichotomous cyme* (fig. 153) is one where two branches spring from beneath the terminal flower, each in its turn capped by a flower and developing two branches

FIG. 153.—Dichotomous cyme of *Cerastium.*

FIG. 154.—Cymose inflorescence of *Myosotis.*

just below it, as in the Chickweed and Centaury. If there be three stalks, the cyme is *trichotomous.*

If but one stalk be given off which is again branched on the same side, and this again repeated a number of times always on the same side, so that the young flowers become coiled like a scorpion's tail, or a shepherd's crook, the *scorpioid cyme* is formed, as in the Forget-me-not, and many of the Boraginaceæ (fig. 154).

The *fascicle* is a cyme which has a large number of flowers on short stalks, as in the Sweet William.

The *glomerulus* is a cyme with a large number of sessile flowers, as in the Box.

The *verticillaster* consists of two cymose bunches placed on opposite sides of the stem, so as apparently to produce a whorl, as in the *Lamium album* (fig. 155), and other members of the Labiatæ.

Mixed Inflorescences.—Sometimes in a plant there is a mixture of the two kinds of inflorescence. Thus in the

FIG. 155.—Verticillaster of *Lamium album.*

Dead-nettle, whilst each separate inflorescence is definite, being a verticillaster, yet, taking the whole plant, the arrangement is indefinite, the lower verticillasters opening first. On the other hand, in most of the members of the natural order Compositæ, whilst each capitulum is itself indefinite, yet, taking the plant as a whole, the arrangement is definite, for the terminal capitulum is the first to open.

Such an inflorescence is said to be mixed.

CHAPTER X.

STRUCTURE AND FUNCTIONS OF PARTS OF THE FLOWER.

THE flower is that part of the plant which is intended to subserve the purposes of reproduction.

When complete, the flower consists of four whorls or series of organs. The two outer ones are merely coverings, whilst the inner ones form the essential organs.

Commencing at the exterior, the outer coat is known as the *calyx* (fig. 156, K), and each division of which it is made up is a *sepal.* The inner coat is the *corolla* (fig. 156, B), and each separate part of it a *petal.*

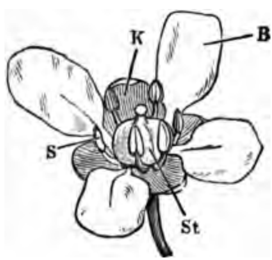


FIG. 156.—Flower of *Sisymbrium Alliaria*: K, calyx; B, corolla; S, stamens; *st*, pistil.

If both coats be present, as in the Buttercup, the flower is said to be *dichlamydeous*; if only one, as in the Anemone, *monochlamydeous*; if both be absent, as in the Ash, *achlamydeous.*

The outermost whorl of the essential organs of the flower is the *andrœcium* (fig. 156, S), consisting of one or more stamens; whilst within there is the *pistil* or *gynœcium* (fig. 156, S*t*), consisting of one or more *carpels.*

This will be a convenient place to note the distinction that is drawn between a complete and a perfect flower.

For a flower to be *complete*, all four of the whorls must be present; if any one be absent, the flower is *incomplete.* On the other hand, the term *perfect* is applied to all those flowers in which both andrœcium and pistil are present, although, as in the Anemone, one of the coats may be *wanting,* or even, as in some flowers of the Ash, both coats *may be absent.* An *imperfect* flower is one where there is only *one whorl of the* essential organs, as in the Hazel and Oak.

It follows that every complete flower must be perfect, but every perfect flower is not necessarily complete; on the other hand, every imperfect flower must be incomplete; but every incomplete flower is not imperfect.

Perfect flowers are sometimes spoken of as *hermaphro-*

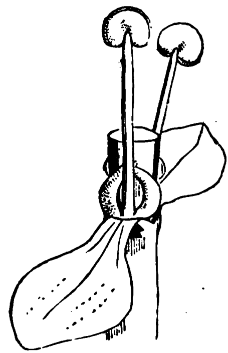


FIG. 157.—Staminate (♂) flower of *Callitriche verna*, with two sickle-shaped bracts.

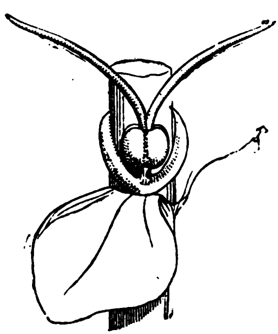


FIG. 158.—Pistillate (♀) flower of *Callitriche verna.*

FIG. 159.—The Hazel (*Corylus Avellana*); branch with male and female flowers.

dite. Imperfect flowers are either *staminate* (fig. 157) if the pistil be absent, or *pistillate* (fig. 158) if the stamens be absent.

If staminate and pistillate flowers grow upon the same plant, as in the Hazel (fig. 159), Oak, and Birch, the plant is said to be *monœcious*; if they grow upon separate plants, as in the Willow (fig. 160), Juniper, and Poplar, it is *diœcious*; whilst if on the same plant are to be found hermaphrodite,

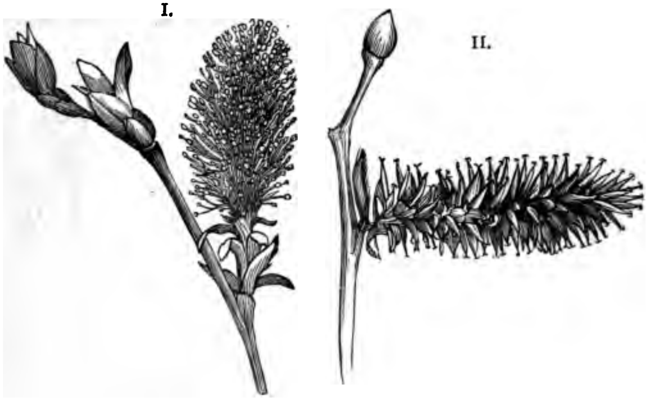


FIG. 160.—Sallow (*Salix caprea*). I. Male catkin. II. Female catkin.

staminate, and pistillate flowers, as in the Ash, it is *polygamous.*

We must now notice each part of the flower more particularly.

CALYX.—The sepals are generally arranged in one whorl,

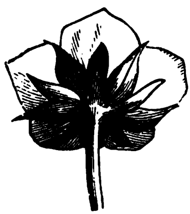


FIG. 161.—Flower of the Strawberry, with calyx in two rows.

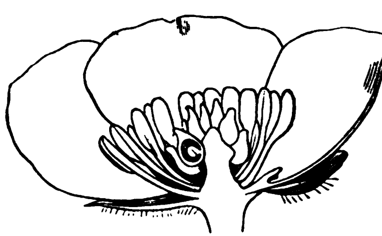


FIG. 162.—Longitudinal section through the flower of *Ranunculus acris*, showing the hypogynous calyx, corolla, and stamens.

but in some cases, as in the Strawberry (fig. 163), there may be two (or even, as in the Cotton, three) whorls.

Generally the sepals are green, but sometimes, as in the Fuchsia, Larkspur, and Garden Nasturtium, they are coloured, or petaloid.

When the calyx is inserted beneath the ovary upon the end of the flower-stalk (which is known as the *thalamus*), it

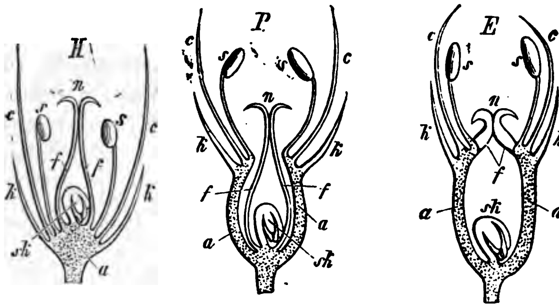


FIG. 163.—Diagrammatic section of hypogynous (*H*), perigynous (*P*) and epigynous (*E*), flowers. *a*, axis, forming convex or concave receptacle, or wall of ovary; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels; *n*, stigma; *sk*, ovules. (After Prantl.)

is said to be *inferior*, and the ovary is *superior*, as in the Ranunculus (fig. 162, and fig. 163, H and P).

FIG. 164.—Spurred calyx of *Tropæolum*.

FIG. 165.—Caducous calyx of Poppy.

In other cases the calyx is adherent to the sides of the ovary, only the free limb springing from its upper part (or the calyx springs entirely from the top of the ovary). It is then said to be *superior*, and the ovary is *inferior* (fig. 163, E), as in the Fuchsia, Willow-herb, Apple, etc.

When the sepals of the calyx are distinct from one another, as in the Strawberry (fig. 161), it is said to be *polysepalous*. If the sepals be united together (fig. 167), as in the Primrose, the calyx is *gamosepalous*.

When the sepals are alike, as in the Buttercup (fig. 162), or Primrose, the calyx is said to be *regular*; if some be differently developed from the rest, the calyx is *irregular*, as in the Garden Nasturtium (fig. 164).

FIG. 166.—Tubular calyx.

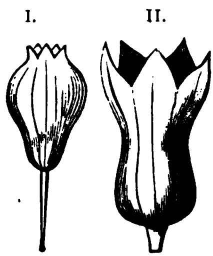


FIG. 167.—I. Turbinate. II. Urceolate calyx (represented diagrammatically).

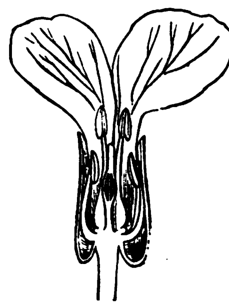


FIG. 168.—Saccate calyx of *Lunaria*.

If, as in the Poppy (fig. 165), the calyx falls off as soon as the flower-bud opens, it is said to be *caducous*; if, as in the Ranunculus (fig. 162), it remains after the flower opens, but falls off before the fruit ripens, it is *deciduous*; whilst if it remains after the fruit has ripened, it is *persistent*, as in the Strawberry (fig. 161).

Sometimes the persistent calyx becomes very much enlarged around the fruit; it is then *accrescent*, as in the Physalis.

There are also certain terms which are used in describing *the shape of the* calyx which are of great importance in *Descriptive Botany.*

Thus it may be ***tubular*** (fig. 166), as in the Centaury; ***urceolate*** (fig. 167, II.) or urn-shaped, as in the Campion; ***inflated*** or swollen, as the Bladder Campion; ***turbinate*** or top-shaped (fig. 167, I.); ***funnel-shaped*** or ***infundibuliform*** (fig. 173), as in the Deadly Nightshade; ***saccate*** (fig. 168),

FIG. 169.—Monkshood (*Aconitum Napellus*). Part of plant.

FIG. 170.—Pilose sessile pappus of *Senecio.*

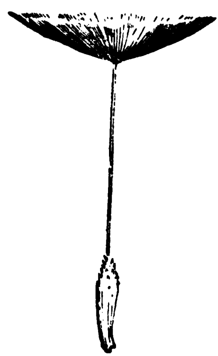


FIG. 171.—Pilose stipitate pappus of Dandelion.

if there are four sepals, two of which are prolonged at the base, as in most cruciferous plants; ***rotate*** (fig. 161), as in the Strawberry; ***bilabiate*** or ***two-lipped*** (fig. 174), as in the Dead-nettle; ***spurred*** (fig. 164), as in the Tropæolum; ***galeate*** or ***hooded*** (fig. 169), as in the Monkshood.

When the calyx is polysepalous, it should be described as *bisepalous*, *trisepalous*, etc. If gamosepalous, it may be described as *toothed*, *lobed*, or *incised*, according to the depth to which it is cut.

A remarkable form of calyx known as *pappus* is met with amongst the composite and some other flowers. In this

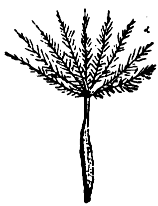


FIG. 172.—Plumose sessile pappus of *Tragopogon*.

FIG. 173.—Deadly Nightshade (*Atropa Belladonna*): flower.

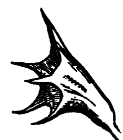


FIG. 174. — Bilabiate five-toothed calyx of *Lamium*.

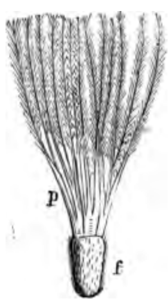


FIG. 175.—Pappus of *Carlina vulgaris*, the feathery rays united below into several bundles and coherent at the base into a ring.

FIG. 176.—Fruit, *f*, of the Tansy (*Tanacetum vulgare*), surmounted by the coronate pappus,

case the sepals are converted into numerous hairs, which crown the ovary, and are often very much enlarged upon the fruit, as is seen in the head of the Dandelion after flowering.

The hairs may be either simple when the pappus is *pilose* (*figs.* 170 and 171), or feathery when it is plumose (figs. 172 and 175). Again, they may be sessile upon the ovary (figs. 170 and 172), or stalked, when they are said to be *stipitate* (figs. 171 and 175) ; so that there are four forms of pappus, viz.:—

Pilose sessile, as in Groundsel.

Pilose stipitate, as in Dandelion.

Plumose sessile, as in Salsify or Goatsbeard.

Plumose stipitate, as in Thistles.

In the Chicory and Tansy (fig. 176) the pappus is *coronate*, forming a crown of broad hairs above the fruit.

COROLLA.—The second enveloping layer of the flower is generally more delicate in its structure than the calyx, and is often highly coloured and possesses odour. If there be only one coat present, as in the Anemone and Marsh Marigold, whatever its appearance, it is spoken of as calyx.

The corolla is either *gamopetalous* or *polypetalous*—*regular* or *irregular*.

If the petals are attached with the calyx beneath the ovary (fig. 163, H), the corolla is said to be *hypogynous*; if the ovary be superior but the petals, instead of being inserted under it, are attached upon the calyx, forming a ring round the ovary, the corolla is *perigynous* (fig. 163, P). When the ovary is inferior and the corolla springs from the top of it with the calyx (fig. 163, E), it is *epigynous*.

The corolla never remains to form a part of the fruit as the calyx does sometimes.

Terms are also employed to describe the shape of the corolla, and of the individual petals.

When the petals are broad above and form a narrow limb below, as in the Pink (fig. 177) and Lychnis (fig. 178), they are said to be *unguiculate* or *clawed*.

When each petal is notched at its free edge, as in the Lychnis (fig. 178), it is described as *bifid*. If there are several notches it is *toothed* (fig. 177), or, if very much divided, *fimbriated*, as in *Dianthus plumarius*.

Again, the corolla may be *tubular*, as in the Bluebottle and other composite plants (fig. 179); *campanulate* or bell-shaped, as in the Campanula (fig. 180); *urceolate* or urn-shaped, as in the Bilberry (fig. 181); *globose*, as in many

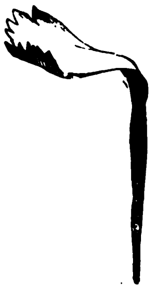


FIG. 177.—Unguiculate petal of *Dianthus*, with toothed lamina.

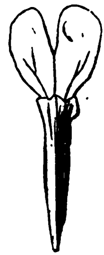


FIG. 178.—Bifid unguiculate petal of *Lychnis*, with ligule.

FIG. 179. — Tubular corolla from the disc of the capitulum of *Centaurea Cyanus*

Heaths (fig. 182); *infundibuliform* or funnel-shaped, as in the Convolvulus (fig. 183); *hypocrateriform* or salver-shaped, with the petals flattened above, as in the Jasmine

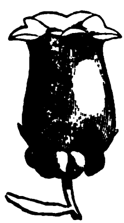


FIG. 180.—Campanulate corolla of the Canterbury Bell.

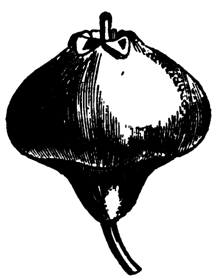


FIG. 181.—Urceolate corolla of *Vaccinium Myrtillus*.

FIG. 182.—Globose corolla of *Erica Tetralix*.

(fig. 184); *rotate* or wheel-shaped, as in the Borage (fig. 185); *cruciform*, or cross-shaped, when there are four petals arranged like a Maltese cross, as in the Wallflower, Stock, or Lunaria (fig. 186); *ligulate* or strap-shaped, when the lower part of the corolla forms a tube and the upper part is flattened out, as in the Globularia (fig. 187), and the ray florets of the Daisy and florets of the Dandelion;

FIG. 183.—Infundibuliform corolla of *Convolvulus arvensis.*

FIG. 184.—Hypocrateriform corolla of the Jasmine.

FIG. 185.—Rotate corolla of the Borage (*Borago officinalis*).

spurred, as in the Violet and many Orchids; *bilabiate* or two-lipped, as in the Dead-nettle (fig. 188). Of this there are

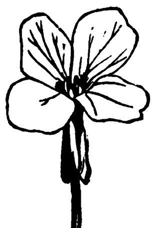


FIG. 186.—Cruciform flower of *Lunaria*, with unguiculate petals.

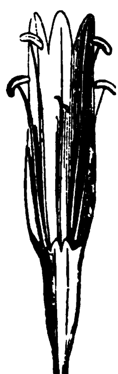


FIG. 187.—Ligulate corolla of *Globularia Alypum.*

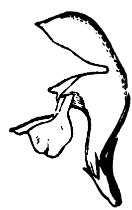


FIG. 188.—Bilabiate ringent corolla of *Lamium album.*

two forms; if the lips are wide apart, as in the Dead-nettle, it is *ringent*; if closed, as in the Snapdragon (fig. 189), it is *personate*; *papilionaceous* or butterfly-shaped, as in the

Laburnum and other members of the Pea-flower tribe (fig. 190). In this case there are five petals, one overlooking the rest, the *standard* or *vexillum* (fig. 190, III.); one standing out on each side, the *wings* or *alæ* (fig. 190, V.); and two united surrounding the stamens, the *keel* or *carina* (fig. 190, IV.).

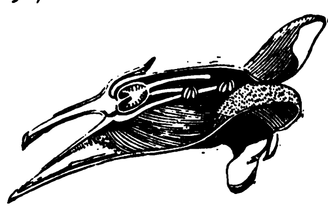


FIG. 189.—Bilabiate personate corolla of *Antirrhinum majus.*

In some cases, as in many of the Orchids, there is a most irregular shape of corolla which has received no special name. The term *caryophyllaceous* is applied to the corolla

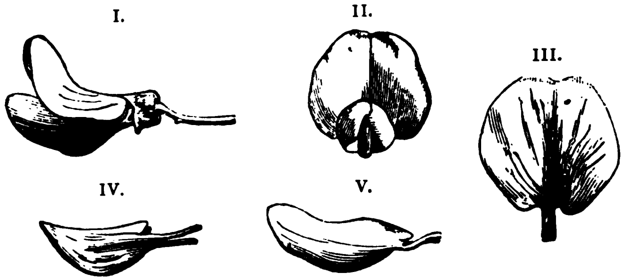


FIG. 190.—Papilionaceous corolla of Laburnum. I. Seen laterally. II. In front. III. Standard. IV. Keel. V. Left wing seen from without.

as is met with in the Pink tribe (figs. 191 and 192), when there are five petals attached by claws to the base of a tubular calyx; whilst if there are five petals, not clawed, and attached in a perigynous manner (fig. 193), the corolla is *rosaceous.*

There are sometimes attached to the corolla subsidiary organs, which are variously arranged, and which, owing to their not being universally present, are not treated of as separate organs. They form the *corona* or *paracorolla*, and are petaloid and well developed in the Narcissus (fig. 194), or small as in the Lychnis (fig. 191), or consist of several hairs as in the Passion Flower and Dead-nettle, or scales with glandular hairs attached as in the Grass of Parnassus

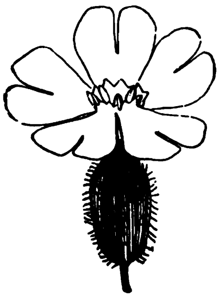


FIG. 191.—Caryophyllaceous corolla of *Lychnis vespertina*, with corona.

FIG. 192.—Longitudinal section through the caryophyllaceous corolla of *Dianthus.*

(fig. 196), or scales known as *staminodes* closing the tube of the corolla as in the Borage (fig. 195).

NECTARIES, or glands for the secretion of honey, are sometimes spoken of as subsidiary organs, but various parts

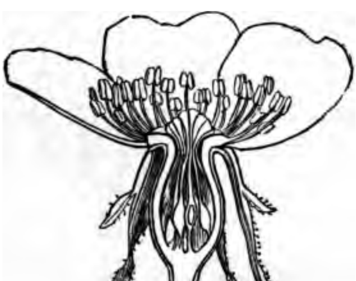


FIG. 193.—Longitudinal section through the rosaceous flower of the Rose; the pistil seated in the base of the urceolate calyx.

FIG. 194. — Petaloid perianth of *Narcissus*, with 6-partite limb and campanulate corona.

of the flower may be specially developed for this function. Thus, there may be scales between the stamens as in the

Grape Vine (fig. 197), or spurs either of the calyx as in the Tropæolum (fig. 164), or of the corolla as in the Valerian (fig. 198), or of both as in the Larkspur (fig. 199), or of the stamens as in the Violet (fig. 201). There may be

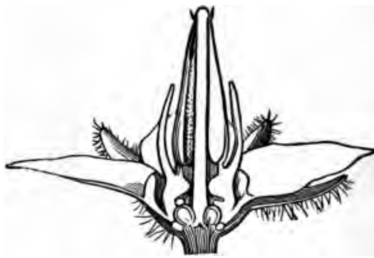


FIG. 195.—Longitudinal section through the flower of the Borage; each bifid stamen bears the anther on its inner half; while the other half forms an erect scale.

specially developed petals, as in the Monkshood (fig. 200); or glands in hollows at the base of the petals, as in the Buttercup.

PERIANTH.—The term *perianth* is generally employed in

I. II.

FIG. 196.—I. Longitudinal section through the flower of *Parnassia palustris*. II. One of the petals; a glandular scale belonging t› the corona attached to it in front.

those cases where the calyx and corolla resemble one another, being both green or both petaloid, especially when it *occurs among* monocotyledonous plants. In this case we *speak of it* as being *gamophyllous* or *polyphyllous*. (Some

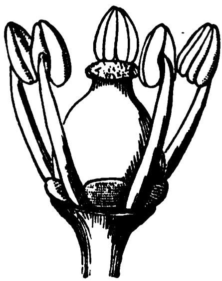


FIG. 197.—Stamens and pistil of the Grape Vine, with a honey gland (nectary) between each pair of stamens.

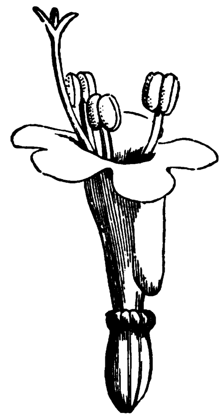


FIG. 198.—Spurred corolla of *Valeriana.*

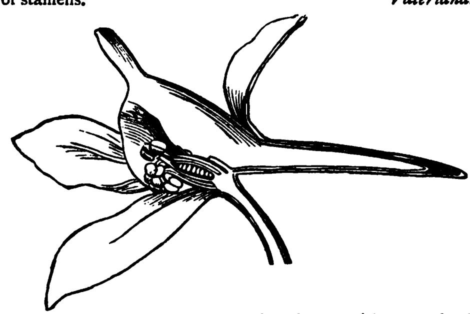


FIG. 199.—Longitudinal section of flower of Larkspur, with spurred calyx and corolla.

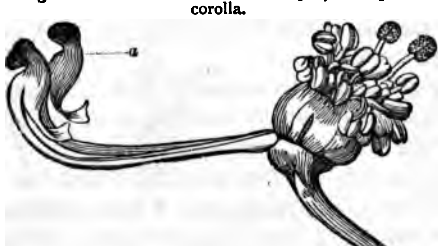


FIG. 200.—Monkshood (*Aconitum Napellus*). Flower, the coloured calyx having *been removed, showing the two petals, a,* developed into nectaries, the remaining *petals being* reduced to scales or altogether abortive.

botanists use the term perianth for describing the flowers which possess only one floral envelope.)

ÆSTIVATION.—Just as the terms *vernation* and *præfoliation* are applied to the arrangement of the foliage leaves in the bud, so the terms *æstivation* and *præfloration* are employed to describe the arrangement of the leaves in the flower bud. The same terms already employed (see Chapter VII.) can also be used in this case. Besides these, however, we apply the term *vexillary* to the æstivation as seen in a papilionaceous plant (fig. 202), and *crumpled* when the petals are crumpled up as in the Poppy.

FIG. 201.—Spurred stamens of Violet.

FIG. 202.—Vexillary æstivation of Papilionaceæ.

ANDRŒCIUM.—We now come to the first whorl of the essential organs of the flower. Each stamen of which the andrœcium is composed consists, when complete, of three parts, viz., the stalk which attaches it to the rest of the flower, and which is known as the *filament*, the knob on the summit, which is in reality a little box, the *anther*, and within this a fine powder, the *pollen*, which is the essential part of the stamen.

These stamens may be either distinct, when they are said to be *free*, as in the Ranunculus (fig. 162), or they are more or less united.

If they are united by means of their filaments into one bundle, whilst their anthers are free, as in the Mallow (fig. 203), they are said to be *monadelphous.*

If there be two bundles, as in the Sweet Pea (fig. 204), the andrœcium is *diadelphous*; and if more than two bundles, as in the Orange (fig. 205), *polyadelphous.* If the stamens are attached together by means of their anthers, whilst the filaments are free, as in the Thistle and other Composite plants (fig. 206), they are *syngenesious*. If the anthers are attached immediately upon the pistil, as in the Birthwort (fig. 207) and various Orchids, they are *gynandrous*.

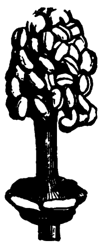


FIG. 203.—Monadelphous stamens of *Malva*.

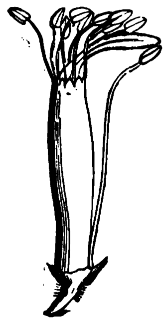


FIG. 204.—Diadelphous stamens of *Lathyrus*; nine filaments united into a sheath at the base; one free.

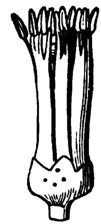


FIG. 205.—Polyadelphous stamens of Orange.

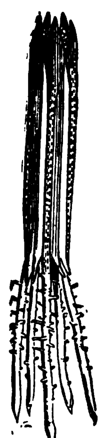


FIG. 206.—Syngenesious anthers of Thistle; the filaments free.

FIG. 207. — Stamens of *Aristolochia* sessile upon the stigma.

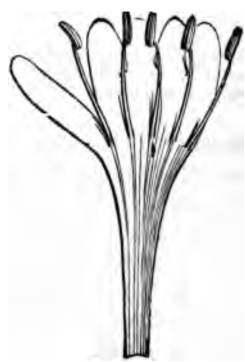


FIG. 208.—Section of corolla of Honeysuckle, with epipetalous stamens.

With regard to the attachments of the stamens, we apply *the same terms* which we used in describing the position of the corolla. Thus, the stamens may be *hypogynous* (fig. 163, H), *perigynous* (fig. 163, P), or *epigynous* (fig. 163, E). In addition to these positions the stamens may be upon the corolla, when they are said to be *epipetalous* (or *epiphyllous* when there is a perianth), as in the Honeysuckle (fig. 208). If the filament of the stamens be absent, as in the Verbena (fig. 209), the anthers are said to be *sessile.*

More often there is a filament present which is generally thin and thread-like, but sometimes, as in some of the stamens of the Water Lily, it is broad and flat. Generally

FIG. 209.—Section of corolla of *Verbena*, with sessile epipetalous anthers.

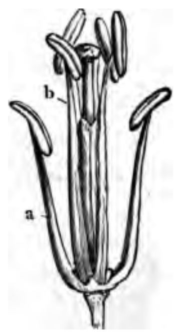


FIG. 210.—Tetradynamous stamens and pistil of *Brassica nigra* : *a* shorter, *b* longer stamens.

FIG. 211. — Flower of *Lamium*, with didynamous stamens.

the various filaments are about the same length, but in some cases there is a constant difference between the stamens on this point. Thus, in the Mustard (fig. 210) and allied plants of the natural order Cruciferæ, there are four long and two short stamens, when they are said to be *tetradynamous* ; whilst in the Dead-nettle and most other plants of the order Labiatæ there are two long and two short, and the stamens are *didynamous.*

If the anthers are attached immediately upon the top of the filaments, they are said to be *innate* in their attachment. If the filament is prolonged up behind the anthers, they are *adnate* ; and if it be attached loosely to the centres of the anthers, so that they swing upon the point of attachment, as in the Wheat (fig. 212), they are *versatile.*

The portion of the filament to which the anthers are attached is called the *connective.* Usually this is not developed to a noticeable degree, but in the Herb Paris it is prolonged beyond the anthers, giving them the appearance of being placed half-way down the stamen.

In the Hornbeam the connective is divided into two equal branches, each of which bears an anther lobe (fig. 213), whilst in the Sage (fig. 214) the branches of the connective are unequal in length; the long one bears a perfect anther

FIG. 212. — Stamen of Wheat, with versatile anther, *b*, lightly fixed at the extremity of the filament, *a*.

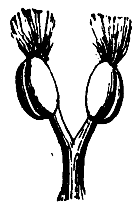


FIG. 213.— Stamen of Hornbeam (*Carpinus Betulus*), with branching connective.

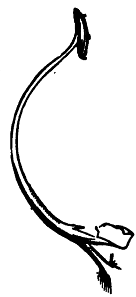


FIG. 214.—Stamen of *Salvia*, with connective branching into two arms of very unequal length; the right-hand arm bearing an abortive anther.

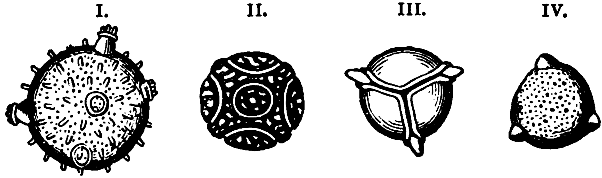
lobe, whilst the short one has an abortive anther, or one destitute of pollen.

The anther lobes are hollow, possessing cells or loculi, of which there is generally one for each lobe, so that the anther is two-celled or *bilocular.* In the early stage of its development there are four cells, two in each lobe; but generally the partition between the loculi in each anther lobe is absorbed, producing the bilocular anther. In some plants, as the Flowering Rush, this division never disappears, and the anther remains four-celled or *quadrilocular* through life. In some few plants, as the Mallow and Milkwort, there is but one cell, and the anther is then said to be *unilocular.*

The surface of the anther to which the connective is attached is known as its *back*, whilst the other side is called the *face*. This is generally grooved, showing the point of attachment of the lobes. When the face is turned towards the pistil, the stamens are said to be *introrse* ; when towards the petals, *extrorse*.

Within the anther lobes there are developed the pollen grains (fig. 215). In the early stages of the growth of the anthers there are a large number of cells forming the central part of each lobe. These are the *parent* or *mother cells* of the pollen grains. Each of these, by cell division, becomes divided into four *special parent cells*, and in each, by a process known as free cell formation, a pollen grain is formed. In free cell formation the protoplasm aggregates around the

I. II. III. IV.



V.

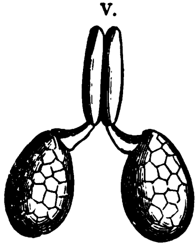


FIG. 215.—Pollen grains. I. *Cucurbita.* II. *Passiflora.* III. *Cuphea platycentra.* IV. *Dipsacus fullonum.* V. Pollen-masses (pollinia) of *Cynanchum Vincetoxicum* (Asclepiadeæ).

nucleus of the mother cell, a cellulose coat is formed around it, and thus for a while we have a cell within a cell. As the pollen grains grow, the walls of the special mother cells and mother cells generally become absorbed and disappear, and the grains thus become loose in the cavity of the lobe. Sometimes, however, the wall of the special parent cells is not quite absorbed, and there is formed a component body of four pollen cells united, whilst in the Orchids the pollen cells of each lobe are completely united together, forming a pollen *mass or pollinium* (fig. 215 E). Each pollen grain possesses two coats : the inner one, the *intine*, is complete ;

the outer one, the *extine*, is pierced by several openings, and is often variously ornamented by spines, protuberances, or reticulations (see fig. 215). The protoplasmic contents of the cell, known as *fovilla*, contain sulphur and fat globules. In form the pollen granule is generally round; in the Chico ey are polyhedral; in the Evening Primrose,

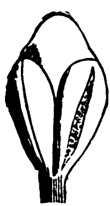


FIG. 216.—Stamen of *Pinus sylvestris* with longitudinal dehiscence.

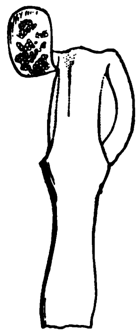


FIG. 217.—Stamen of Barberry, the anther opening by recurved valves.

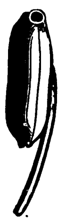


FIG. 218.—Stamen of *Rhododendron*, each anther-lobe opening by a pore.

FIG. 219.—Stamen of Bay (*Laurus nobilis*), with two glands at the base of the filament, the anther opening by recurved valves.

FIG. 220.—Stamen of *Erica*, the anther opening by pores and bearing two appendages at its base.

triangular; in the Basella, cubical; in the Tradescantia, cylindrical; and in the Zostera, thread-like.

In size they vary from $\frac{1}{200}$ to $\frac{1}{1000}$ of an inch. Generally the grains are yellow, in species of Mullein they are red, in some Willow Herbs blue, black in the Tulip, and in other plants green or of a whitish colour.

When the pollen is ripe the anther lobes open to let it fall out. They open or dehisce in various ways.

1. *Longitudinal dehiscence*, as in the Pine (fig. 216) or Tulip, when there is a slit running along the face of the anther from top to bottom. This is the commonest form.

2. *Transverse dehiscence*, generally met with in unilocular anthers, as the Lady's-mantle.

3. *Porous dehiscence*, openings being produced either at the apex of the lobe as in the Rhododendron (fig. 218), or in the side as in the Heath (fig. 220).

4. *Valvular dehiscence*, when a portion of the anther lobe lifts up like a trap door, as in the Barberry (fig. 217) or Bay (fig. 218).

GYNŒCIUM OR PISTIL.—Each of the carpels of which the pistil is made up consists, when complete, of a swollen basal portion, the *ovary*; above this a stalk or *style*, which is capped by the *stigma*. The ovary is a hollow box containing one or more rounded bodies, the *ovules*. Generally the carpels of the pistil are united together either entirely, as in the Lily (fig. 221), or, as is often the case, the ovaries are united whilst the styles and stigmas are free, as in the Sea Lavender (fig. 222). In these cases the pistil is said to be *syncarpous*. When the ovaries are distinct, as in the Buttercup (fig. 162), it is *apocarpous* (when there is only one carpel to the pistil, as in the case of the Pea, it is also said to be *apocarpous*). If there be but one carpel, the pistil is said to be *monocarpellary*. A *bicarpellary* pistil has two carpels, a *tricarpellary* three, a *polycarpellary* pistil more than three.

FIG. 221.—Pistil of Lily, with ovary, style, and stigma.

FIG. 222.—Papillose stigma of *Statice*.

In a syncarpous pistil we can often tell the number of carpels present by the separate stigmas (or styles) (fig. 222).

In other cases we find on making a section that the syncarpous ovary possesses several cells or loculi, each corresponding with a single carpel, so that from them we can count the number of carpels (fig. 223). Sometimes we find that there is but a single loculus in the ovary, and we can then often tell the number of carpels by noticing in how many places the ovules are arranged (fig. 224).

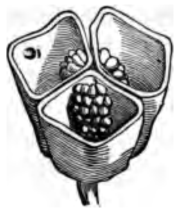


FIG. 223.—Capsule of *Colchicum*; transverse section.

FIG. 224.—Section of ovary of *Viola*.

In some few cases it is difficult or almost impossible to be able to say definitely in an individual plant how many carpels are present. The ovary, as we have seen, may be either *inferior* or *superior*. In the former case it is either inserted in the fleshy end of the flower stalk known as the *thalamus* or *receptacle*, so that the calyx springs from above it, or the calyx tube is adherent to the wall of the ovary, the free limb springing from the top. We often find two lines running down the ovary from apex to base. These are known as the *sutures*: the one towards the centre of the flower is the *ventral suture*, whilst the one turned towards the perianth is the *dorsal suture*.

When the pistil is apocarpous, each ovary contains but one cell, or is *unilocular*, although sometimes there are false partitions growing partially across the cell.

In syncarpous ovaries there are often numerous cells agreeing with the numbers of the carpels (fig. 225, D), when the ovary is *bi-*, *tri-*, or *multilocular*. In other cases there is but one cell (fig. 225, B), the ovary being *unilocular*. Sometimes there are partial dissepiments formed by an infolding of the edges of the carpels (fig. 225, C). In some few cases there are actual divisions; thus, the ovary of the Labiatæ and Boraginaceæ is originally bilocular, but by a subsequent division it becomes divided into four cells. The ovules are not, as a rule, distributed indiscriminately over the surface of the ovary, but are arranged on certain parts of the wall, each of which is called a *placenta*, whilst the arrangement of the ovules is spoken of as *placentation*.

In the case of apocarpous pistils, where there are more than one ovule, they are generally arranged along the ventral

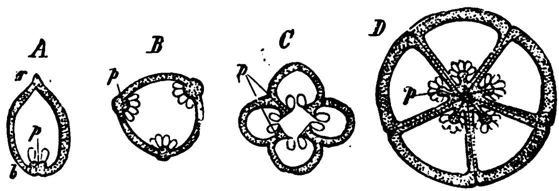


FIG. 225.—Diagrammatic sections of Ovaries: *p*, the placenta, to which the seeds are attached; *A*, monocarpellary unilocular; *B*, polycarpellary unilocular; *C*, polycarpellary falsely multilocular; *D*, polycarpellary multilocular; *r*, dorsal suture, or midrib; *b*, ventral suture, or margins of carpel. (After Prantl.)

suture, and the placentation is said to be *marginal* (figs. 226 and 225, A). In the multilocular syncarpous pistil the ovules are generally arranged in the central axis, where the cells of the ovary meet (fig. 225, D), and the placentation is *axile*.

When the ovary is unilocular, the ovules are arranged either upon the wall (fig. 225, B), or upon slight projections (fig. 225, C), and the placentation is *parietal*.

In some cases of a unilocular ovary, as in the Primrose and Pink, the ovules are attached to the end of the flower stalk which grows up into the ovary (fig. 227). In this case, which is known as *free central placentation*, the walls of the ovary are perfectly free from the ovules, as can be seen by cutting the pistil of a Pink or Primrose, when the walls can be cut away, leaving the column of ovules in the centre.

The style, when present, forms a conducting tube from he stigma to the ovary. In the Violet and Flowering Rush it consists of a perfectly hollow tube ; more often, although hollow at first, it becomes afterwards filled up by the growth of 'conducting tissue,' so that at the time of fertilisation no channel is evident. As a rule, the style grows from the top

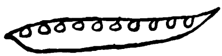


FIG. 226.—Marginal placentation.

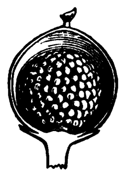


FIG. 227.—Unilocular ovary of *Hottonia*, with free central placenta.

FIG. 228.—Lateral style of Strawberry.

of the ovary, when it is said to be *terminal.* If it springs out from the side, as in the Strawberry (fig. 228), it is *lateral*; if from the base, as in the Alchemilla (fig. 229), it is *basilar.*

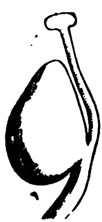


FIG. 229. — Basilar style of *Alchemilla*.

FIG. 230.—Petaloid stigmas of *Iris*.

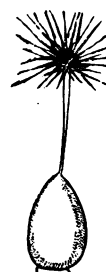


FIG. 231. — Pistil of *Parietaria*, with penicillate stigma.

Very often the style is absent, in which case the stigma is said to be *sessile* upon the ovary.

The *stigma* is intended to receive the pollen grains, and hence its presence is necessary in the perfect pistil. It varies much in appearance. In some cases it is merely an opening at the top of the style, upon which is secreted some glutinous fluid. In other cases it is variously enlarged. It is *capitate*, or forming a head, in the Primrose and Lily (fig. 221); *petaloid* in the Iris (fig. 230); *penicillate*, with a number of hair-like arms, in the Pellitory of the Wall (fig. 231); *peltate*, or shield-like, in the Poppy (fig. 232).

FIG 232.—Peltate stigma of Poppy, with hypogynous stamen.

The *ovule*, when in a young state, consists simply of a mass of parenchymatous cells; these soon become surrounded by coats, the *primine* (*ai*, fig. 233), and the *secundine* (*ii*, fig. 233). These coats are not complete, leaving an opening, the *micropyle* (fig. 233, *m*), leading into the interior of the ovule, which is composed of the original cellular mass forming the *nucleus* (*k*), amongst which is one cell, the *embryo sac* (*em*), larger than the rest.

The ovule is generally attached to the placenta by a short stalk, the *funiculus* (*f*), but at other times it is sessile

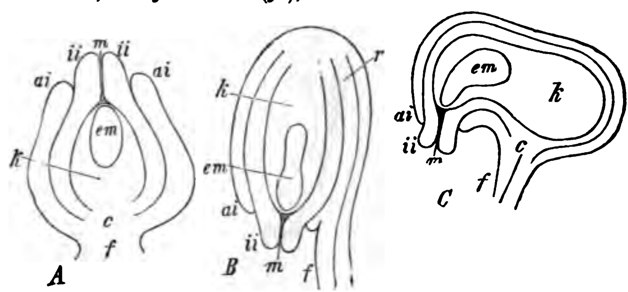


FIG. 233.—Diagrammatic longitudinal sections of ovules: *A*, orthotropous or straight; *B*, anatropous or inverted; and *C*, campylotropous or bent ovule. *ai*, outer integument or primine; *ii*, inner integument or secundine; *m*, the micropyle; *k*, the nucleus, with the embryo-sac, *em*; *c*, the chalaza or base of the nucleus; *f*, the funiculus; *r*, the raphe of the anatropal ovule, formed by the fusion of the outer integument and funiculus. (After Prantl.)

upon the ovary. The point by which the ovule is attached *to the funiculus* (or placenta) is the *hilum*, whilst the point by which the nucleus is attached to the integuments is the *chalaza* (*c*).

There are three forms of ovules differing in their arrangements of the parts :—

Orthotropous ovule (fig. 233, A). In this case the nucleus is straight, the chalaza and hilum are in proximity, and the micropyle is removed to a distance from the funiculus. This form is rare, being met with in the Rhubarb and its allies in the natural order Polygonaceæ.

Anatropous ovule (fig. 233, B). In this case the nucleus is straight, but is inverted upon the funiculus, so that the micropyle is brought down into close proximity with the stalk, whilst the hilum and chalaza are separated, being united by a prolongation of the funiculus known as the *raphe.* This form is well seen in the Dandelion and White Water Lily.

Campylotropous or *bent ovule* (fig. 233, C). In this case the nucleus is bent, so that whilst the micropyle is brought near the funiculus, as in the anatropous form, the chalaza and hilum are in close proximity as in the orthotropous form, and there is no need of a raphe. The Wallflower and Mallow are examples of this kind. These three forms are united by many modifications.

THALAMUS AND DISC.—The thalamus, or end of the flower stalk upon which the various floral organs are inserted, is often specially modified. Thus, in all plants with a free central placentation it is prolonged into the ovary, bearing the ovules. In other cases, as in the Umbelliferæ and Geraniaceæ, it is prolonged between the carpels and beyond the ovary, and is known as the *carpophore* (see page 140).

In other cases, as in some forms of Lychnis, Pink and Passion-flower, it is prolonged beyond the calyx, forming a stalk for the ovary (fig. 234), and it is known as the *gynophore.* In many plants it is much swollen, and the ovaries are sunk or embedded in it, often giving them a syncarpous appearance when they are truly apocarpous.

We sometimes find between the calyx and pistil a body or bodies which are not universal among flowers, and which cannot be referred to any of the organs above described. To this body the name of *disc* is applied. In the Mignonette and Orange it forms a fleshy swelling below the pistil; in Umbelliferous plants it surmounts the ovary adhering to the styles. In other cases it is variously developed.

FERTILISATION.—In order that the ovary and ovules may properly perform their functions, it is necessary that they should be fertilised by the pollen. The pollen grains adhere to the stigma (fig. 235, *b*), and being nourished by the viscid secretion present, a portion of the intine protrudes either through an opening already existing in the extine, or forcing its way through a part where the outer walls were thinner. The prolongation thus formed is known as a *pollen-tube* (fig. 236). These tubes grow down the loose conducting tissue of the style and enter the ovary.

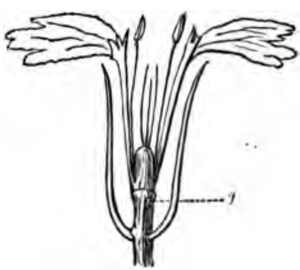


FIG. 234.—Section of *Lychnis Flos-Jovis*, with gynophore, *g*.

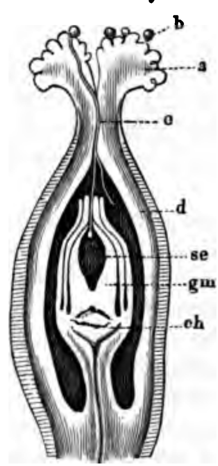


FIG. 235.—Longitudinal section through the uniovular ovary of *Polygonum Convolvulus* at the time of flowering: *a*, stigma; *b*, pollen grains; *c*, pollen-tube; *d*, wall of the ovary; *gm*, the erect orthotropous ovule; *se*, its embryo-sac; *ch*, chalaza; two pollen-tubes have penetrated through the conducting tissue of the style, one of which has entered the micropyle of the ovule, the other not.

The time necessary for this varies from a few hours to several weeks. In the Crocus it takes from twenty-four to seventy-two hours; in the Arum over five days, and in the Orchids even some months. Just previous to this, or about the same time, a change has been going on in the embryo-sac of the ovule. Usually one or two cells are produced

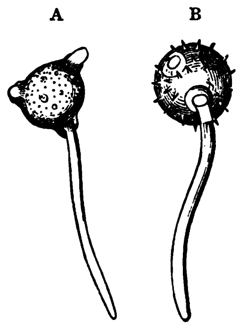


FIG. 236.—Pollen grains putting out their pollen-tube: A, *Dipsacus fullonum*; B, *Cucurbita.*

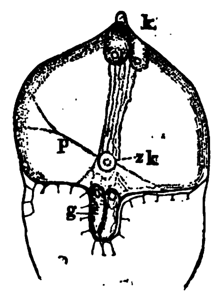


FIG. 237.- Upper part of the nucleus of the ovule of *Crocus*: *p*, the embryo-sac with its nucleus, *zk*; *k*, the embryonic vesicles; *g*, the antipodal cells.

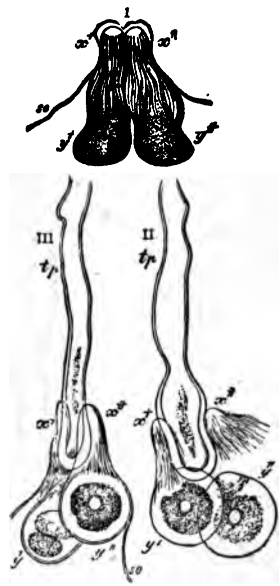


FIG. 238.—The process of fertilisation in *Gladiolus segetum*. I. The two embryonic vesicles at the apex of the embryo-sac; *x' x''*, the filiform apparatus; *y' y''*, the balls of protoplasm ready for fertilisation; *s e*, the wall of the embryo-sac. II. A pollen tube, *t p*, which has just fertilised the two embryonic vesicles in contact with it; the cell-walls which surround the balls of protoplasm are still very thin. III. A somewhat later stage; the cell-walls are thicker; the fertilised vesicle *y'* is beginning to develop and to divide into two.

within the embryo-sac at the end away from the micropyle. These are known as *antipodal cells* (fig. 237, *g*), and their function is unknown. Soon after their formation two nuclei are produced at the other end of the embryo-sac, round which the protoplasm becomes aggregated, forming two *embryonic* or *germinal* vesicles or cells (fig. 237, *k*). These vesicles appear to be membraneless before fertilisation, but on the approach of the pollen-tube a cellulose coat is formed round each. The pollen-tube passing into the ovary enters the micropyle of one of the ovules, and, arriving at the apex of the embryo-sac, comes in contact with one of the embryonic vesicles, fertilising it by the passage of the fovilla of the pollen into it by osmosis (figs. 238 and 239). The first change that takes place (after the surrounding of the embryonic vesicle by a cellulose coat) is the division of the vesicle into two (fig. 238, II., *k*). The upper cell being developed into a suspending cord, the *suspensor* or *proembryo* (fig. 240, *et*), at the end of which the *embryo* or young plant, formed by the division of the lower cell, is attached (fig. 240, *e*). At the same time a number of cells are produced within the embryo-sac by free cell formation; these are filled with nutritive materials, and are known as *endosperm*. Sometimes nutritive cells are produced within the nucleus *outside the* embryo-sac. In this case the term *perisperm* is employed. Very often as the embryo increases in size the

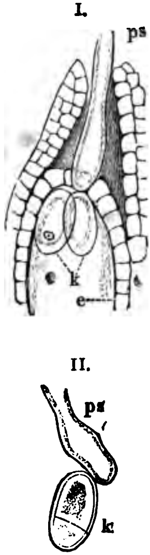


FIG. 239.—Fertilisation of *Canna*. I. Apex of the embryo-sac, *e*, at the time when the pollen tube, *ps*, has just come into contact with the embryonic vesicle, *k*. II. Fertilised embryonic vesicle separated.

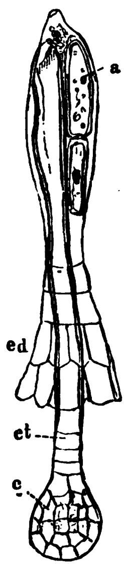


FIG. 240.—Formation of the embryo of *Heliotropium*: *ed*, endosperm; *et*, suspensor; *e*, rudiment of the embryo, its enveloping membrane being already formed; *a*, cells developed out of the two embryonic vesicles.

nutritive cells around are absorbed, until, as we have seen is the case with the Broad Bean, the young plant occupies the

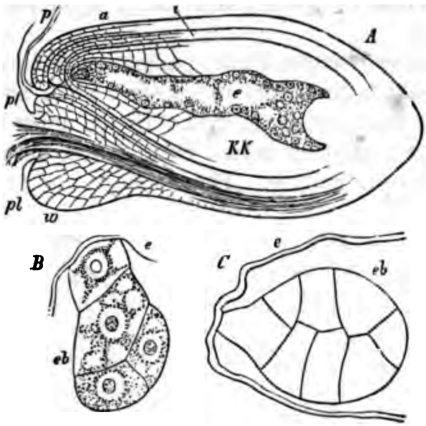


FIG. 241.—*Viola tricolor*. *A*, longitudinal section of anatropous ovule after fertilisation: *pl*, placenta; *w*, swelling on the raphe; *a*, outer; *i*, inner integument; *p*, pollen-tube entering micropyle; *e*, embryo-sac, with the fertilised germinal vesicle, at the micropyle end, and numerous endosperm cells at the other. *B*, apex of embryo-sac, *e*, with young embryo, *eb*, of three cells, and one cell forming the suspensor or pro-embryo. *C*, same, further advanced. (After Sachs.)

whole of the nucleus. In other cases a part of the endosperm, or of the perisperm, or of both, persists, forming the so-called *albumen*, so that this latter may consist of endosperm, or of perisperm, or of both.

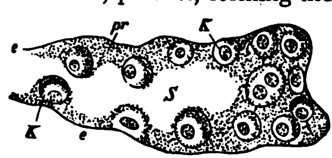


FIG. 242.—*Viola tricolor*. Posterior kind of embryo-sac: *e*, wall; *S*, cavity of the cell; *K*, *K*, young endosperm cells formed by free cell formation in the protoplasm, *pr*. (After Sachs.)

In the fertilisation of the Fir trees and their allies there is a modification of this process. In the first place the pollen grains divide into two cells before pollination, and the tube, instead of being formed from the entire grain, is produced by one of the cells (fig. 243). In the next place the ovules, instead of being enclosed in an ovary, are naked (whence the plants are said to be *gymnosperms*, or naked-seeded plants, whilst other flowering plants are *angiosperms*, or enclosed-seeded plants), so that the pollen falls direct upon the micropyle (fig. 244).

The embryo-sac soon after pollination is filled with endosperm, which disappears after a short while, and a second quantity is subsequently formed. In the upper part of this there are several cells which enlarge and form *secondary embryo-sacs* or *corpuscula*. These split up into two cells, the

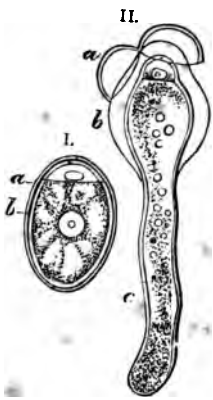


FIG. 243.—Fertilisation of *Cupressus sempervirens* (Coniferæ). I. A pollen grain with its two cells; *a*, extine; *b*, intine. II. Pollen grain in which the pollen tube, *c*, has been formed.

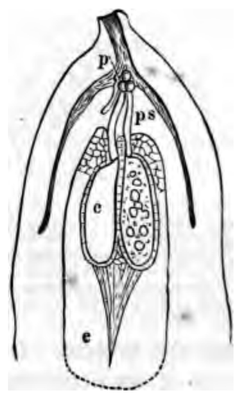


FIG. 244.—Fertilisation of *Abies excelsa*: *p*, pollen grains; *ps*, pollen tubes; *c*, two corpuscules in the embryo-sac, *e*.

upper or neck cell breaking up into several, which form a tube or neck leading into the lower cell, which enlarges, forming the *oosphere*. The pollen tube grows down to the oosphere, fertilising it and causing it to break up into a *pro-embryo* or *suspensor*, which forces its way through the embryo-sac, and at the end of which the embryo is produced.

Recent investigations seem to point out that in the fertilisation of *Angiosperms* there is a certain approach to this process as seen amongst the Gymnosperms. In 'Nature' for July 1879 an interesting paper appeared, giving an account of the researches of Messrs. Strasburger and Elfving, at Jena. They treated pollen grains with osmic acid so as to render the contents more visible, and then they grew them artificially in sugar solutions. In a number of the cases observed there seemed to be a breaking up into two or three cells previous to the emission of the tube, which latter was given off from one of the cells (fig. 245), as we have seen is the case with Gymnosperms. It is a question which requires further investigation.

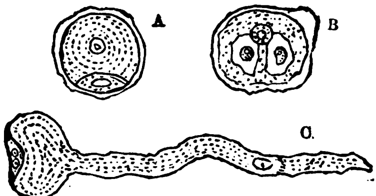


FIG. 245.—Pollen of Tulip, A, B; and of Flowering Rush, C.

As a general rule the pollen is not capable of fertilising the ovules of the *same* flower, and hence has to be taken to another, and the process known as *cross-fertilisation* is brought about. The pollen is carried from flower to flower by various means. The first agency we shall notice is the wind. In the Hazel, for example, we have a monœcious plant with unisexual flowers. It is evident that the pollen must be transferred from one flower to another. The male and female catkins are on the same plant (fig. 159), the former pendulous with numerous anthers and a large quantity of pollen, the latter erect with the red stigmas appearing through the enveloping bracts. When the pollen is fully ripe it is shed from the anther cells and scattered by the wind; the greater portion is wasted, but some falls upon the stigmas, fertilising them. Such a plant is said to be *anemophilous*, or wind fertilised. Other examples of anemophilous plants are to be found in the Oak, the Willow (where the staminate and pistillate flowers are on separate trees), the Fir, the Yew, and various Grasses and Cereals. In all these cases the flowers are small and inconspicuous and destitute of odour, whilst the pollen is produced in a far larger quantity than is actually needed for fertilising purposes. Often in Fir forests the pollen is given off into the air in such enormous quantities that it is washed down by the rain as a yellow powder, and is popularly known as *sulphur rain.*

More important agents in the fertilisation of flowers are insects. In all cases of insect-fertilised (*entomophilous*) plants the flowers possess either rich and variegated colours, or sweet odours, or have both qualities. These serve to attract the insect, whilst in some part of the flower honey is stored up in a nectary. Whilst endeavouring to obtain this, the insect comes into contact with the anther, and the pollen is scattered over portions of its body, and, being carried away, adheres to the glutinous stigma of the next flower visited.

The mechanical contrivances and arrangements to ensure this proper distribution of the pollen are very numerous. In an elementary book such as this it is only possible to notice a few typical forms.

In many cases it is impossible for the flowers to be self-fertilised, as either the anthers are ripened before the stigmas, or the stigmas before the anthers. This is known as *dichogamy*, and in the former case the flower is *protandrous*, and the pollen has to fertilise the pistil of a flower which preceded it in opening; whilst in

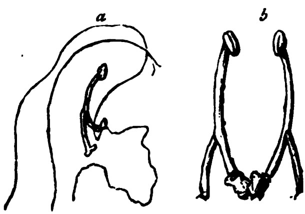


FIG. 246.—Sage fertilisation.

the latter case the flowers are *protogynous*, and the pollen fertilises a later flower.

A good example of a protandrous plant, and one which at the same time shows mechanical arrangements for ensuring the delivery of the pollen upon the right part of the insect's body, is to be found in the Sage. Fig. 246 shows in diagrammatic form the arrangement of the parts in *Salvia officinalis.* The corolla is bilabiate, the lower lip forming a convenient resting place for the insect to stand upon, whilst the upper lip protects the stamens and pistil from the rain.

The stamens, two in number, have branched connectives; the lower lobes are abortive and united together (*b*), so that if either be pushed it affects both stamens. The upper lobe is full of pollen, and is poised upon the movable connective in such a manner that if the abortive lobes are pushed backwards and upwards the upper ones come downwards and forwards. In the corolla tube honey is secreted. The style and stigmas at first are placed well back against the upper lip, and are not matured until after the pollen. When they are matured, however, the style bends forward (*d*), bringing the stigmas near the centre of the mouth. If a bee visits one of the flowers, which has its pollen matured, in order to seek for honey, it will, on entering the flower and plunging its proboscis into the tube, strike its head against the lower anther lobes, bringing the fertile lobes down against its sides, covering its body with pollen (*c*).

If it now visits another flower in the same condition, it will simply have its stock of pollen increased; but if it visits a flower which has its pistil bent over, evidently the stigmas will strike against the insect's back, and some of the pollen scattered there will adhere to the glutinous stigmatic surface.

Other protandrous flowers are met with in the Mallows, the Geraniums, many Campanulas, the Pinks and other members of the Caryophyllaceæ, many Compositæ, Umbelliferæ and others.

Protogynous flowers are much less common, but they are met with amongst the Plantains, the Scrophularias, the Magnolias and other species of plants.

Another arrangement is known under the name of *heterostylism,* where the pistils and stamens of different flowers are of various lengths. A good example of a heterostylic flower is to be found in the common Primrose. If we examine a bunch of common Primroses we shall find the flowers of two different kinds. Some have a little knob filling up the mouth of the corolla tube, and others a rosette. On making a vertical section of one of each kind of flower, we find the arrangement as shown in fig. 247. In the first case we have the pistil with a long style (247, I.), the stigma of which forms the 'knob' filling up the corolla tube, whilst the stamens are placed low down in the tube. In the other case the stamens are high up, forming the 'rosette' (247, II.), whilst the style is short and the stigma at about the same height as the stamens in the preceding variety. Such a flower is said to be *dimorphic*, and we can speak of the 'long-styled' and 'short-styled' varieties of Primrose. There is a slight difference in the pollen and the stigmas in the two cases. The pollen grains of the short-styled flowers are larger than those of the long-styled flowers, and the stigma in the latter case is globular, whilst in the former it is depressed in the centre. A number of careful experiments by Professor Darwin and others show that long-styled flowers are fertilised by the pollen from short-styled, and *vice versa* the short-styled are fertilised by the pollen from the long-styled. Such a cross Mr. Darwin calls *legitimate union*, whilst the term *illegitimate union* is applied to the union of long-styled pollen with long-styled stigma. This illegitimate union will not produce seeds to the extent that the legitimate will, and in some dimorphic flowers none at all are formed.

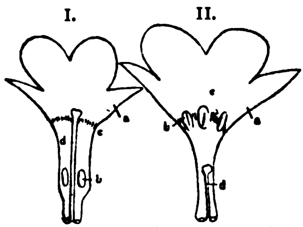


FIG. 247.—Dimorphic flower of *Pulmonaria*. I. Long-styled. II. Short-styled form: *a*, corolla; *b*, anthers; *c*, ring of hairs; *d*, pistil.

In some species of Lythrum we have *trimorphic* flowers: one with long style, six medium stamens, and six short stamens; one with medium style, six long stamens, and six short stamens; and one with short style, six long stamens, and six medium stamens. In such cases we always find that the long style is fertilised by the long stamens, the medium style by the medium stamens, and the short style by the short stamens, as shown by the lines in the diagram.

Whilst these provisions for cross fertilisation are the rule amongst flowers, in some few cases there is a special arrangement for self-fertilisation. The Sweet Violet is a good example. The well-known flowers that appear in the spring do not, although fertilised by insects, bear fruit. They are

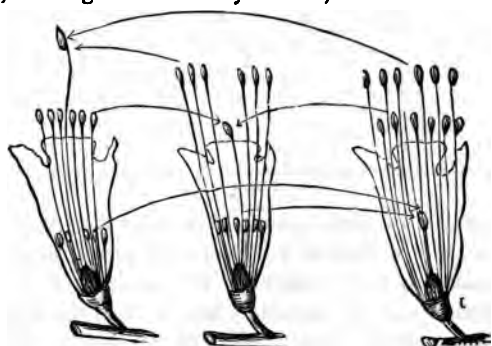


FIG. 248.—Trimorphic forms of *Lythrum*.

followed in the summer by small inconspicuous apetalous flowers, where the stamens and pistil are enclosed in a calyx which does not open. The result is, the flowers are fertilised by their own stamens. Such flowers are said to be *cleistogamous*. Besides this there are other examples where self-fertilisation is specially provided for.

RELATION OF FLOWER TO OTHER PARTS OF THE PLANT.

The parts of the flower must be looked upon as modified foliar organs. This is pretty evident in the calyx and corolla, but not so well seen at first in the stamens. We have proof, however, in the facts, 1st, of the tendency in *double flowers* to form petals instead of stamens; and

2nd, the gradual transition from petals to stamens as seen in the white Water Lily, or *Rosa centifolia* (fig. 249).

In some cases the filament appears to represent the petiole, the connective the midrib, and the anther the blade, when the pollen would represent the general internal tissue of the leaf. In other cases the filament appears to be the leaf blade, and the anthers and pollen appendages upon it.

We must regard the carpels as leaves (carpellary leaves), either folded over so that their edges meet, when the dorsal

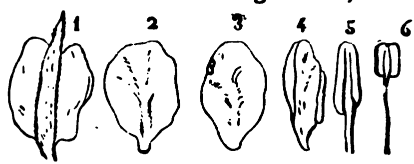


FIG. 249.—Stages of transition between the petals and stamens of *Rosa centifolia.*

suture marks the midrib, and the ventral the margin of the leaves, or, in a unilocular polycarpellary pistil, the carpellary leaves unite by their margins. The placenta is developed on the margin of the carpellary leaves, or in the free central placentation on the prolongation of the stem. The ovules are appendages of the carpellary leaves or, in the case of the free central placentation, buds upon the prolonged axis.

CHAPTER XI.

FRUIT AND SEED.

AFTER fertilisation a change takes place in the ovary; it enlarges and changes very much in appearance, forming the fruit. Botanically the fruit is the ripened ovary. Many so-called fruits, however, have in addition to the ovary some other part of the flower attached. Thus in the *Strawberry* and Apple, the fleshy edible part is the enlarged *receptacle or thalamus*, the pips of the Strawberry and the core of the Apple being the true fruits. In these cases the term *pseudocarp* is applied. Sometimes the whole inflorescence will be matured into a single fruit-like mass, when the term *syncarp* is used; whilst if the bracts or any other part of the floral organs are added in so as to produce a pseudocarp, as in the Pineapple and Mulberry, the term *pseudosyncarp* is employed (fig. 250).

(Care must be taken not to confound the terms *syncarp* and *syncarpous* pistil or fruit, the latter term being, as we have seen, restricted to those ovaries and fruits where the carpels are united together, whilst the former term is used for matured inflorescences even if the pistil be apocarpous.)

FIG. 250. — Multiple pseudocarp of the Mulberry.

The walls of the ovary consist of three layers: hence in the fruit we find three layers present, the outer or *epicarp*, the middle or *mesocarp*, and the inner or *endocarp*. Often these three layers cannot easily be distinguished from one another, at other times they are very evident. The number of cavities or loculi in the fruit generally corresponds to that in the ovary; sometimes, however, some of the partitions disappear, so that the fruit possesses fewer loculi than the ovary.

We may divide fruits into those which are *dehiscent* or break, and those which are *indehiscent* or do not break, when ripe.

DEHISCENT FRUITS.

When a dehiscent fruit opens so that the seeds fall out, it is known as a *capsule*. The dehiscence may take place longitudinally or from top to bottom of the fruit, breaking it into several valves, it is then said to be *valvular*; or it may take place in a transverse manner, opening off like a lid, when it is described as *transverse* or *circumscissile* dehiscence (fig. 252); or lastly, there may be small openings or pores, when the dehiscence is *porous* (fig. 253).

If the longitudinal dehiscence is partial, so as to only take place at the top of the fruit by means of a number of teeth, it is *dehiscence by teeth* (fig. 251).

If the dehiscence is complete, it may either take place by the ventral suture, or by the dorsal suture, or by both. Again, in some cases, the walls of the loculi split open, leaving the septa attached to them, as in the Lily and Iris;

FIG. 251. — Capsule of *Primula* dehiscing by ten teeth.

FIG. 252.—Capsule or pyxis of *Anagallis*, with circumscissile dehiscence.

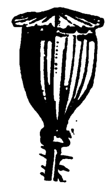


FIG. 253. — Capsule of Poppy, dehiscing by pores beneath the peltate stigma.

the dehiscence is then said to be *loculicidal.* It is *septicidal* when the fruit breaks up into its separate carpels, the dehiscence taking place down the septa themselves, as in the Rhododendron and Colchicum; and it is *septifragal* when

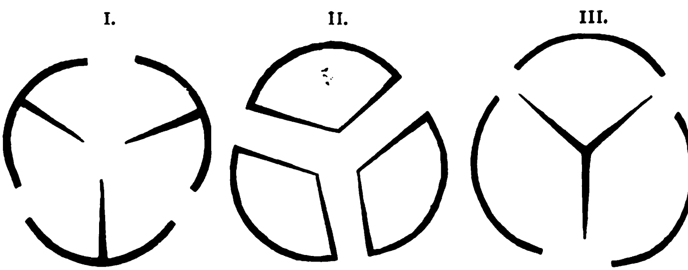


FIG. 254.—I. Diagram of a loculicidal capsule. II. Diagram of a septicidal capsule. III. Diagram of a septifragal capsule.

the carpels, opening by their dorsal sutures, the dissepiments separate from the valves, being still attached in the centre, as in the Thorn Apple (see figs. 254 and 255).

Some forms of capsules have received special names. *A pyxis is* a capsule dehiscing transversely, as in the *Anagallis (fig.* 252), and Plantago (fig. 256).

A *legume*, or pod, is a unilocular monocarpellary capsule, dehiscing by both dorsal and ventral sutures, as in the Pea (fig. 257).

A *follicle* is a monocarpellary capsule dehiscing by

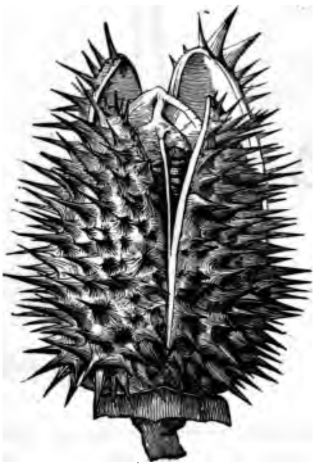


FIG. 255.—Septifragal capsule of *Datura*.

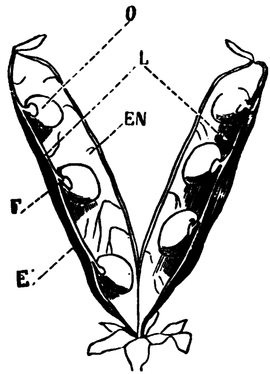


FIG. 257.—Legume of Pea split lengthwise: E, outer; E N, inner layer of the pericarp; L, placenta; F, funiculus; O, seed.

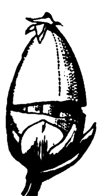


FIG. 256. — Capsule or pyxis of *Plantago*, with circumscissile dehiscence.

FIG. 258.—Fruit of *Illicium* or Star-Anise, consisting of a number of follicles.

ventral suture (figs. 258 and 259), or, in some Magnolias, by dorsal suture, only.

A *siliqua* is a syncarpous bicarpellary capsule, one-celled, with a false division or *replum* running up the centre. It is long and narrow in shape, and the two side walls break away, leaving the central replum with the seeds. An example is seen in the fruit of the Wallflower (fig. 260).

A *silicula* resembles the last, except that instead of being long and narrow, it is short and broad (fig. 261).

When a dehiscent fruit breaks up into several portions which

FIG. 259.—Fruit of Peony, consisting of two follicles.

FIG. 260.—Wallflower (*Cheiranthus Cheiri*). Siliqua.

are usually one-seeded and remain closed, although they do in some few cases open to allow the seeds to fall

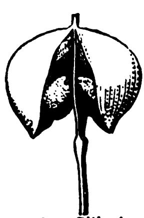


FIG. 261.—Silicula of *Cochlearia*, open and showing the seeds attached to the replum.

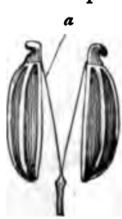


FIG. 262.—Cremocarp of the Fennel: *a*, carpophore.

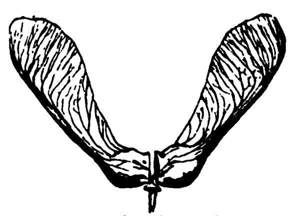


FIG. 263.—Bipartite schizocarp of the Maple, consisting of two samaræ.

out, it is called a *schizocarp*, the divisions being called mericarps.

There are also several varieties of schizocarp.

A *cremocarp* is a bicarpellary schizocarp dehiscing into *two mericarps* attached to a central carpophore. Examples are found in the Fennel (fig. 262) and the other members of the order of Umbelliferæ.

A *samara* is a winged fruit; in some cases, as in the Maple (fig. 263), it is a schizocarp breaking up into two one-seeded portions; in other cases, as in the Birch (fig. 264), it is an indehiscent fruit.

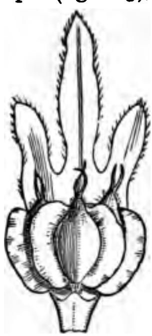


FIG. 264.—Bract of the Birch (*Betula*), with three samaræ in its axis.

FIG. 265. — Lomentum of *Hedysarum*.

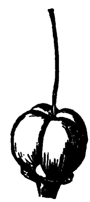


FIG. 266.—Quadripartite schizocarp of *Ajuga*, consisting of four nucules.

FIG. 267. — Tripartite schizocarp of *Tropæolum*.

A *lomentum* is a schizocarp dehiscing transversely into two or more one-seeded mericarps, as in the Hedysarum (fig. 265), and Radish.

A *carcerulus* is a quadripartite schizocarp, as seen in the Bugle (fig. 266) and other labiate plants. Each of the four divisions is often called a *nucule*. In other cases the schizocarp may be *tripartite* (divided into three mericarps) as in the Indian Cress (fig. 267), *quinquepartite* (five mericarps) as in the Geranium (fig. 268), or *multipartite* (many mericarps) as in the Mallow (fig. 269).

INDEHISCENT FRUITS.

The *drupe* or *stone fruit*. In this case the three layers of the fruit are always distinct. The endocarp is hard, forming the so-called stone. The epicarp and mesocarp differ in their consistency. In the Plum, Cherry, and

Peach (fig. 270), the epicarp forms the skin, and the mesocarp the succulent edible portion. In the Cocoanut (fig. 271) both epicarp and mesocarp are dry and fibrous, whilst in the Almond and Walnut they are leathery. In some few cases, as in the Cornel

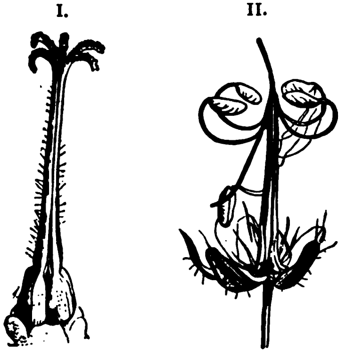


FIG. 268.—Quinquepartite schizocarp of *Geranium Robertianum*. I. The immature pistil. II. The mature fruit.

FIG. 269.—Multipartite schizocarp of *Malva*.

(fig. 270, II.), there are two loculi in the drupe, usually there is but one.

The *berry*, as seen in the Gooseberry (fig. 272), Grape, or Currant, has the endocarp soft and succulent, as well as the mesocarp, whilst the epicarp forms a skin. In the Gourd

FIG. 270.—I. Longitudinal section through the unilocular drupe of the Peach. II. Through the bilocular drupe of *Cornus*.

and Cucumber we have a fruit much resembling the true berry, but the outer layers are firmer and harder ; such a variety of berry is known as a *pepo*. The fruit of the Orange, known as a *hesperidium*, is a multilocular berry, whilst in the Apple we have a berry-like pseudocarp, the fleshy edible portion being the enlarged thalamus and the scales above forming the remains of the calyx, whilst the core is the true fruit. This variety is known as a *pome*.

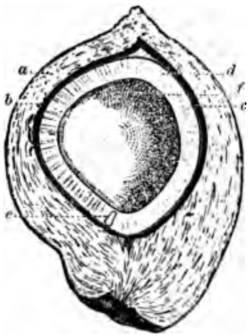


FIG. 271.—Longitudinal section of Cocoanut : *a*, epicarp ; *b*, endocarp ; *c*, testa ; *d*, endosperm or albumen ; *e*, embryo ; *f*, cavity in the endosperm which contains the milk.

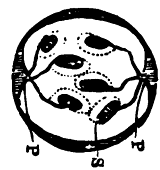


FIG. 272. — Transverse section through a Gooseberry ; the firmer outer layer of the pericarp encloses the succulent flesh ; the seeds lie imbedded in the latter, and are attached by long funiculi to two opposite parietal placentæ.

In the *achene* (fig. 274) all three layers of the fruit are dry, whilst if they are lignified, as in the Nut and Acorn (fig. 275), the term *glans* is employed.

Sometimes we have several fruits produced from the ripening of the apocarpous pistil of a single flower, and the name of *etærio* is applied.

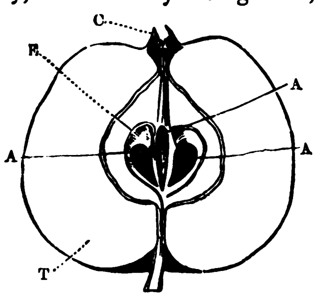


FIG. 273. — Longitudinal section through an Apple : C, dry persistent calyx limb ; E, loculi with cartilaginous pericarp ; T, mesocarp.

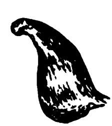


FIG. 274.—Achene.

Thus in the Raspberry, Blackberry, and Dewberry (fig.

276) we have an etærio of drupes. In the Buttercup and Strawberry we have an etærio of achenes (in the latter

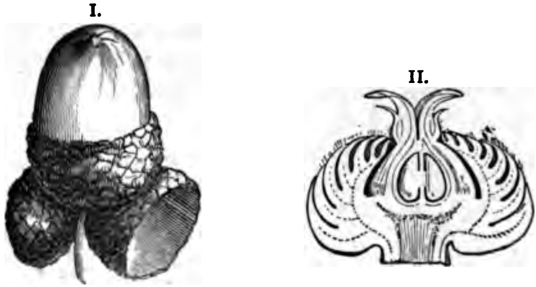


FIG. 275.—I. Acorn of *Quercus sessiliflora*, with two empty cupules. II. Longitudinal section through the fertilised pistillate flower, with the cupule in an early state.

case, as we have seen, the edible portion is the enlarged thalamus).

In the Rose (fig. 278) we have an etærio of achenes

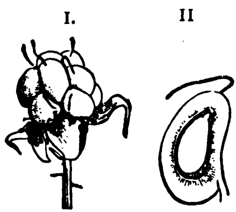


FIG. 276.—Fruit of Dewberry (*Rubus cæsius*). I. Natural size. II. A single drupel.

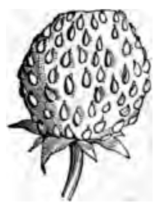


FIG. 277.—Pseudocarp of the Strawberry.

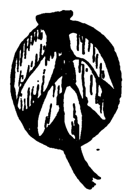


FIG. 278.—Section of fruit of Rose.

contained within a hollow receptacle, and the whole pseudocarp is called a *cynarrhodum.*

THE SEED.

We have already, in Chapter II., described the seed in a general manner ; there are, however, a few details which it is necessary to note at this point. Various terms are used to describe the arrangement of the radicle and cotyledons in the embryo. When the two cotyledons lie flat upon one another and the radicle is placed upon the line which separates them, as is the case with many cruciferous plants (fig. 279), the embryo is *pleurorhizal.*

When the cotyledons are flat upon one another, but the

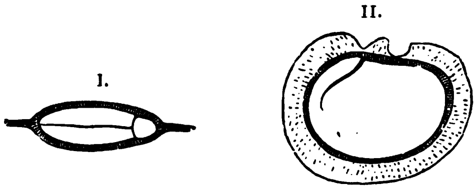


FIG. 279.—Pleurorhizal embryo of *Lunaria.* I. Transverse. II. Longitudinal section through the seed.

radicle is placed upon the back of one of them (fig. 280), the embryo is *notorhizal.*

When the two cotyledons are folded upon one another, leaving a hollow channel in which the radicle is placed (fig.

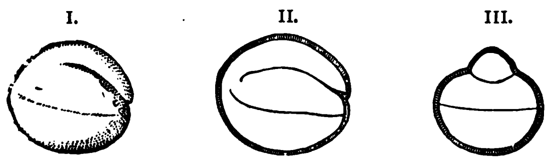


FIG. 280.—Seed of *Neslea paniculata.* I. Entire. II., III. Sections in two different directions showing the notorhizal embryo.

281), the embryo is *orthoplozic.* When, lastly, the flat cotyledons are spirally coiled (fig. 282), the embryo is *spiral.*

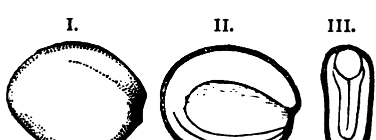


FIG. 281.—Seed of *Eruca sativa.* I. Entire. II., III. Sections in two different directions showing the orthoplozic embryo.

FIG. 282.—Spiral embryo of *Bunias Erucago.*

Again, in albuminous seeds, if the embryo is in the centre surrounded by the endosperm, as in the Pansy (fig.

283), the former is said to be *central*, and the latter *peripheric.*

The case is just reversed in the *Mirabilis Jalapa* (fig. 284), where the peripheric embryo is bent round the central endosperm.

At other times the embryo and albumen are placed more side by side, when they are said to be *lateral.*

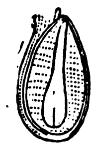


FIG. 283. — Peripheric endosperm surrounding the central embryo in the Pansy.

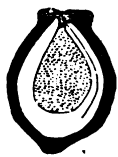


FIG. 284.—Peripheric embryo surrounding the central endosperm in *Mirabilis Jalapa.*

FIG. 285.—Lateral embryo of *Menispermum canadense.*

In some plants a peculiar appendage is developed from the hilum of the ovule after fertilisation, and growing up

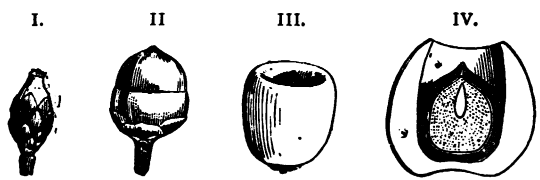


FIG. 286.—I., II., III. Development of the arillus of the Yew. IV. Longitudinal section through the ripe seed.

round the seed, forms either a complete coat as in the Yew (fig. 286), a perforated coat as in the 'mace' of the Nutmeg, or hairs as in the case of the Willow. This is known as the *arillus.*

CHAPTER XII.

CLASSIFICATION.

UNDER the head of Classification we include the grouping of plants into classes according to their affinities. There are two great systems of classification, the *artificial*, or (as it is often called) the Linnæan, and the *natural*. In the former case the plants are arranged simply according to the number, position, and relation of their stamens and carpels; in the second case the general structure and arrangement of the plant as a whole is taken into account. The result is that although the artificial system is a most useful one for the purpose of tracing out a flower whose name we may wish to discover, yet since it depends solely on the arrangement of one set of organs, it often separates plants which are evidently closely allied, and on the other hand unites those which possess no common properties. For these reasons, for the purposes of classification, the Natural system is now always employed.

The sub-kingdom of Flowering Plants is divided into two classes, the *Dicotyledons* and *Monocotyledons*, most of the distinctive characteristics of which we have already noted, and hence it will only now be necessary to tabulate them as follows.

DICOTYLEDONS.	MONOCOTYLEDONS.
Embryo with two cotyledons.	Embryo with one cotyledon.
Primary root growth exorhizal.	Primary root growth endorhizal.
Growth of wood with open bundles, exogenous.	Growth of wood with closed bundles, endogenous.
Leaves net-veined.	Leaves parallel-veined.
Parts of the flower arranged (as a rule) in fours or fives.	Parts of the flower arranged in threes.

Each of these classes is divided into sub-classes, of which there are four in the Dicotyledons, and two in the Monocotyledons.

If we examine four such flowers as the Buttercup, Rose, Dead-nettle, and Hazel, we shall easily be able to understand the grouping.

In the first three specimens the flowers are complete, in the Hazel incomplete, the calyx and the corolla being absent. The Hazel stands, then, as a representative of the sub-class *Incompletæ.*

In the first two specimens the flowers are polypetalous; in the Dead-nettle the corolla is gamopetalous ; the latter therefore is an example of the sub-class *Corollifloræ* or *Gamopetalæ.*

In the Buttercup the petals and stamens are hypogynous, which characterises the sub-class *Thalamifloræ* ; whilst in the Rose they are perigynous (in some members of the group they are epigynous), and the sub-class is known as the *Calycifloræ.*

We may tabulate these result thus :—

Dicotyledons.	Complete	Polypetalous	Petals and stamens hypogynous .	THALAMIFLORÆ
			Petals and stamens perigynous or epigynous. .	CALYCIFLORÆ
		Gamopetalous		COROLLIFLORÆ
	Incomplete			INCOMPLETÆ

The Monocotyledons are divided into two sub-classes: the *Petaloidæ* which, like the Lily or Tulip, possess an evident perianth; and the *Glumaceæ* which, like the Grasses, have their flowers arranged in those peculiar bracts known as glumes.

Each of these sub-classes is divided into several natural orders. In this work we shall deal with the principal orders, fifteen in number, which are given in the elementary syllabus issued from South Kensington, and which can be recognised as follows.

DICOTYLEDONS.

THALAMIFLORÆ.

Pistil apocarpous.	Petals few, stamens many	RANUNCULACEÆ.
Pistil syncarpous	Corolla cruciform, stamens tetradynamous . .	CRUCIFERÆ.
	Leaves opposite, stems swollen at nodes, sepals and petals 5. Free central placenta . .	CARYOPHYLLACEÆ.

CALYCIFLORÆ.

Pistil apocarpous	Flowers papilionaceous, stamens 10, mono- or diadelphous, pistil monocarpellary . . .	LEGUMINOSÆ.
	Flowers regular, petals 5, stamens and carpels numerous . . .	ROSACEÆ.
Pistil syncarpous	Flowers arranged in umbels, petals and stamens epigynous, fruit a cremocarp . . .	UMBELLIFERÆ.

COROLLIFLORÆ.

Flowers compound (in a capitulum)	Stamens syngenesious .	COMPOSITÆ.
Flowers simple	Stem square, leaves opposite, corolla bilabiate, stamens didynamous, ovary *four*-lobed . .	LABIATÆ.
	Stamens didynamous, ovary *two*-lobed . . .	SCROPHULARIACEÆ.

INCOMPLETÆ.

Flowers not in catkins	Calyx present, stamens opposite sepals, ovary 1-celled . . .	CHENOPODIACEÆ.
Flowers in catkins,	Trees or shrubs . .	AMENTACEÆ.

MONOCOTYLEDONS.

PETALOIDÆ.

Flowers irregular, ovary inferior, stamens gynandrous	ORCHIDACEÆ.
Flowers regular, ovary superior, 3-celled; perianth 6 divisions, stamens 6	LILIACEÆ.

GLUMACEÆ.

Stems solid, sheaths of leaves not split, no ligule present	CYPERACEÆ.
Stem hollow, leaf-sheath split, ligule present . .	GRAMINACEÆ.

Each of these orders contains numerous plants, which are arranged in *genera* and *species.* A genus is an assemblage of plants which resemble one another more closely in general structure and appearance than they do other species of plants. Thus, if we examine a Sweet Violet, a Dog Violet, and a Pansy, we find that, although they differ in many minor points of detail, yet there is a great resemblance between them which causes them all three to be grouped under the genus Viola. By a species we mean an assemblage of individuals which, whilst possessing the characteristics of the genus, possess in addition distinctive characters which separate them from the allied plants of the same genus. Thus the points in which the Sweet Violet, Dog Violet, and Pansy agree would be their generic characters; whilst the points in which they differ are their specific characters. When the seed of a plant is grown it always reproduces the same species as the parent. In giving the name of a plant we place the generic name first, followed by the specific name. Thus, the Sweet Violet is *Viola odorata,* the Dog Violet *Viola canina,* and the Pansy *Viola tricolor.*

Sometimes the pollen of one species will fertilise the ovule of a closely allied species, and a plant is thus obtained which combines the properties of both. Such a plant is said to be a *hybrid.*

We will now give a detailed account of the various orders, in each case mentioning a typical plant that should be carefully examined and compared with the description of the order.

DICOTYLEDONS.

RANUNCULACEÆ.

Plant for examination, Buttercup (there are several species, any of them will answer for the purpose).

Note that the plant is a *herb* (the Clematis is a *shrubby climber*; otherwise the plants of the order are all herbs). If you have a specimen with leaves on the stem, they are arranged in an *alternate* manner (in the Clematis they are *opposite*). Often the bases of the leaves sheath around the stem. Examine the flower, making a vertical section through one

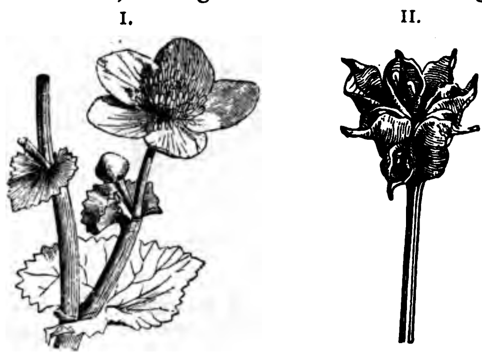


FIG. 287.—Marsh Marigold (*Caltha palustris*). I. Part of plant. II. Fruit, consisting of follicles.

(fig. 162), and removing the parts of another. The sepals are *five* (in the order they vary from three to six, usually five), inferior. Corolla usually of *five petals* (varies in order from three to fifteen), *hypogynous.* (In some plants of the order, as Marsh Marigold (fig. 287) and Anemone, the corolla is absent.) Stamens *numerous*, *hypogynous*; carpels *distinct*, *numerous*, *superior* (sometimes in the order they are few). Fruit, an etærio of achenes. Some Ranunculaceæ have follicles (figs. 259 and 287, II.). The flowers in the case of the Buttercup are *regular*; in other cases, as in the Aconite (fig. 169) and Larkspur (fig. 199), they are *irregular.* Plants of this order contain a watery acrid juice which is often poisonous. They grow in damp and marshy places, especially in the temperate regions.

Principal Plants of the Order.

Aconitum. The British plant, *A. Napellus*, the Monkshood, is easily recognised by its hooded calyx (fig. 169), the petals being small and developed as nectaries (fig. 200). The plant is very poisonous: the root has been mistaken for Horseradish with fatal results; it is, however, much more conical in shape. It is most useful for medicinal purposes.

Adonis, Pheasant's Eye (fig. 288). Much like the Buttercup, but the petals are bright scarlet and have no

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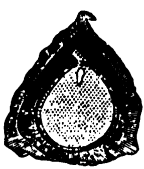

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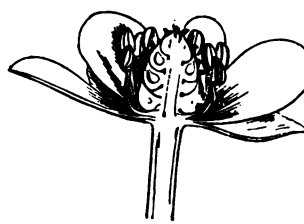

FIG. 288.—Pheasant's Eye (*Adonis*). I. Longitudinal section through achene. II. Longitudinal section through flower.

nectaries at the base. Flowers in the summer and early autumn in cornfields.

Anemone, Wind-flower. No corolla present, the calyx either coloured as in the Pasque-flower, or white as in the Wood Anemone. Flowers in the spring; several species cultivated in our gardens for their showy colours.

Aquilegia, Columbine. With its five sepals petaloid, and five petals with spurs twisted up in a horn-like manner. Grown in gardens.

Caltha, Marsh Marigold (fig. 287). A marsh plant with large flowers, yellow sepals, and no petals.

(Note, although this and other plants of the order are incomplete, the corolla being absent, yet we place them in this thalamiflorous order because their general affinities resemble those of the other plants of the group. The same remark is true of many incomplete plants of other orders.)

Clematis, Old Man's Beard, or Traveller's Joy. A shrubby climber with opposite leaves. The sepals are petaloid (greenish white in the British species), and petals absent. Many exotic Clematis are cultivated for their beautiful flowers.

Delphinium, Larkspur (fig. 199). Flowers with one sepal spurred. Two petals small and united within the spurred sepal. Stavesacre is obtained from an exotic Delphinium.

Helleborus, Hellebore. Sepals large and petaloid, petals small and tubular. The Christmas Rose is an exotic Helleborus.

Myosurus, Mouse-tail. Small clawed petals, and carpels arranged in a dense cylindrical spike, whence the name.

Pæonia, Pæony. Large showy flowers with deep red petals and stamens inserted in a prominent disc.

FIG. 289. — Wallflower (*Cheiranthus Cheiri*), Siliquosæ. Part of plant.

Ranunculus, Crowfoot or Buttercup. A numerous genus, the flowers usually yellow, in some few cases white, but all characterised by the presence of nectaries at the base of the petals.

CRUCIFERÆ.

Typical plant, Wallflower (*Cheiranthus Cheiri*) (fig. 289). Note the stem is *shrubby* below and *herbaceous* above (the plants of the order are generally herbs, sometimes undershrubs). Leaves *alternate* and *exstipulate*; flowers are arranged in a *raceme*; calyx four *sepals*, *saccate*; corolla four *petals*, *cruciform*; stamens six in number, *tetradynamous* (fig. 210) (note, in cultivation there is always a tendency for the stamens to become the same length); pistil with single ovary and two stigmas; fruit a *siliqua*. (Besides the siliqua there is also met with in the order the *silicula*, the *lomentum*, and an indehiscent fruit as seen in the Woad, figs. 261 and 290.) This is a large and widely distributed order, easily recognised by the cruciform corolla and tetradynamous stamens. *No plant of this order is poisonous.* Many are used for food purposes. Many of the plants contain sulphur and are pungent in taste.

I. II. III. IV.

FIG. 290.—I. Schizocarps of *Isatis tinctoria*. II. Transverse section of angustisept silicula of *Capsella*. III. Transverse section of latisept silicula, *a*, of *Camelina*; *b*, four seeds. IV. Lomentum of *Raphanus*.

Principal Plants of the Order.

Brassica. A large and important genus. Leaves irregularly pinnate; flowers yellow; fruit a siliqua, often beaked at the end. Principal species are—*B. Sinapis*, Mustard; *B. oleracea*, which yields all the varieties of Cabbage, Cauliflower, Broccoli, Brussels Sprouts, and Savoys; *B. Napus*, Rape; *B. campestris*, Swedish Turnip, the seeds of which with some other species yield colza oil; *B. Rapa*, Turnip.

Capsella (fig. 99), Shepherd's Purse. One of the commonest weeds, and a good example of a silicula-bearing crucifer. Flowers small, white; fruit a silicula with replum *running across* the narrow diameter (*angustisept*) (fig. 290, II.).

Cheiranthus, Wallflower,

Cochlearia. Fruit a silicula with replum running across the broad diameter (*latisept*) (fig. 290, III.), so that the fruit is nearly globose. There are two British species, the Horse-radish and the Scurvy-grass.

Crambe, Sea Kale. Fruit two-jointed, upper joint with one seed indehiscent, lower joint forming a stalk above the calyx ; might be mistaken for a gynophore.

Iberis, Candytuft. Petals unequal, the two exterior petals larger than the interior ones ; fruit silicula, angusti-septate.

Isatis, Dyer's Woad. Small numerous yellow flowers ; fruit pendulous, flattened, indehiscent. The plant yields a blue dye.

Lepidium, Cress. Numerous small white flowers, petals equal ; fruit silicula, angustiseptal, one seed in each cell.

Matthiola, Stock. Plants hoary from minute hairs ; large purple flowers ; fruit a cylindrical siliqua.

Nasturtium, Watercress. Small yellow or white flowers; fruit a siliqua, generally somewhat curved. (This must not be confounded with the garden Nasturtium, which is a Tropæolum belonging to quite a different order.)

Raphanus, Radish. Fruit a lomentum.

CARYOPHYLLACEÆ.

Typical plant, the Greater Stitchwort (*Stellaria Holostea*).

Note, the plant is *herbaceous*; the leaves are opposite, *exstipulate* ; in some few genera there are small scarious (scaly) stipules. The stem is swollen at the *nodes.* Inflorescence a *dichotomous cyme* (fig. 153), usually to be found in the order ; calyx five separate sepals (in some genera calyx is gamosepalous) ; corolla five petals notched (this is often the case in the order, and in many cases the petals are unguiculate, figs. 177, 178, and 192); stamens ten, seldom in the order fewer ; pistil with *syncarpous* ovary, *three styles* (in the order the number varies from two to five) ; free central placentation, *very characteristic* of order. A very wide-spread order, found in all parts of the temperate regions, especially in the northern hemisphere.

Principal Plants of the Order.

Cerastium, Mouse-ear Chickweed (fig. 153). A numerous genus. Flowers with separate sepals, two-cleft petals, five styles ; the fruit often prolonged in a horn-like manner, and opens by ten valves or teeth.

Dianthus, Pink (fig. 144). Calyx gamosepalous with two or more scales (bracts) outside, two styles. There are several species cultivated, such as the Clove Pink or Carnation, Maiden Pink, Cheddar Pink, Sweet William, &c.

Lychnis (fig. 191). Gamosepalous calyx, ebracteate, ovary with five styles. Several species grow as common weeds, such as Ragged Robin, Evening Campion, and Corn Cockle.

Silene. Differs from the Lychnis in having three or four styles. Several species of Campion and Catchfly.

Stellaria. Differs from Cerastium in having three styles and capsule opening by six valves or teeth. Several species of Chickweed and Stitchwort.

We now come to the

CALYCIFLORAL ORDERS.

LEGUMINOSÆ.

Typical plant, Sweet Pea (*Lathyrus odoratus*) (fig. 92).

Note, the plant is *herbaceous* (in the order there are also shrubs and trees) ; leaves *alternate*, *stipulate*, often compound and pinnate, as in this case ; calyx *gamosepalous* with five teeth ; corolla *papilionaceous* ; stamens ten, *diadelphous* (in several genera they are monadelphous) ; pistil monocarpellary ; fruit a legume.

There are three sub-orders of this important order. All the British plants, however, belong to one of these, the *Papilionaceæ*, which is distinguished by having papilionaceous flowers, and hence can be easily recognised.

In the other two sub-orders, which are exclusively extra-European, the flowers are regular, the petals being imbricated in the *Cæsalpineæ*, and valvate in the *Mimoseæ* (fig. 291). The order is a very large one and widely distributed, very varied in its properties, some of the plants being most useful as food and fodder plants, others as drugs, whilst others, again, are poisonous.

Principal British Plants.

Astragalus. Milk Vetch. Leaves imparipinnate; stamens diadelphous; keel of corolla blunt; legume not jointed, but more or less divided into two cells by a partition. A good fodder plant.

FIG. 291.—Sensitive Plant (*Mimosa pudica*).

Genista, Green Weed and Dyer's Weed. Leaves simple; stamens monadelphous; calyx bilabiate. The Dyer's Weed (*G. tinctoria*) yields a yellow dye.

Lathyrus, Peas and Vetchlings. Leaves imparipinnate, ending in tendrils, with few leaflets and sagittate or half-sagittate stipules; stamens diadelphous, style flattened above. Several species used as fodder plants. The Sweet Pea (*L. odorata*) and Everlasting Pea (*L. latifolius*) are exotic species. The edible Pea is separated into another genus, Pisum.

Lotus, Birdsfoot Trefoil. Leaves trifoliate, with large leaf-like stipules; stamens diadelphous; calyx with five equal teeth; legume imperfectly many-celled. A good fodder plant.

Medicago, Medick or Lucerne. Leaves trifoliate; stamens diadelphous; legume more or less spirally twisted (fig. 292), sickle-shaped, indehiscent. Much cultivated as a fodder plant, especially *M. sativa*, the Lucerne.

Melilotus, Melilot. Leaves trifoliate; flowers in long loose racemes; stamens diadelphous; legumes with one or very few seeds, longer than the calyx. Fodder plants.

FIG. 292.—Twisted legume of Lucerne (*Medicago sativa*).

Onobrychis, Sainfoin. Leaves imparipinnate; stamens diadelphous; legume flat, hard, one-seeded and indehiscent. A valuable fodder plant.

Sarothamnus, Broom. Leaves trifoliate, three digitate leaflets; stamens monadelphous; calyx campanulate, with two lips, minutely toothed; legume flat, many-seeded.

Trifolium, Trefoil or Clover. Leaves trifoliate; flowers in abbreviated heads (fig. 293); stamens diadelphous; legume few seeds, concealed within calyx and often indehiscent. Many species are very largely cultivated as fodder plants.

FIG. 293.—Abbreviated inflorescence of Clover.

Ulex, Furze. Leaves simple and acerose; two sepals; stamens monadelphous.

Vicia, Vetch and Tares. Leaves imparipinnate, ending in tendrils and with many leaflets; stamens diadelphous; style thread-like. Very useful fodder plants. One exotic species, *V. Faba*, gives us the Broad Beans.

The following are important exotic plants belonging to this sub-order. Used for food purposes: *Arachis*, Ground Nuts; *Ervum*, Lentils; *Phaseolus vulgaris*, the French Bean; and *P. coccineus*, the Scarlet Runner; *Pisum*, Pea. Used for various purposes: Balsam of Tolu, Indigo, Kino, *Laburnum*, Liquorice, Ordeal Bean, Rosewood, Tonquin Beans.

The following important plants belong to the other two sub-orders :—Braziletto-wood, Cassia, Copal, Copaiba Balsam, Locust-tree, Logwood, Sandal-wood, Sanders-wood, Sensitive-plant, Tamarind.

ROSACEÆ.

Typical plant, Bramble (*Rubus fruticosus*) ; also compare with it Blackthorn or Sloe, Rose, and Apple.

Note, the plant is a *shrub* (in the order there are also herbs and trees) ; leaves *alternate*, stipules present adhering to the petiole (stipules are seldom absent in the order) ; calyx *gamosepalous*, five *divisions inferior* (there may be but four divisions to the calyx—in the Rose it forms a cup-like tube enclosing the carpels (fig. 193), and in the Apple and Pear it is adherent to the carpels, figs. 294 and 273) ; corolla *polypetalous*, *five petals*, *perigynous* (in a few cases there are four petals, and in some cases none) ; stamens *numerous*, *perigynous* ; carpels *numerous* (in the Blackthorn there is but one), *apocarpous* ; fruit an etærio of drupes. (In the order the fruit is very various. Thus, it may be a single *drupe*, Blackthorn ; *etærio* of *achenes*, Strawberry ; *cynarrhodum*, Rose ; *follicles*, Meadow Sweet ; or *pome*, Apple.)

FIG. 294.—Longitudinal section through the flower of the Pear.

This large and important order is widely distributed, especially in the temperate regions. Many of the plants very much resemble the Ranunculaceæ, but a careful examination will show the great distinction from that order in the perigynous stamens and petals.

The Rosaceæ is divided into four sub-orders :—

1. DRUPACEÆ or AMYGDALEÆ. Trees or shrubs with simple leaves ; fruit a drupe. Many parts of the plants contain hydrocyanic or prussic acid.

Prunus is the only British genus of this sub-order. It has the nut of the drupe smooth or slightly seamed. The native species include the Sloe, Wild Plum, and Cherry. Amongst exotic species of the same genus which are largely cultivated are the Apricot, Cherry Laurel, and Portuguese Laurel.

Amygdalus is the exotic genus which yields us Almonds both bitter and sweet, Peaches, and Nectarines.

2. ROSEÆ. Shrubs or herbs; stipules adherent; ovaries one or more, not adherent to calyx; fruit etærio or follicles.

Principal British Plants.

Agrimonia, Agrimony. Flowers in loose spikes; calyx five-cleft, top-shaped with hooked bristles; stamens not more than fifteen; carpels two. The plant was formerly used by herbalists.

Fragaria, Strawberry. Calyx ten-cleft, in two rows; fruit an etærio of achenes on an enlarged and fleshy receptacle.

Potentilla differs from the Strawberry principally in the fruit being on a dry receptacle; *P. Tormentilla* has but four petals.

Rosa. Calyx urn-shaped; fruit a cynarrhodum. There are several species of wild Roses and Briars, from which many of our cultivated Roses are obtained; others come from exotic species.

Rubus, Bramble. Calyx five-cleft; fruit etærio of drupes. The genus includes the Raspberry, Blackberry, Dewberry, and Cloudberry.

Spiræa. Calyx five-cleft; fruit three to twelve follicles. Several species of Meadow Sweet. Some of the exotic plants are cultivated for their flowers.

3. SANGUISORBEÆ. Herbs or undershrubs; flowers often unisexual; petals absent (fig. 295); carpel solitary; fruit an achene (fig. 295, II.).

British Plants.

Alchemilla. Calyx eight-cleft, in two rows; stamens one to four. The species of Lady's-mantle and Parsley Piert are used as fodder plants.

Poterium, Salad Burnet. Calyx four-cleft, petaloid; flowers unisexual; stamens numerous. A good salad plant.

I II.

FIG. 295.—*Sanguisorba officinalis.* I. Flower. II. Fruit.

Sanguisorba, Great Burnet. Calyx four-cleft, petaloid; stamens four. Grown in Germany as a fodder plant.

4. POMEÆ. Trees or shrubs; carpels one to five, adhering more or less to one another, and sunk in the receptacle, thus becoming inferior; fruit a pome.

British Plants.

Cratægus, May or Hawthorn. Fruit hard or bony; calyx divisions sharp.

Mespilus, Medlar. Differs from the May in its larger flowers and foliaceous calyx divisions.

Pyrus. Calyx divisions small; fruit fleshy. Its species include the Apple, Pear, Rowan-tree or Mountain Ash, and Wild Service-tree. The exotic genus Cydonia yields us the Quince.

From many of the plants of this sub-order also prussic acid is obtainable.

UMBELLIFERÆ.

Typical plant, Cow Parsnip (*Heracleum Sphondylium*).

Note, the stem is *herbaceous, hollow*, except at the nodes; leaves *alternate, sheathing at base, bi-* or *tripinnate* (leaves in the order are generally much divided); flowers in *compound umbels* (in Hydrocotyle the umbels are simple, in Sanicula and Eryngium the flowers are arranged in tufted heads); calyx *adherent* to ovary, free limb absent, or as five *small teeth*; corolla *five petals, polypetalous, epigynous*; stamens *five, epigynous*; pistil *inferior, two cells, two styles*; fruit a cremocarp.

This is a very large and wide-spread order, easily recognisable by its umbellate flowers and two-celled ovary with cremocarp. The plants of the order are, however, very difficult to identify, as the distinctions of the genera and species depend principally upon small points of detail in the structure of the seed and the fruit.

The properties of the order are very various; some members yield us food plants, others are very poisonous, and again others yield useful drugs.

Principal British Plants.

Angelica. Fruit two flattened carpels united by their faces, with three sharp ridges at the back of each, and two at the side expanding out. The leaf-stalks are used candied as sweetmeats.

Æthusa, Fool's Parsley (fig. 296). Fruit nearly globose; no general bracts, but three partial bracts to each secondary umbel, which hang down (figs. 296 and 148). A very poisonous plant, liable to be mistaken for true Parsley; distinguished by its bracts.

Apium, Celery. Fruit roundish egg-shaped, the carpels flattened and united by the narrow edge, five slender ridges on each; no bracts. In the wild state poisonous; when blanched by etiolation, fit for eating.

Bunium, Earth-nut. Oblong fruit of flattened carpels united by narrow edge with five blunt ridges; no general involucre, but a slight partial one. The tuberous root is esculent.

Carum, Caraway. Oblong fruit of flattened carpels united by narrow edge with five slight ridges; no bracts, or at most but one general bract. Roots and leaves are edible, and fruit used under the name of Caraway seed.

Chærophyllum, Chervil. Fruit contracted at sides, with short beak, five blunt ridges on each carpel; several partial bracts. Formerly cultivated as a culinary herb.

Cicuta, Water Hemlock. Fruit of two globose carpels united by narrow edge with five broad flattened ridges. A most virulent poison.

Conium, Hemlock. Fruit egg-shaped, with five wavy ridges on each lobe. Plant emits, when bruised, a nauseous 'mousy' smell. A most poisonous plant, useful medicinally.

Coriandrum, Coriander. Fruit globose (fig. 297), scarcely prominent ribs, very aromatic. Fruit used under name of Coriander seed.

FIG. 296.—I. *Æthusa Cynapium* (Fool's Parsley). II. Fruit. III. Section of fruit.

Crithmum, Samphire. Leaves succulent; fruit elliptical, with spongy lobes. The plant is edible, being used as a pickle.

Daucus, Carrot. Fruit slightly flattened, prickly (fig.

298), there being rows of prickles between the bristly ridges. The root is edible, forming the cultivated Carrot.

Eryngium, Sea Holly. Flowers in dense prickly heads.

Fœniculum, Fennel. Fruit elliptical (fig. 262), carpels with five bluntly keeled ridges. Plant esculent.

Helosciadium, Marsh-wort, or Fool's Watercress. Plant much resembling Watercress but leaves more pointed and

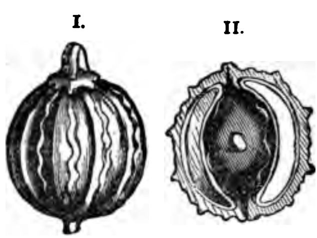

FIG. 297.—I. Fruit of Coriander (*Coriandrum sativum*), Cœlospermæ. II. Transverse section.

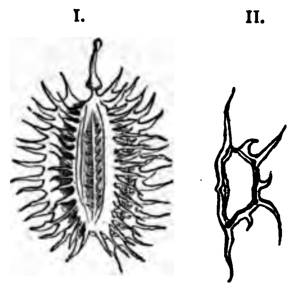

FIG. 298.—I. Fruit of Carrot (*Daucus Carota*), Orthospermæ. II. Transverse section; the four secondary ridges are conspicuous; of the primary ridges the two lateral ones are scarcely visible, the median (carina) and intermediate ones are spiny.

serrate. No general bracts, five partial. Very poisonous, hence importance of distinguishing it from Watercress.

Heracleum, Cow Parsnip. Very common weed. Flowers white, the outer petals of umbel larger than the inner ones, else very like the true Parsnip. Might be used as an esculent herb.

Hydrocotyle, White Rot. A marsh plant with simple umbels and peltate leaves.

Ligusticum, Lovage. Fruit elliptical, not flattened, the five ridges to each lobe sharp and winged. Used as a vegetable in many parts.

Myrrhis, Sweet Cicely. Very aromatic; fruit large, with deep furrows between carpels, and five sharply keeled ridges. Pot herb.

Œnanthe, Water Drop-wort. Fruit egg-shaped, with five blunt ridges; petals notched. Very poisonous plant.

Pastinaca, Parsnip. Fruit very flat with broad border; flowers yellow, all small. Root edible.

Petroselinum, Parsley. Fruit very much like Celery; numerous partial bracts. Esculent plant.

Pimpinella, Burnet Saxifrage. Fruit much like Celery, but ribs less prominent. Aniseed is obtained from an exotic species of this genus.

Sanicula, Sanicle. Flowers in tufted heads, imperfect, the outer pistillate, inner staminate. Was formerly supposed to possess healing qualities.

The following exotic plants belong to this important order:—*Anthriscus*, Chervil; *Anethum*, Dill; *Cuminum*, Cummin; *Dorema*, which yields gum ammoniacum; *Ferula*, yields asafœtida; and *Opoponax*, yielding the gum resin of that name.

COROLLIFLORAL ORDERS.

Compositæ.

Typical plant, Dandelion (*Taraxacum Dens-leonis*). Also compare with it a Daisy.

Note the plant is herbaceous (some exotic Compositæ are shrubby); leaves exstipulate; flowers arranged in a *capitulum*, surrounded by an *involucre* of bracts; calyx *superior*, a *pappus* (note the pappus absent in the Daisy); corolla *gamopetalous*, *epigynous*, *ligulate* (note in the Daisy the florets of the disk have *tubular* corollas, whilst those of the ray have *ligulate* corollas), *five teeth*; andrœcium *five stamens*, *epigynous*, *syngenesious*; pistil *syncarpous*, *single style*, and bifid stigma.

The plants of this order are easily recognised by their flowers being arranged in capitula with *syngenesious* stamens, the latter characteristic distinguishing them from the allied *Teasel family*.

It is the largest of all natural orders, containing one-tenth of the known plants of the world. The members of the group differ much in their properties and uses.

The British plants are divided into two sub-orders:—

TUBULIFLORÆ, which have all their florets (as the Corn Bluebottle), or inner ones only (as Daisy), tubular.

LIGULIFLORÆ have all their florets ligulate (as Dandelion).

Principal British Plants.

TUBULIFLORÆ.

Anthemis, Chamomile. Flowers arranged on a convex receptacle with tubular perfect florets in disk, and ligulate pistillate flowers in ray; the receptacle has scales between the flowers. Used medicinally.

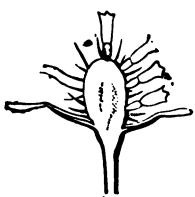

FIG. 299.—Common receptacle of *Anthemis arvensis*, with paleæ between the flowers.

Arctium, Burdock. All flowers tubular, perfect, and in a convex head; a globose involucre present with hooked points to the bracts; pappus short. Various parts of this plant may be eaten, either as a salad or cooked.

Artemisia, Wormwood. All flowers tubular, perfect, in a flat head; no pappus, only few flowers in the head. A very bitter plant used in the manufacture of *absinthe*.

Bellis, Daisy. Flowers as in Anthemis, but without scales on receptacle, involucre of two rows of equal bracts.

Carduus, Thistle. All florets tubular, perfect, in a convex head; involucre swollen below, with thorn-like scales (fig. 143).

Centaurea, Knapweed and Bluebottle. Florets tubular, inner perfect, outer large and neuter somewhat irregular (*figs. 179* and 300).

Chrysanthemum. Disk florets tubular and perfect, ray florets ligulate and pistillate; involucre flat; receptacle naked, and no pappus.

Inula, Elecampane. Disk florets tubular and perfect, ray ligulate, all yellow; pappus present; many-rowed involucre. Formerly used as a sweet-meat.

Senecio, Ragwort and Groundsel. Disk florets tubular and perfect, ray ligulate and pistillate (latter wanting in Groundsel), all yellow; simple pappus scales outside the involucre.

FIG. 300.—Neuter flower of *Centaurea Cyanus.*

Tussilago, Coltsfoot. Flowers appear in spring before the leaves; flower stalks covered with scale-like bracts; few disk florets, tubular, perfect; many narrow ray florets, ligulate, pistillate, all yellow. Often used as a remedy for colds and coughs.

LIGULIFLORÆ.

Cichorium, Chicory. Flowers blue, sessile upon tough stems, involucre of two rows. It is the root which is used to mix with coffee.

Lactuca, Lettuce. Few florets with hairy pappus and oblong imbricated involucre. The garden Lettuce is an exotic species of this genus.

Taraxacum, Dandelion. Lyrate leaves radical; flower stalk hollow, leafless; outermost bracts of the involucre recurved; receptacle dotted. The young plant forms a good salad and is often used by herbalists as a tea.

The following exotic genera yield important plants:—*Arnica*, used medicinally in case of bruises; *Calendula*, Marigold, also used as an external remedy for cuts, and to adulterate saffron; *Carthamus*, Safflower, or Bastard Saffron, often used instead of true saffron to yield the pink dye; *Cynara*, Artichoke; *Helianthus*, Jerusalem Artichoke and Sunflower.

LABIATÆ.

Typical plant, White Dead-nettle (*Lamium album*, fig. 155).

Note the plant is *herbaceous*; stem *square*; leaves *opposite*; flowers in *verticillasters*; calyx *inferior*, five-toothed (it may be ten-toothed in the order); corolla (figs. 301 and 188) *bilabiate*, *ringent* (in some cases the corolla is almost regular, fig. 302); stamens *didynamous*, *epipetalous*, fig. 211 (in the Sage there are only two

FIG. 301.—*Lamium album.* Longitudinal section of flower.

FIG. 302.—Nearly regular flower of Peppermint (*Mentha piperita*).

stamens with branched connective, fig. 214); pistil *superior*, *four-lobed*; fruit a *carcerulus* (fig. 266).

The four-lobed ovary is a most important point, as it distinguishes the order from the next where there are only two lobes. *No plant of the order is poisonous.* Many contain aromatic essential oils, and are used for flavours and perfumes. It is chiefly distributed in temperate regions.

Principal British Plants.

Calamintha, Wild Basil and Basil Thyme. Calyx with *thirteen* nerves upon it; corolla longer than calyx; lower lip with three broad lobes; outer stamens longest, but not diverging from inner ones.

Lamium, Dead-nettle. Calyx ten ribs and five teeth; corolla with upper lip arched; lower lip with large middle lobe, two side ones small.

Marrubium, White Horehound. Stamens shorter than the tube of the corolla; calyx with five or ten teeth and ribs; upper lip of corolla deeply notched. Used as a remedy for coughs.

Mentha, Mint. Corolla nearly regular; stamens four, equal. There are many species used as flavours and odours; principal are Spearmint, Peppermint, and Pennyroyal.

Origanum, Marjoram. Flower in panicles or corymbs; a bract under each flower. Used as a potherb.

Salvia, Sage or Clary. Two stamens with branched connectives.

Teucrium, Germander. Upper lip of corolla apparently wanting, but appearing as two small teeth, one on each side of the lower lip.

Thymus, Thyme. Calyx bilabiate, upper lip three-toothed, lower two-toothed; corolla with upper lip flat and erect, lower spreading; outer stamens diverging from the inner ones.

Amongst exotic genera we have :—*Hyssopus*, Hyssop; *Lavandula*, Lavender; *Melissa*, Balm; *Ocymum*, Basil; *Pogostemon*, Patchouly; *Rosmarinus*, Rosemary; *Satureia*, Savory.

SCROPHULARIACEÆ.

Typical plant, Great Snapdragon (*Antirrhinum majus*, fig. 142).

Note the plant is *herbaceous*; leaves *opposite* (rarely alternate); corolla *bilabiate*, *personate*, fig. 249 (it may be almost regular as in the Foxglove, fig. 303, or ringent as in the Scrophularia); stamens *epipetalous*, didynamous (only two in Veronica); pistil *superior*, *two-lobed*; *dumb-bell-shaped placenta* (fig. 304).

It is most important to note the two-lobed ovary, which distinguishes this order from the last, as many plants of the Scrophulariaceæ are poisonous. Distributed all over the world.

FIG. 303.—Flower of Foxglove (*Digitalis purpurea*).

Principal British Plants.

Antirrhinum, Snapdragon. Corolla personate, not spurred, but with a protuberance at base.

Digitalis, Foxglove. Corolla irregularly bell-shaped; leaves alternate. Very poisonous; used medicinally.

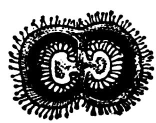

FIG. 304.—Bilocular ovary of *Antirrhinum*, with axile placentæ.

Euphrasia, Eyebright. Calyx four-cleft; corolla ringent; upper lip two-lobed, spreading.

Linaria, Toadflax. Differs from Snapdragon in having spurred corolla.

Melampyrum, Cow-wheat. Calyx four-cleft; corolla ringent; upper lip compressed laterally.

Rhinanthus, Rattle. Differs from the last in having the calyx much swollen, with four small teeth.

Scrophularia, Figwort. Calyx five-lobed; corolla ringent, nearly globose; flowers small. Poisonous.

Verbascum, Mullein. Corolla rotate, five-lobed; five stamens.

Veronica, Speedwell. Corolla rotate, four-lobed; two stamens.

INCOMPLETÆ.

CHENOPODIACEÆ.

Typical plant, White Goosefoot (*Chenopodium album*).

Note, plant *herbaceous* (some plants are somewhat shrubby), *succulent*; leaves *alternate* (often in the order very succulent); flowers inconspicuous (in many plants of the order we have separate staminate and pistillate flowers); calyx *inferior*, *five-lobed* (in the order it is from two- to five-lobed, usually five), persistent (often in the order it very much enlarges as it surrounds the fruit); corolla *absent*; stamens *five*, *opposite the sepals* (rarely in order one or two); pistil *superior*, *syncarpous*; two or three *styles*.

This order is widely distributed, the plants growing especially in salt marshes. Many of the plants are esculent, others were formerly much employed in the manufacture of soda, which was obtained from their ashes, known as *barilla*.

Principal British Genera.

Atriplex, Orache and Purslane. Flowers generally unisexual; perianth five-cleft in staminate, and two-cleft in pistillate flowers, very much enlarged round fruit, which is one-seeded. Several species of common weeds.

Beta, Beet. Fruit one-seeded, immersed in succulent base of calyx; three small bracts beneath the calyx. Edible; much cultivated for manufacturing sugar. Mangold Wurzel is a variety of the Beet.

Chenopodium. Flowers differ from above in having no bracts, and the perianth not becoming fleshy on fruiting. There are several species. *C. album* is the commonest, a plant which overruns gardens and grows on waste places. It may be used as a potherb. *C. Bonus-Henricus*, Good King Harry, or All-good, is also edible. *Spinacea oleracea*, Spinach, is an exotic genus with four styles cultivated for *food purposes.*

AMENTACEÆ

Typical plant, Common Hazel (*Corylus Avellana*), fig. 159.

Note, the plant is a *shrub* or *small tree* (trees and shrubs are met with in the order); leaves *alternate*; flowers in *catkins*, *monœcious* (in many plants of the order, as the Willow, the flowers are diœcious); staminate catkins *pendulous*; numerous *wedge-shaped bracts*; no *perianth*; eight *stamens attached to each bract*, fig. 305 (in the order the number of stamens present varies from two upwards, and a slight perianth is sometimes present); pistillate inflorescence a

III.

I. II.

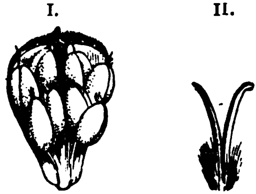

FIG. 305.—The Hazel (*Corylus Avellana*). I. Male flower. II. Female flower. III. Fruit with laciniated spurious cupule.

bud-like catkin with two flowers within surrounded by numerous bracts, each flower consisting of a two-celled ovary with two red stigmas (in the order the pistillate catkins are either pendulous like the staminate, with one, two, or three flowers on each scale-like bract, or in a bud-like head with two or three flowers in the centre); fruit a one-seeded nut (in some plants of the order a capsule). This is an important and extensive family, distributed all over the globe, especially in temperate regions, and yields a large number of timber trees as well as esculent plants.

It is divided into several sub-orders, four of which are represented in this country, viz. :—

SALICINEÆ. Generally diœcious ; pistillate flowers in catkins ; fruit a capsule.

BETULINEÆ. Flowers generally monœcious ; pistillate flowers in catkins ; fruit a flat nut.

MYRICEÆ. Flowers generally diœcious; pistillate flowers in catkins ; fruit a false drupe from the scaly bracts becoming fleshy.

CUPULIFERÆ. Pistillate flowers in tufts or spikes ; bracts grow up around fruit to form a cup or cupule (figs. 275 and 305).

Principal British Plants.

SALICINEÆ.

Populus, Poplar. Stamens eight to thirty ; stigmas deeply forked, slight ; perianth present. Several species grown as ornamental and timber trees.

Salix, Willow and Osier. Stamens one to five ; stigmas slightly forked ; no perianth present. Very numerous species.

BETULINEÆ.

Alnus, Alder. Fruit not winged ; two flowers on each pistillate bract. The wood is very durable and yields good charcoal.

Betula, Birch. Fruit winged, three in each bract (fig. 264). The timber is utilised, and from the sap Birch wine, which is used medicinally, is obtained.

MYRICEÆ.

Myrica, Sweet Gale. Diœcious, four to eight stamens, two stigmas.

CUPULIFERÆ.

Carpinus, Hornbeam. Stamens twelve to each scale; pistillate catkins slender and loose; a three-lobed scale (perianth?) to each pistil, which enlarges with the fruit (fig. 306). Used for timber.

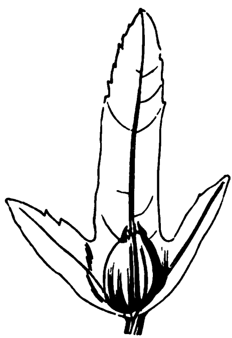

FIG. 306.—Fruit of the Hornbeam (*Carpinus Betulus*), with its three-lobed perianth.

Corylus, Hazel. Stamens eight to each scale; two pink stigmas to each ovary; fruit a nut in a leafy involucre. Filberts, Cobs, and Barcelona nuts are varieties of Hazel.

Fagus, Beech. Staminate flowers in a globose catkin; stamens five to fifteen; fruit two three-cornered nuts in a prickly involucre. The wood yields good charcoal.

Quercus, Oak. Stamens five to ten; staminate flowers in a long drooping catkin; fruit surrounded with a cup-shaped involucre. The timber is most valuable for many purposes. Cork is the outer bark of *Q. Suber.* Oak galls and Oak apples are also obtained from various species, whilst the bark is often used for tanning.

Exotic plants of interest belonging to this order are :—*Carya*, Hickory; *Castanea*, Sweet Chestnut; *Juglans*, Walnut; *Liquidambar*, species of which yield resins known as storax and liquidambar; and *Ostrya*, Iron-wood.

MONOCOTYLEDONS.

ORCHIDACEÆ.

Typical plant, Spotted Orchis (*Orchis maculata*).

Note the plant is *herbaceous*; flowers *very irregular* (fig. 307); *perianth superior* (note, the twisted ovary may be mistaken for a stalk), *six-lobed*; there are three outer and three inner segments, all petaloid; one of the inner lobes is

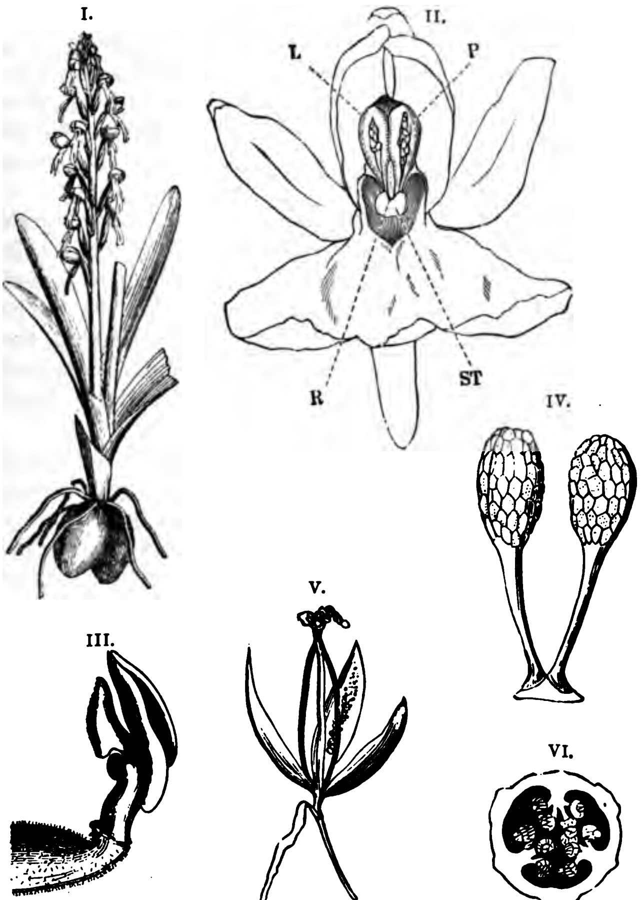

FIG. 307.—I. *Aceras anthropophora* (Man Orchis), whole plant. II. Flower of an Orchid looked at in front, the ovary being concealed: L, P, anther lobes, each containing a pollinium; ST, stigma; R, rostellum. III. Gynostegium of *Cypripedium*, seen laterally; above to the right the anther, to the left the stigma. IV. *Pollinia* of an Orchid with their pedicels, united by the rostellum. V. *Burst capsule.* VI. Transverse section of an ovary.

flattened out, forming a *lip* or *labellum*, and is also prolonged below into a *spur*. Behind the labellum there is a short column terminating in a knob, the *rostellum* (fig. 307, II, R), and a single stamen with two anther lobes (fig. 307, II., L, P) containing not free pollen, but a mass united together and stalked, a *pollinium* (fig. 507, IV.). Below the rostellum and stamen is the stigma (fig. 307, II., ST), so that the arrangement is gynandrous. Below is the one-celled ovary with three parietal placentas.

Taking a flower which has but recently expanded, push gently a sharpened pencil into the spur. It is found that on touching the rostellum its pouch-like membrane is pushed down and the pencil comes in contact with the viscid substance at the base of the pollinia. On removing the pencil one or both of the pollinia are removed attached to it. It will be found after removal they gradually bend over towards the point of the pencil.

If an insect, such as a bee, visits the plant for the honey contained in the spur, it presses its head against the rostellum, and flies away with the two pollinia attached; on visiting a second flower, these have bent forward, so that instead of returning to the same place from which they were taken in the previous flower, they strike against the viscid stigma, and some of the pollen remains attached.

The exact method of fertilisation varies in the different plants of this order. It is very widely distributed, especially in tropical regions. Many of the plants are *epiphytes*, or air plants: clinging to the trunks of trees, their roots are green with stomata, and never reach the soil; they absorb all their nourishment from the air. Many of the plants are remarkable for the singular shapes of their flowers, which simulate various natural objects, insects, birds, reptiles, &c. So much so that Dr. Lindley says, 'So various are they in form, there is scarcely a common reptile or insect to which some of them have not been likened.' Amongst our British genera we have the Fly Orchis (*Ophrys muscifera*), which presents the appearance of several flies growing up the stem; Bee Orchis (*Ophrys apifera*), and Spider Orchis (*Ophrys aranifera*), each with the flowers like the insects named. There are various species of the genus Orchis, all of which have spurred flowers: *Aceras*, or Man Orchis (fig. 307, I.); *Listera*, or Twayblade; *Habenaria*, or Butterfly Orchis, and others. Though so numerous a family, the plants are not economically useful. Salep is a starchy esculent substance obtained from the roots of several species of Orchis, and vanilla is a flavouring material obtained from the fruit of an exotic plant, *Vanilla aromatica.* The marvellous forms of the flowers cause them to be much cultivated in our greenhouses.

LILIACEÆ.

Typical plant, Bluebell (*Scilla nutans*, or *Agraphis nutans*).

Note the plant is *herbaceous* (the Butcher's Broom is the only British plant which is shrubby, but exotics may be shrubs or trees); perianth *inferior*, *polyphyllous* (it may be *gamophyllous*), *six divisions* (in Herb Paris there are eight); stamens *six* (eight in Herb Paris); pistil *syncarpous*, *three-celled*, with *axile placentæ*, and *numerous ovules* (four-celled in Herb Paris).

This large and important order is widely distributed throughout the world. It is divided into several sub-orders, some of which are sometimes raised to the dignity of orders.

The British genera may be grouped into the five following sub-orders:—

TRILLIDEÆ. Leaves net-veined; styles distinct; fruit a berry.

(All the other sub-orders have parallel-veined leaves.)

CONVALLARIEÆ. Fruit a berry; styles united; testa of seed membranous.

ASPARAGEÆ. Fruit a berry; styles united; testa of seed hard and black.

LILIEÆ. Fruit a capsule ; styles united.

COLCHICEÆ. Fruit a capsule ; styles distinct.

Principal British Plants.

TRILLIDEÆ.

Paris, Herb Paris. A remarkable plant with four net-veined leaves upon a short stem, and the parts of the flower arranged in fours, thus resembling Dicotyledons; but otherwise a monocotyledonous plant.

CONVALLARIEÆ.

Polygonatum, Solomon's Seal. Flowers axillary, drooping; perianth gamophyllous, shortly six-cleft, tubular.

Convallaria, Lily-of-the-valley. Differs from last in flower-stalk being leafless ; perianth campanulate.

ASPARAGEÆ.

Asparagus. Leaves small, subulate, surrounded by short scarious scales ; flowers small, polyphyllous; two ovules

FIG. 308.—Leaf-like branch or phylloclade of *Ruscus aculeatus* : *a*, flower.

in each of three cells of ovary ; style single, and three-lobed stigma. The young succulent shoots are eaten.

Ruscus, Butcher's Broom. Shrubby plant. The branches are leaf-like (fig. 308), and known as *phylloclades*, the true leaves being scales upon them. The flowers are small, sessile upon the phylloclades.

LILIEÆ.

Allium, Garlic, Chives, &c. Flowers in an umbel, with two or three thin bracts at base, flower-stalk leafy. Amongst cultivated species of this genus are the Onion (*A. Cepa*), Garlic (*A. sativa*), and Leek (*A. Porrum*).

Fritillaria, Fritillary. Flowers generally single on the stalk, polyphyllous; the three inner segments have each a nectary at the base; anthers attached above their bases; style three-cleft.

Ornithogalum, Star of Bethlehem. Flowers in racemes or corymbs; perianth persistent; a scarious bract at base of each flower-stalk.

Scilla, Squill, Bluebell, &c. Flowers blue or pink, in racemes or panicles; perianth not persistent. The medicinal Squill is an exotic species of this genus.

Tulipa, Tulip. Flowers solitary on leafy stalk; petals without a nectary; anthers innate; style absent.

COLCHICEÆ.

Colchicum, Meadow Saffron. Flowers with long tube, so that the ovary is underground, but superior; styles three, very long and thread-like.

Amongst exotic plants of this order which are grown for ornamental purposes, or are variously employed, are several species of the genus *Lilium*, also *Hyacinthus*. The genus *Aloë* yields several species, some of which are used medicinally: *Dracæna Draco* is the famous Dragon-tree of Teneriffe; *Phormium* yields New Zealand flax; *Sanseviera* yields African hemp; the buds of the *Xanthorrhœa*, or Grass-tree of Australia, are eaten like Asparagus; and *Yucca* is the Adam's Needle.

CYPERACEÆ.

Typical plant, common Cotton Sedge (*Eriophorum polystachyum*). See fig. 82.

Note: the stem is *herbaceous*, *solid*; leaves *sheathing*; the sheaths are entire, not split down the side of the stem opposite to the free lamina; flowers arranged in a spike with numerous scaly bracts (*glumes*), the outer of which are empty and the inner ones contain the bisexual flowers; perianth consists of numerous hypogynous bristles, which elongate on fruiting (in some plants of the order no perianth is present); stamens *three*; anthers *innate*; ovary *one-celled*, with three simple stigmas. This order contains numerous grass-like plants. In the large genus of Carex (Sedges) there are unisexual flowers (fig. 310).

FIG. 309.—Flower of *Cyperus longus* with the parts separated.

The Sand Sedge (*Carex arenaria*) is very useful for

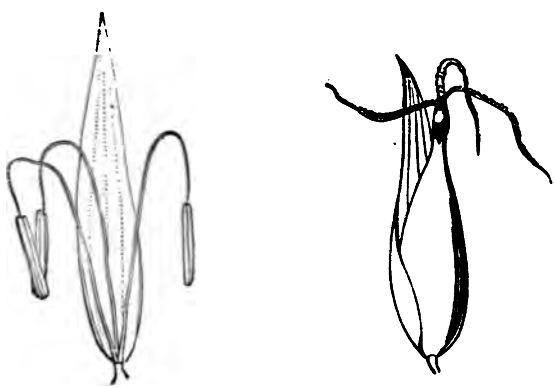

FIG. 310.—I. Male flower; II. Female flower, of *Carex*.

binding together the loose sand by means of its creeping stems. The Lake Scirpus (*Scirpus lacustris*) is used for chair bottoms, baskets, mats, &c. Papyrus was obtained from the stems of an Egyptian Cyperus.

GRAMINACEÆ.

Typical plant, common Wheat (*Triticum vulgare*).

Note: plant is *herbaceous* (some exotics are shrubby); leaves *sheathing*, sheath *split in front*; an appendage on the

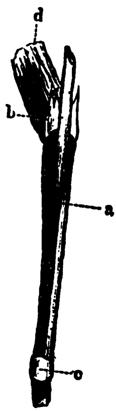

FIG. 311.—*a*, Split leaf-sheath of a Grass: *b*, ligule; *d*, part of the lamina of the leaf; *c*, node of the culm.

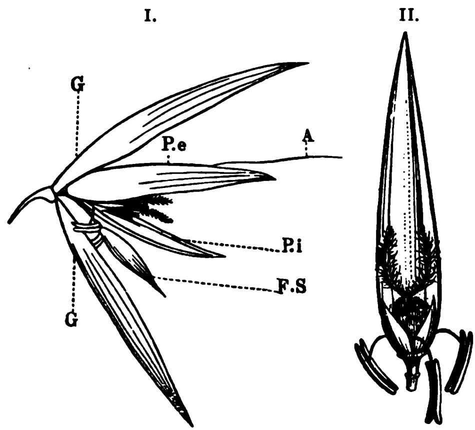

FIG. 312.—I. Expanded spikelet of the Oat, with a fertile and a barren flower, F S; G, glumes; *Pe* outer pale, with awn, A; *Pi* inner pale, within are the feathery stigmas. II. Fertile flower with the outer pale removed.

leaf where it separates from the sheath known as the *ligule* (fig. 311, *a*); stem *hollow*, except at nodes.

Flowers arranged in a spike with glumes, as in Cyperaceæ. If we remove one of the spikelets from the centre of the spike (fig. 312, I.) we find there are two outer bracts (*glumes*), G, G, containing several flowers, some fertile and others barren, F S. Each fertile flower is enveloped by two scales, one with a prolongation or *awn*, A, the flowering *glume* or *outer pale*; *the other, P i*, more delicate, the *inner pale*. Within these there are two minute scales, feathery above, the *lodicules*. These represent all there is of the perianth (see fig. 312, II.); then three stamens with *versatile anthers*, and lastly a single ovary with *two feathery stigmas*.

This is the general structure of the plants of the order; there are, however, minor points of deviation. Thus, in the Sweet-smelling Vernal Grass there are four outer glumes to each spikelet, in the Rye Grass one, and in the Mat Grass none. Sometimes the pale is absent, as in the Foxtail; or the lodicules, as in the Vernal Grass, Mat Grass, and Foxtail. In the Rice there are six stamens, and in the Mat Grass only one stigma. The Indian Corn has monœcious flowers; the staminate flowers have two lodicules and three stamens; the pistillate flowers no lodicules and but one stigma.

This large and wide-spread order is one of the most important to man, yielding, as it does, the various cereals that he employs as food, and the grasses used as food for cattle. Amongst the cereals the first place must be given to Wheat (*Triticum vulgare*). The origin of this important plant is entirely lost in the past. We are not acquainted with the wild stock from which it has been produced. Numerous varieties of Wheat are cultivated, some with awns to the flowering glumes and some without. Interesting experiments have been tried by Major Hallett in Sussex. By choosing the best ears and grains, and using these for sowing, and by repeating this process several times, the Wheat is greatly improved in character. By this process of artificial selection what is known as 'Pedigree Wheat' is obtained. The seeds in the case of all the plants of the Graminaceæ are albuminous, and flour is obtained from the crushed albumen.

Barley (*Hordeum vulgare*) is another important cereal, probably one of the first cultivated. Malt is prepared from Barley by allowing it to begin to germinate and then heating it to 160° or 180°; by this means the starch of the grain is converted into sugar, which is capable of fermentation.

Oats (*Avena sativa*), Rye (*Secale cereale*), and Millet, which is obtained from several genera, are also cultivated. Indian Corn is obtained from *Zea Mais*, which is a native of the New World. Rice is obtained from *Oryza sativa*, a tropical plant.

Besides these food plants, we have the important Sugar-cane (*Saccharum officinarum*), the clarified juice of which yields us sugar, whilst the residue produces molasses and treacle.

Numerous Grasses are grown for fodder purposes, whilst from some sweet essences are obtained. Lemon-grass oil is extracted from *Andropogon citratum*, citronelle oil from *Andropogon Nardus*, and some suppose that the spikenard oil of Scripture was obtained from *Andropogon Iwarancusa.*

The Bamboo is an arborescent genus of this order, used for many important purposes.

It will be well in conclusion to point out the differences between the two allied orders Cyperaceæ and Graminaceæ in a tabular form.

Cyperaceæ.	*Graminaceæ.*
Stem solid.	Stem hollow.
Leaf-sheaths entire.	Leaf-sheaths split.
No ligule present.	Ligule present.
No lodicules.	Lodicules generally present.
Anthers innate.	Anthers versatile.
Stigmas three, simple.	Stigmas two, feathery.

PLAN FOR DESCRIBING A PLANT.

Root.—Kind.

Stem.—*a.* Kind (herbaceous, shrubby, or woody).
b. Shape (rounded, angular, square, ribbed, &c.).
c. Direction (upright, spreading, creeping, climbing, &c.).
d. Surface (smooth, hairy, rough, &c.).

Leaves.—1. Insertion (opposite, alternate, radical, &c.).
2. Petiole (presence or absence, peculiarities).
3. Lamina.
a. Composition (simple or compound).
b. Venation.
c. Margin.
d. Incision.
e. Apex.
f. General outline.
g. Surface (smooth, hairy, &c.).
4. Stipules (present or absent, shape if present. Also note if sheath).

Inflorescence.—Kind of inflorescence and bracts.

Flower.—1. Calyx.
a. Cohesion (gamosepalous or polysepalous).
b. Number of sepals or divisions.
c. Adhesion (inferior or superior).
d. Specialities (colour, shape, &c.).

2. Corolla.
a. Cohesion.
b. Number.
c. Adhesion.
d. Specialities.
} as above.

Note. If perianth be present, describe it in same manner.

3. Corona or other appendages between corolla and andrœcium should be described here.

4. Andrœcium.
a. Cohesion (free, monadelphous, &c.).
b. Number.
c. Adhesion.

d. Specialities (if tetradynamous or didynamous, also peculiarities of filament and anther).

5. Gynœcium.

a. Cohesion (syn- or apocarpous).

b. Number of carpels.

c. Adhesion (inferior or superior).

d. Peculiarities of ovary, including—

α. Number of cells.

β. Placentation.

γ. Number of ovules.

e. Peculiarities of style and stigma.

Fruit and Seed.

EXAMPLE.

SWEET VIOLET (*Viola odorata*).

Root.—Fibrous.

Stem.—Slightly shrubby, rounded, short, underground forming a rhizome; surface scarred.

Leaves.—Apparently radical, but really growing in a tuft at apex of stem. *Petiole* evident, covered with short scattered hairs. *Lamina* simple, net-veined, unicostate, curved-veined, crenate margin, apex either rounded or somewhat acute, cordate or reniform, surface hairy, especially upon the margins and veins. *Stipules* present, slightly membranous, undivided, lanceolate.

Inflorescence.—Single flowered, the flower-stalks growing from the axils of the leaves and bearing two small nearly opposite linear bracts about the centre.

Flower—

Calyx.—Polysepalous; five sepals, inferior, irregular, each sepal broad in centre and pointed towards the two extremities, green, hairy.

Corolla.—Polypetalous; five petals, hypogynous. Irregular, either purple or white; in the former case the lower petal has several darker lines converging towards interior of flower; the lateral petals have a hairy tuft near mouth of tube, the inferior petal is prolonged into a short blunt spur.

Andrœcium.—Stamens free, five in number, hypogynous, almost sessile, the filament being very short; connective prolonged beyond the anthers as an orange-coloured mass; two of the stamens spurred, the spurs passing into the spur of corolla.

Gynœcium.—Syncarpous, three carpels, superior; ovary one-celled with three parietal placentas and numerous ovules; surface of ovary hairy; style curved; stigma hooked.

QUESTIONS FOR EXAMINATION.

[Those followed by a date are questions which have been set at previous examinations held in connection with the Science and Art Department, South Kensington.]

1. How can you distinguish a plant from an animal?
2. Into what two great sub-kingdoms may plants be divided?
3. Describe fully the seed of a Bean. (1875 and 1878).
4. Compare the seed of the Oat with that of the Bean.
5. Explain the terms 'albuminous' and 'exalbuminous,' and mention some albuminous seeds.
6. What is a vegetable cell?
7. What are the composition and properties of cellulose?
8. Enumerate and describe briefly the most important substances which are formed *within* the protoplasm of plant cells.
9. Give an account of the general properties of chlorophyll and of the conditions which are necessary to its formation.
10. What remarkable change do plants show when they are grown in the dark? (1876).
11. Why does heaping earth round Celery cause the stalks to be white? (1877).
12. What is the nature of starch? How is it formed, and what is its use? (1879).
13. Explain the structure of a cell and the changes it undergoes in the growth of a plant. (1878).
14. What conditions modify the shape of cells?
15. How are thickened cells produced?
16. In what respects does the wood of the stem of a Conifer (Fir-tree) differ from that of a dicotyledonous plant? Describe the development of 'bordered pits.'
17. What is meant by a vessel? How is it formed, and what is its use? (1878).
18. How are the cells, say in the leaf of a plant, increased in number?

19. Give an account of 'parenchyma.' Explain how it is formed. (1875).
20. Describe what happens in the germination of a Bean seed. (1878).
21. What requisites are needed for germination?
22. Compare the germination of the following seeds: Broad Bean, Acorn, Cress, Mustard, Pine, Date, and Wheat.
23. Describe the way in which roots grow. (1877).
24. The seeds of Mustard and Cress will germinate on flannel soaked with rain-water. Will they go on growing under these circumstances? and if not, why not? (1879).
25. When any vegetable material is burned, what constituents go off as gas? What are left behind? (1877).
26. What are the principal substances which form the food of plants? (1875).
27. What part of the food of a plant is taken up by the roots? (1878).
28. Explain how the food is absorbed by the roots.
29. Of what substances in the plant is nitrogen an essential ingredient? How does the plant obtain the nitrogen? (1876).
30. Why do plants require nitrogen, and in what form do they take it in? (1880).
31. Explain the 'rotation of crops.'
32. Explain why the root of a turnip first grows faster than the stem, and then stops while the stem grows rapidly. (1877).
33. What are the chief differences between a root and a stem? (1876).
34. Compare the appearance of a monocotyledonous and dicotyledonous stem as seen in transverse section.
35. What is the cause of the ring-like markings seen in the cross-section of a tree-trunk? (1876 and 1881).
36. Describe and explain as much of the texture of a deal plank as can be made out with the naked eye. (1879).
37. Explain the difference in the growth of the bark of a tree and that of the wood. (1880).
38. What is the structure and use of cambium?
39. Describe a 'runner,' a 'rhizome,' an 'offset,' and give examples.

40. Give a full account of a Potato, and explain as much as you can of its structure. (1875).
41. Explain why a Potato is considered to be a stem. (1878).
42. Describe and explain the structure of an Onion. (1876 and 1880).
43. Why can a tree be transplanted more safely in the winter than in the summer? (1877).
44. Describe a bud. To what structures do the outer coverings correspond? What is the origin and use of the resinous secretion with which they are often covered? (1877 and 1881).
45. Why are some of our fruit trees thorny in the wild state, but not when cultivated? (1879).
46. Mention, with examples, the different members of the plant which may be modified into tendrils.
47. Explain precisely how a tendril acts. (1881).
48. Explain the process of grafting. (1876).
49. What is the structural difference between a prickle (as in the Rose) and a spine (as in the Blackthorn). (1881).
50. What is a leaf? What is its use to the plant. (1877).
51. Describe the general structure of a leaf.
52. What are stomata? Where are they found in the plant, and what is their use? (1880).
53. When a branch of a tree is cut off, why do the leaves of the branch fade, while those of the tree remain fresh? (1876 and 1880).
54. What is the general plan of arrangement of leaves on a stem? Why is it the most advantageous to the plant? (1881).
55. What components of the atmosphere are taken from it by plants, and for what purpose? (1881).
56. What is the cause of the green colour of plants? What is its use? (1875).
57. State why absence of light is injurious to plants. (1881).
58. Why will a plant grown in a dwelling-room be less vigorous than one grown in the open air? (1879).
59. What is meant by respiration? Describe an experiment for showing that plants respire. (1878).
60. What is meant by transpiration? Under what circumstances do plants transpire most? (1879).

61. What are the conditions, external and structural, which regulate the amount of evaporation from leaves?
62. Explain the action of the leaves of carnivorous plants.
63. What are bracts? Give some of their modifications.
64. What is meant by definite and indefinite inflorescence? Give examples and draw diagrams to explain your answer. (1875).
65. If an inflorescence appears at the end of a branch of a tree, what is the effect on the future growth of the branch? (1879).
66. Tabulate the principal indefinite inflorescences.
67. What is meant by 'mixed inflorescence'?
68. What is a flower? What structures compose it, and what are their use? (1877).
69. Give the names and brief descriptions of the enveloping and essential organs of a flower. (1875).
70. Some English plants have one, others have two, and even three kinds of flowers. Explain how this is possible. (1879).
71. Explain the terms 'polygamous,' 'diœcious,' 'gynandrous,' 'syngenesious,' 'hypogynous,' 'perigynous,' 'inferior,' 'epigynous.'
72. Explain fully the various respects in which a petal differs from a leaf. (1880).
73. How do you explain the fact that while the leaves of most plants are green their flowers are of some other colour? (1878).
74. What is pollen? What is its use? (1875 and 1878).
75. What is meant by an inferior ovary? Give examples. (1875).
76. What is meant by placentation? Describe the various forms.
77. Explain the terms 'monadelphous,' 'diadelphous,' 'adnate,' 'innate,' 'versatile,' 'introrse,' 'extrorse.'
78. Mention plants whose flowers contain nectar. What is its use? (1877).
79. Describe the general structure of an ovule.
80. Explain the terms 'orthotropous,' 'anatropous,' 'raphe,' 'hilum,' 'micropyle.'

81. Explain what is meant by an irregular flower. What is the advantage to a plant of having such flowers? (1878 and 1881).
82. What provisions are made for cross-fertilisation?
83. What is a fruit?
84. Explain the terms 'syncarp,' 'pseudocarp,' 'drupe,' 'achene,' 'pome.'
85. Classify the dehiscent fruits.
86. What is a berry? What is the advantage to a plant to have this kind of fruit? (1877).
87. Explain the essential differences of structure in the fruits of the Strawberry and Blackberry. (1881).
88. How do the fleshy parts of the Strawberry, Blackberry, Apple; and Plum originate? (1876).
89. Describe as fully as you can the structure of an Apple, and explain the origin of the different parts. (1879).
90. Explain the terms 'epicarp,' 'mesocarp,' 'endocarp,' 'loculicidal,' 'septifragal,' 'circumscissile.'
91. In what points of structure does an ovule differ from a seed (1880).
92. What are 'endosperm' and 'perisperm'? Also give the structure of the arillus.
93. What is a hybrid? (1876).
94. What are the characters of the two groups of flowering plants?
95. Describe the typical structure of a stamen. State the peculiarities characteristic of those of a Crucifer. a Composite, a Labiate, and a Grass. (1880).
96. In what important respects does the fruit of a cruciferous plant (such as Shepherd's Purse) differ from that of a leguminous plant (such as a Pea)? How can the differences be accounted for? (1880).
97. Describe the general structure of the ovary and of the fruit in Rosaceæ and Leguminosæ.
98. Compare the natural orders Labiatæ and Scrophulariaceæ.
99. Give an account of the structure of the head of a Daisy. (1880).
100. What is the difference between an annual and a perennia plant? (1875).

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