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Professor Dewar in a
lecture on Chemistry of the
Organic world at Royal
Institution stated that
if plants are grown in
the dark they come
having half their weight
the carbon passes away
as Carbon Acid, and
the starch is transformed
into grape sugar. Plants
germinating in light gain
about half the weight of
their seed.
Liebig believes that the
soil alone provides
the nitrogen of plants.

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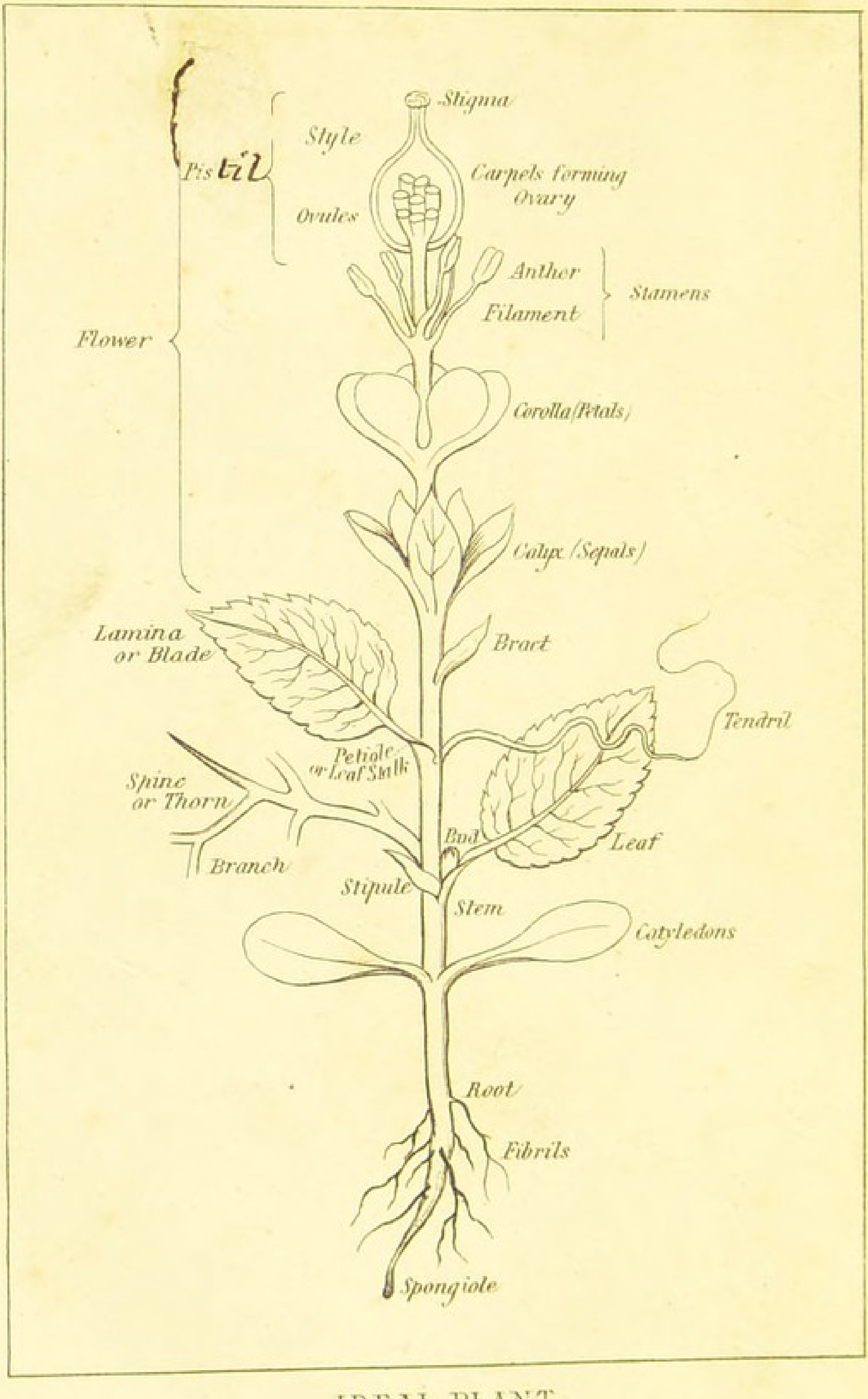

Stigma
Style
Pistil
Carpels forming Ovary
Ovules
Anther
Filament
Stamens
Flower
Corolla (Petals)
Calyx (Sepals)
Lamina or Blade
Bract
Tendril
Petiole or Leaf Stalk
Spine or Thorn
Bud
Leaf
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FIRST BOOK OF BOTANY;

BEING

AN INTRODUCTION TO THE STUDY

OF THE

ANATOMY AND PHYSIOLOGY OF PLANTS.

SUITED FOR BEGINNERS.

BY

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1874.

PREFACE.

THIS First Book of Botany is intended to be an Introduction to the Study of the Anatomy and Physiology of Plants, suitable for beginners. In the present day the study of the Natural History Sciences is beginning to constitute an important part of the education of the pupils who attend our schools, and Botany is the department which seems to be best suited for the youthful mind. It is a science having reference to the trees, shrubs, and herbs which are objects of daily observation. It can be prosecuted at all times, and adds interest to every walk in the country. It quickens the powers of observation, and promotes the formation of orderly habits. It teaches the pupil to mark the differences and resemblances of the objects around him, and leads to accuracy of description and definition. It is the simplest of the Natural History Sciences, and the materials for its prosecution are within reach of all. The poorest child can be taught to see beauty in the buttercup, the violet, and the daisy, which beset his path, and may be led to view these common things with something more than an idle gaze.

The wonderful arrangements and adaptations seen in the meanest weed give to the mind exalted ideas of the wisdom and power of the Creator, and exhibit the care which He bestows on the lowliest flower. It is only by a careful and intelligent examination that we can see the exquisite symmetry of God's work. When we contemplate the mode in which the lovely colours of the lilies are produced, we are led to understand more fully the statement that even Solomon in all his glory was not arrayed like one of them; and when we look to the clothing of the grass, we feel that He who thus adorns the pasture, and watches over every blade, cares also for us.

Speaking from some experience in the teaching of the young, I can truly say that the little botanical lessons given to children in the course of summer rambles have been a source of great pleasure and enjoyment alike to teacher and pupil. I would therefore strongly urge the propriety of making Botany a part of elementary teaching.

The study of the structure and form of the various parts of plants, and of the functions which they perform, will lead to a consideration of the mode in which they are classified and named. This department of the Science is reserved for a Second Book of Botany.

In the present edition of this work some Introductory Remarks are given on the subject of the Chemistry of Vegetation, embracing a consideration of the organic and inorganic constituents of plants, and of the sources from whence these are derived.

Royal Botanic Garden,
Edinburgh, *January, 1874.*

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CHAPTER III.

FIRST BOOK OF BOTANY.

INTRODUCTORY REMARKS ON THE CHEMISTRY OF VEGETATION.

Before entering upon the study of the structure and functions of plants, it may be useful to make a few remarks on the materials which enter into the composition of their various parts or organs, and the changes produced in these materials during the growth and decay of the plant. This subject may be included under the title of The Chemistry of Vegetation.

The substances which enter into the composition of plants are derived from the atmosphere and the soil. They are of two kinds, organic and inorganic. The former make up the great bulk of the tissues, and they are decomposed when the plant is burnt. The latter are present in comparatively small quantity; and form a large part of the ash which is left after the plant has been burnt.

The vegetable organic constituents are composed chiefly of Carbon (C), Oxygen (O), Hydrogen (H), and Nitrogen (N). The inorganic constituents are metallic salts, which are much more simple in their composition. In the fresh plant there is usually a large amount of water, which is composed of two atoms of hydrogen and one of oxygen (H_2O); it is removed by drying the plant.

Carbon enters largely into the composition of plants. In general, it may be said to form two-thirds of the weight of the dried plant. This substance is familiar to us in the form of wood-charcoal, and, in its purest state, as the diamond. Charcoal is porous, and has the property of containing within its pores large quantities of soluble gases; it separates saline and other matters from solutions, and removes offensive gases. When carbon is burned in the air, it unites with two atoms of oxygen, and forms carbonic acid or carbon dioxide (CO_2). It is in this condition that it is taken up by leaves and other parts of plants, either as a gas or dissolved in water. The sparkling of beer and of other fluids depends on the escape of carbonic acid. It is produced in the oxidation (burning) of all organic substances, as in the breathing of man and other animals, and in the ordinary processes of combustion. It is also formed in the decay of animal and vegetable matter; and vast quantities are thrown into the air by volcanic action. The atmosphere contains about $\frac{4}{10000}$ of its volume of the gas; and although the quantity contained in the air is comparatively small as regards bulk, still it is sufficient to supply the carbon required by plants. The presence of carbonic acid in a room may be shewn by its causing lime-water to become milky, on account of the formation of an insoluble carbonate of lime. While animals by breathing take oxygen from the air, and give off carbonic acid, the green parts of plants, under the influence of light, decompose carbonic acid and give off oxygen. When plants decay, they yield what is called *humus*, or vegetable mould, which forms the chief part of the organic matter in soils.

Oxygen is another organic element of plants. It is known to us only in the gaseous state. It forms 21 per cent. of the bulk of the atmosphere, and is concerned in the processes of respiration and combustion. When one measure of oxygen is combined with two of hydrogen, water is formed (H_2O). In combination with metals and metalloids, oxygen forms nearly three-fourths of the mass of the globe.

Hydrogen is another constituent of plants, known to us in the state of a gas. It does not, however, occur free and in a simple state upon the earth. Combined with carbon, it enters into the composition of almost all animal and vegetable substances.

These three substances, carbon, oxygen, and hydrogen, variously combined, form the non-nitrogenous constituents of plants, such as cellulose, starch, gum, and sugar. All these substances may be considered as being derived from carbonic acid (CO_2), and water (H_2O), which the plant has been able to decompose and construct into more complex products for the building up of its tissues.

Cellulose ($C_6H_{10}O_5$, or some multiple of these numbers) forms the membrane of cells and vessels. It may be obtained from cotton and linen, which are almost pure cellulose, by acting upon them with an alkali, alcohol, and ether, so as to separate any impurities. When acted upon by strong sulphuric acid, it is converted into a substance which is coloured blue by iodine, and by still further action is converted into dextrine, and then into grape-sugar. Cellulose is altered in the progress of growth, and forms thickened ligneous matter.

Cellulose is present in all plants, and enters into the composition of the walls of cells and vessels. It may be called the basement tissue. In the hairs of cotton and in the pith of plants it is found nearly pure. Cellular tissue is composed of cells with walls formed of cellulose. In a succulent state this tissue is digestible; but when hardened by deposits inside, it is no longer fit for food. Pure cellulose is white, tasteless, and insoluble in water, alcohol, ether, or oils. Sulphuric acid converts it into dextrine, and afterwards into grape-sugar. In its natural state it is not coloured blue by iodine; but when acted upon by sulphuric acid, a blue colour is produced when iodine is added. By the combined action of sulphuric and nitric acid, cellulose is converted into gun-cotton (Pyroxyline). This has the property of taking fire and burning rapidly on the application of flame. A solution of gun-cotton in ether and alcohol is known as collodion, which is used by surgeons in covering ulcerated surfaces.

Lignine is the name given to the encrusting matter which is formed on the inside of the walls of cells so as to constitute woody tissue or hard cells, as the shells of nuts. It contains a larger amount of hydrogen than is found in cellulose. It is soluble in alkaline liquids. The ligneous matter of plants is used for the manufacture of paper, after maceration. This matter, during the decay of plants, gives rise to the formation of humus, peat, bituminous matter, and coal.

The tissue of plants formed of rounded, elliptical, or angular cells is called parenchyma, while that formed by spindle-shaped (fusiform) thickened cells constitutes prosenchyma, seen in the wood of trees; and that kind of tissue which is much elongated is denominated vascular tissue. The last-mentioned tissue has its walls formed either simply of cellulose, or of cellulose and lignine, and sometimes the lignine occurs in the form of a spiral coil, or of rings or bars.

Starch has a similar composition with cellulose. It exists largely in plants. It consists of organised granules, which are insoluble in cold water, alcohol, and ether. When heated with water to about 70° C,, the granules swell up and split, forming a thick pasty mass. Starch granules often exhibit a striated appearance. The striæ, or lines on starch grains, are supposed to depend on a wrinkling of the covering. [Starch grains with striæ are seen in fig. 11, p. 14.] When starch is heated to about 105° C., and a small quantity of hydro-chloric or nitric acid is added, a substance called dextrine is procured, which has the same composition as starch, and is soluble in water. It is one of the stages of transformation of starch during the progress of vegetable growth. Insoluble starch stored up in cells and vessels is thus converted into the soluble form of dextrine, and this substance is in its turn converted into grape-sugar. By the action of iodine starch becomes blue.

Gum ($C_{12}H_{22}O_{11}$) is another organic substance which is produced by plants. It is seen as an exudation from many plants, such as species of *acacia*, the cherry, plum, &c.

Sugar is another organic constituent of plants, which, like the above substances, consists of carbon combined with oxygen and hydrogen in the proportion to form water. On account of this peculiarity in their composition, these substances are classified as carbo-hydrates. There are two kinds of sugar found in plants, cane-sugar and grape-sugar. Cane-sugar, or sucrose ($C_{12}H_{22}O_{11}$), exists in the juice of some plants, such as the sugar-cane (*Saccharum officinarum*), sugar-maple (*Acer saccharinum*), and in beet-root (*Beta vulgaris*). It is also found in carrots and turnips, and in the young shoots of the maize or Indian corn (*Zea Mais*). [See Second *Book of Botany*, fig. 155]. Grape-sugar, called also glucose ($C_6H_{12}O_6$) is a product of germination, being formed during the early growth of the embryo plant, and it exists in many kinds of fruits. It may be procured by boiling starch in dilute sulphuric acid, neutralising the acid by chalk, and evaporating the liquid till it becomes a syrup, when the sugar crystallises.

Other organic substances found in the tissues of plants have nitrogen in their composition, along with carbon, oxygen, and hydrogen. The substances thus formed are usually in combination with sulphur and with alkaline or earthy phosphates. The constituents of these substances are commonly known as albumen, fibrine, and caseine. Gluten, consisting mostly of fibrine and albumen, is the glutinous part of wheat. It remains after the starch and the soluble constituents of the grain have been removed. *Nitrogen* enters largely into the composition of the tissues of animals, and therefore is required in their food. Nitrogen is known to us as a gas, forming 79 volumes per cent. of the atmosphere, and moderating the effect of oxygen on all oxidisable bodies. It enters into composition with hydrogen, and forms ammonia, consisting of one atom of nitrogen and three of hydrogen, H_3N. Ammonia is a very pungent gas, and is slowly given off during the decay of nitrogenous animal and vegetable tissues. It is exceedingly soluble in water, and is a powerful base, uniting with carbonic acid, and all acids, to form ammonia salts. The ammonia in the air is dissolved by rain and brought down to the soil, where it forms salts, which afford nourishment to plants. The nitrogen of the air does not appear to be taken up directly by plants; but, according to recent researches, it seems to be absorbed to a certain extent by the soil, and there hydrogen, derived from the decomposition of organic matter, combines with it to form ammonia. The nitrogenous substances found in plants are known as proteine compounds, and are called albuminoids.

The nourishment which plants derive from the soil may be called their telluric food. It consists of certain inorganic matters, the amount of which is ascertained by the quantity of ash left after burning. There are at least 12 inorganic elements which enter into the composition of plants,—Sulphur (S), Phosphorus (P), Silicon (Si), Chlorine (Cl), Iodine (I), Fluorine (F), whose acids form salts with basic oxides of the metals—Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg), Iron (Fe), and Manganese (Mn):—

Sulphur, S, as Sulphates.			
Phosphorus, P, as Phosphates.			
Silicon, Si, as Silicates.			
Chlorine, Cl, in combination with metals, as Chlorides.			
Iodine, I,	do.	do.	as Iodides.
Fluorine, F,	do.	do.	as Fluorides.
Potassium, K, as Potash salts.			
Sodium, Na, as Soda salts.			
Calcium, Ca, as Lime salts.			
Magnesium, Mg, as Magnesia salts.			
Iron, Fe, as Iron salts.			
Manganese, Mn, as Manganese salts.			

Alumina (Al_2O_3), the sesquioxide of aluminum, which has been noticed by some authors as another inorganic constituent of plants, seems to be an accidental ingredient, being sometimes present, and at other times absent. There are also indications of the presence of bromine (Br.) in some plants.

The quantity of inorganic matter in plants is small when compared with the organic constituents. It is nevertheless essential to the life and vigour of plants. Sulphur and salts of phosphoric acid are necessary for the formation of albumen, fibrine, and caseine.

Some of the substances constituting the ash of plants are found in a crystalline form in the living plant, and are called raphides (fig. 12, p. 14). These consist generally of phosphate or oxalate of lime, and they are either in the form of needles or of rhombohedral crystals, single or connected in clusters. The needle-formed crystals may be seen in the common hyacinth or in the cuckoo-pint *(Arum)*, while the other form occurs in the outer scales of the onion, in the cactus, and in rhubarb.

In the interior of cells we find fluid matter called cell sap, of a pale colour (see *Chara*, fig. 10, p. 14), green corpuscles called chlorophyll, and a formative matter called protoplasm, concerned specially in the formation of new cells.

Chlorophyll is common in plants, constituting their green colouring matter. It is a substance insoluble in water, but soluble in alcohol and ether. From the green alcoholic solution chlorophyll may be obtained by evaporation, but not pure. The action of light is required for the development of chlorophyll; and by the aid of light it decomposes carbonic acid, and sets free oxygen. During the progress of plant-growth, it undergoes changes in colour. In autumn it assumes various tints of yellow, and red, and brown.

Protoplasm is a proteine compound formed of nitrogenous matter, with starch, fatty matter, water, and mineral salts. It is concerned in the growth of the cell-wall and the development of new cells. It is stained by the action of iodine and carmine, while the cell-wall remains unchanged. By the action of dilute caustic potash or acetic acid the protoplasm is dissolved. We see protoplasm contained in the cells of plants; but it is said that some of the lowest plants and animals consist of this substance uncovered by any cell-wall. This is observed in the animal (protozoon) called amœba, where there is at first a plasma or protoplasm, which may afterwards receive a covering.

Cells have the power of forming new cells in their interior, and also of budding and of dividing. A cell may produce a partition or septum in its interior, so as to become divided into two, and each of these may again divide in a similar manner. These phenomena are seen in the young cells of the embryo plant in its earliest stages.

The soil in which plants grow supplies various materials for growth. These are absorbed in a fluid state by the delicate cells at the ends of the roots, and pass upwards to the leaves and flowers. Soils may be divided into sandy or siliceous; clayey or argillaceous; calcareous, containing above 20 per cent. of lime; marly and loamy, with a small percentage of lime; and humus soils or vegetable moulds.

The presence of sand and gravel renders soils loose and friable. Such soils are usually dry. Clayey soils contain a large quantity of alumina. Such soils are stiff and firm, and absorb and retain alkaline matters which are useful for plants. Calcareous soils supply lime, which is taken up by plants in the form of soluble salts.

The alkalies, potash and soda, are constituents of plants, and exist in soils. Their salts are almost all very soluble, and are easily absorbed by plants.

STRUCTURE AND FUNCTIONS

OF THE

VARIOUS ORGANS OF PLANTS.

CHAPTER I.

ORGANS OF NUTRITION.

A PLANT consists of certain parts called **Organs,** which assume various forms, according to the functions which they perform in the economy of vegetable life. These organs, generally speaking, are denominated Root, Stem, Leaves, and Flowers. The first three are specially concerned in the nourishment of the plant, and are called Nutritive Organs; while the flowers are connected with the production of fruit and seed, and the continuance of the species, and are called Reproductive Organs. There is a common axis, one part of which penetrates the earth, constituting the root-system or **Descending axis,** while the other rises into the air, bearing leaves and flowers, and forms the stem-system or **Ascending axis.** Each of these parts gives origin to buds, which in the former are developed as roots and rootlets, in the latter as leaves and leaflets of various kinds. The ordinary leaf may be said to be the type of the organs connected with the ascending portion of the axis. This type undergoes various modifications. Some leaves are green, others are coloured—some are placed close together or united, others are separated—some are thick and fleshy, others are thin and membranous, or mere scales—some are flat, others are folded so as to become hollow—some are changed into tendrils, others into thorns. The leaflets forming the flowers are usually very different in aspect from the ordinary leaf. It will be found, however, that they are all formed according to the leaf-law, and that they often show this in an evident manner when altered by cultivation or otherwise.

Fig. 1 (*Frontispiece*) represents an ideal plant with its different parts. There is a general axis from which proceed the descending part, forming the root, with its fibrils, the extremities of which are called spongioles; and the ascending part, forming the stem, with its various joints or divisions. On the stem, leaves are produced, first in the form of temporary seed-leaves (cotyledons), and then in the form of simple or compound leaves. Buds are produced at the points where these leaves join the stem, from which proceed branches. In process of time the flower is produced, consisting of calycine leaves or sepals, corolline leaves or petals, staminal leaves or stamens, and pistilline leaves or carpels which form the ovary and cover the young seeds or ovules. The latter are either attached to the edges of the carpels or are produced at the extremity of the ascending axis. In this ideal figure, the parts of the flower or blossom are represented as separated from each other by spaces. In general they are found close to each other in nature.

Such is a comprehensive view of the organs of plants. We shall now proceed to consider them in succession, commencing with their structure, as observed by means of the microscope.

I.—Microscopic Structure of Plants.

As regards their minute structure, plants have been

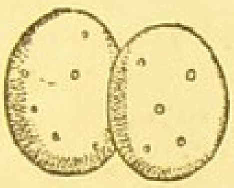


Fig. 2.

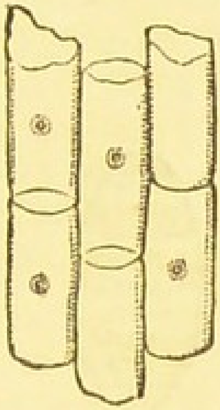


Fig. 3.

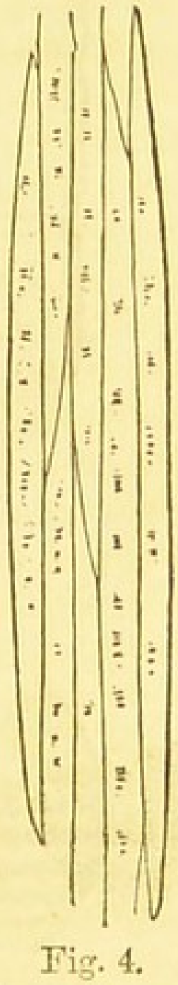


Fig. 4.

divided into those which are composed entirely of small bladders or vesicles called **Cells** (fig. 2), united together in various ways (fig. 3); and those which are furnished not only with cells, but with long closed tubes, called **Vessels** (fig. 4). The former are denominated **Cellular plants**; and they may be illustrated by mushrooms, sea-weeds, and lichens, which have no conspicuous flowers, and are reproduced by small cellular germs; the latter receive the name of **Vascular plants**, and are seen in the case of ordinary trees, shrubs, and herbs, which have more or less evident flowers, and are reproduced by true seeds.

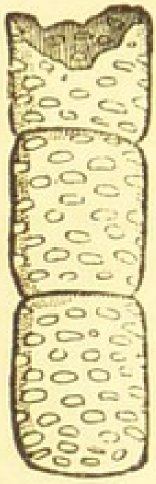
The structure of the cells and vessels of plants can only be fully seen by the aid of the microscope. The

Fig. 2.—Two cells or vesicles (magnified). The dots are places where the membrane, forming the walls of the cells, is thin.

Fig. 3.—Cylindrical cells (magnified) united together and forming cellular tissue. Some of them are represented as containing small cells (cellules or nuclei).

Fig. 4.—Elongated spindle-shaped woody tubes, closed at each end, and united together, so as to form a kind of vascular tissue.

examination of these tissues amply repays the trouble



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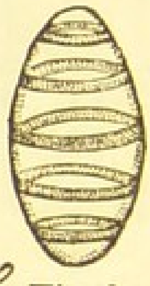

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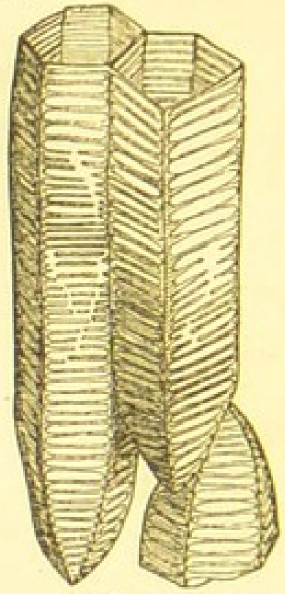


Fig 7.

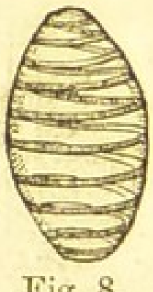


Fig. 8.

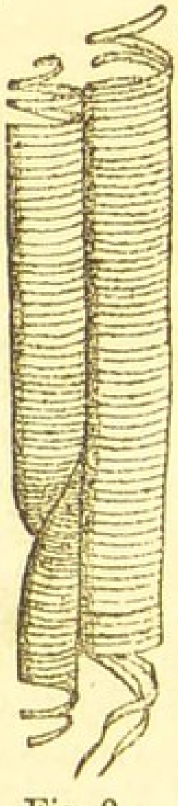


Fig. 9.

attendant upon it. In some cells and vessels there are seen markings in the form of dots (fig. 5), or rings (fig. 6), or bars (fig. 7), or fibres, coiled up like a corkscrew (figs. 8 and 9). Hence arise the various names of dotted or pitted, annular or ringed, barred or ladder-like, and spiral, cells and vessels. These, along with woody tubes (fig. 4), may be seen in different parts of the same plant.

Seaweeds are composed of cells united together; so are the pith of trees, cotton, cork, from the outer bark of the

Fig. 5.—Dotted or pitted vessel, composed of united cells with the partitions obliterated. Fig. 6.—Annular or ringed cell, with fibres in the form of rings. Fig. 7.—Scalariform or ladder-like vessels of ferns; the fibre is in the form of bars or lines, like steps of a ladder. *Scala* is the Latin name for a ladder.

Fig. 8.—Spiral cell, with an elastic spiral fibre inside.

Fig. 9.—Spiral vessels, with spiral fibres inside, capable of being unrolled.

cork-oak, rice-paper, and the paper of the ancients, made from the papyrus—the bulrush of Scripture. All fleshy fruits, as the peach, and succulent roots, as turnip and carrot, contain a large quantity of cellular tissue; and the object of the gardener in many instances is to increase it, and thus to render vegetables tender and succulent, which would otherwise be tough and dry. Cells often become hardened and thickened by matter deposited within. Thus the hard shell of seeds, and the stone of fruits, consist of woody cells.

The woody parts of plants consist of elongated tubes, tapering to each end (fig. 4), and rendered tough by hard matter deposited within. These woody tubes can be separated from the bark and stems of many plants by maceration or steeping in water; and in this way hemp and flax are procured. Each minute thread of these substances consists of numerous woody tubes overlying each other, as represented in fig. 4, and thus having considerable tenacity. Spiral vessels are met with abundantly in the higher tribes of plants. They may be procured from common asparagus after being boiled, by separating the cellular portion in water under the simple microscope. The spiral fibre of the vessels may be exhibited by making a superficial cut round the leaf-stalk of a geranium or strawberry, and then pulling the parts gently asunder. When the coil is unrolled, it appears like the threads of a cobweb. In the common hyacinth and lilies, these spiral fibres can be easily seen. Vessels having bars arranged like the steps of a ladder (fig. 7) occur in ferns.

Thus all the parts of plants, including root, stem, leaves, flowers, and fruit, are composed of cells and vessels of different kinds, either separate or combined; and by means of these simple tissues the Creator carries on all the wondrous processes of vegetable life. The absorption of nourishing fluids takes place by the cells of the root; the sap then rises through the cells and vessels of the stem; it reaches the cells and vessels of the leaf, and is there exposed to the action of air and light, so as to fit it for its various uses. Thus the function of nutrition or nourishment is accomplished. The cells and vessels of the flower are concerned in the function of reproduction, or the production of seed.

Besides a general movement of sap, there are also special movements occurring in cells and vessels. In the cells of aquatic plants, such as **Chara** (fig. 10) and

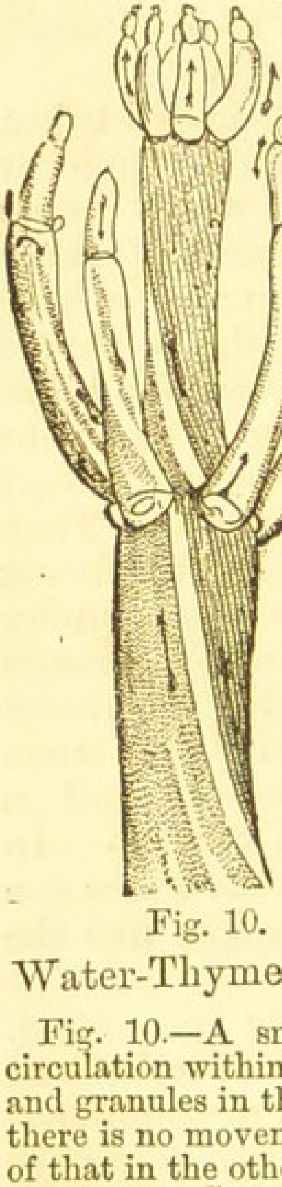


Fig. 10.

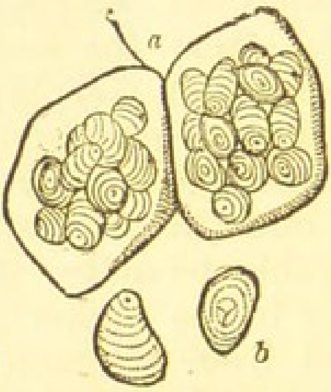


Fig. 11.

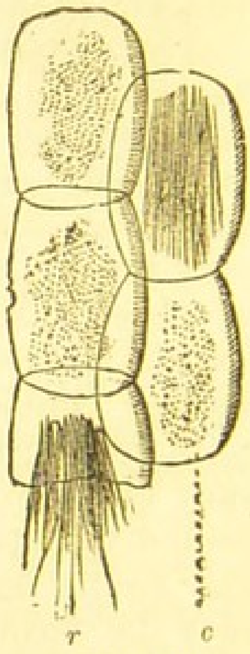


Fig. 12.

Water-Thyme (**Anacharis**), there is a regular motion

Fig. 10.—A small portion of a Chara magnified to show the circulation within cells. The arrows mark the direction of the fluid and granules in the different cells. The clear spaces are parts where there is no movement. The circulation in each cell is independent of that in the others.

Fig. 11.—Starch-cells of the pea, showing striated grains of starch in the interior.

Fig. 12.—Cells of Dock *c*, containing raphides *r*. The raphides consist of needle-like crystals joined together in clusters. The Greek word *raphis* means a needle.

of granules, which is easily seen under the microscope. These movements are promoted by moderate heat, and seem to take place in a spiral manner round the cells. In the hairs of the common nettle similar motions are observed. In certain vessels also movements of granular matter have been detected.

Cells contain various kinds of fluids—some coloured, others colourless; some thin, others thick and viscid. They also contain starch (fig. 11), sugar, wax, fatty and oily matters, air, and crystals which are called needles (raphides) (fig. 12). These crystals are easily seen in the common hyacinth.

II.—Structure, Conformation, and Functions of the Root.

The root is the first part of the young plant which protrudes from the seed (fig. 13 *r*). It descends into the ground in order to fix the plant and to imbibe nourishment. On account of its downward tendency, the name of Descending Axis is sometimes applied to it. The cells situated near the extremities of the minute fibrils of the root, are those which are chiefly concerned in taking up nourishment from the soil (*Frontispiece*, fig. 1). They are called spongioles. One of them is represented on a magnified scale in fig. 14, *sp*. The other cells of the root are indicated by *c c*, and these pass gradually into vessels *v*.

Some roots taper, as in the carrot, bryony, and radish, and are called tap-roots (figs. 16, 17); others branch in various ways (fig. 15). In grasses we see frequently numerous fibrils proceeding from one point, and giving rise to fibrous roots (fig. 19). In the turnip the root is large and succulent (fig. 18).

As plants are fixed to a spot, their food must be always within reach; and it is requisite that the roots should have the power of spreading, so as to secure renewed supplies of nutriment.

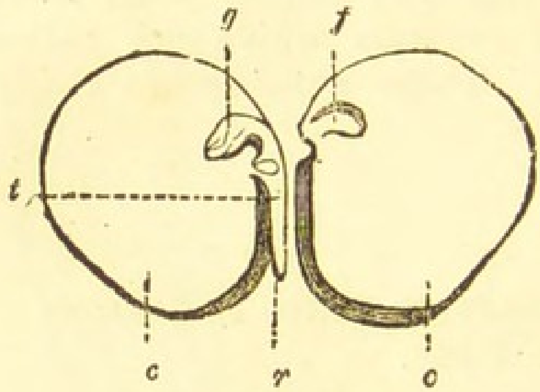


Fig. 13.

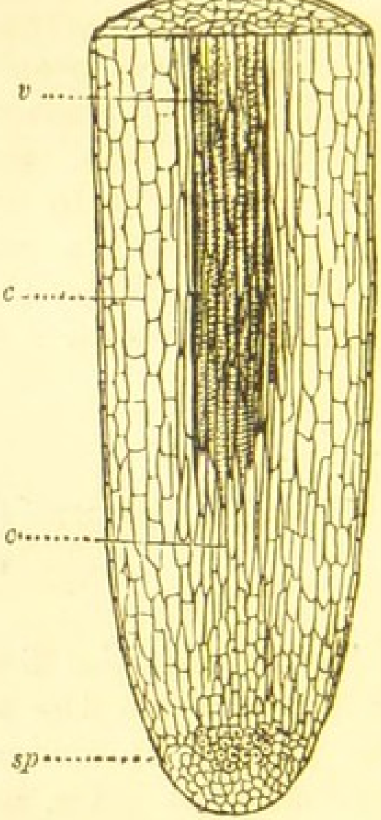


Fig. 14.

The root, in its growth, keeps pace with the development of the stem and its branches. As the stem shoots upwards and produces its leaves, from which water is constantly transpired, the roots continue to spread, and to renew the delicate cells and fibrils which absorb the fluid required to compensate for that lost by evapora-

Fig. 13.—Young Plant (embryo) of the Pea. The cotyledons *c c*, or seed-lobes, are fleshy, and remain below ground. The radicle *r* protrudes through a hole in the seed, and is the first portion of the embryo which appears during sprouting. The plumule or first bud *g*, afterwards appears and rises upwards to form the ascending axis. The common axis *t*, whence the radicle and plumule proceed, is united to the cotyledons by a short stalk; *f*, a small depression in one cotyledon, where the young bud *g* lay.

Fig. 14.—Vertical section of a rootlet of an Orchis, much magnified; *sp*, the minute cells at the extremity, called spongioles or spongelets; *c c*, the other cells of the root; *v*, dotted vessels.

tion, or consumed in growth. There is a constant rela-

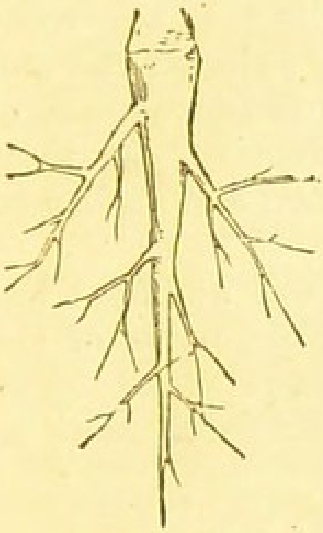


Fig. 15.

Fig. 16.

Fig. 17.

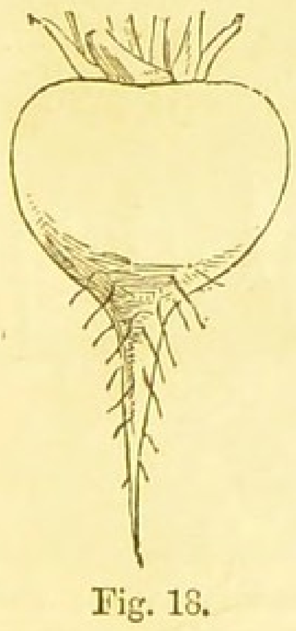


Fig. 18.

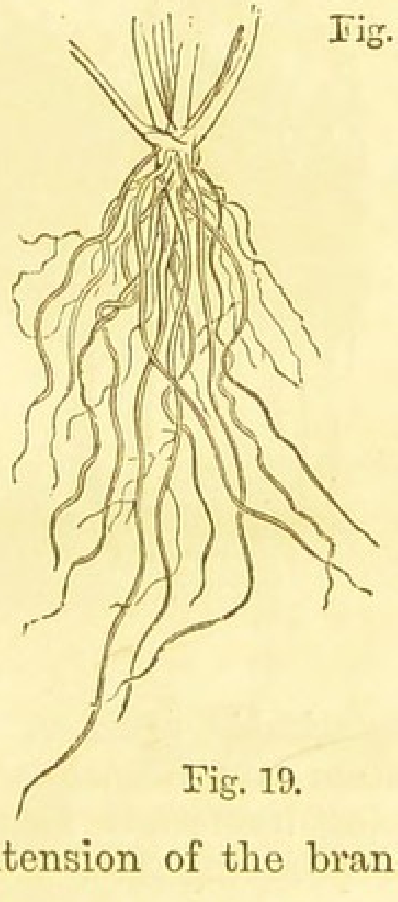


Fig. 19.

tion between the horizontal extension of the branches

Figs. 15 to 19.—Various forms of root. 15. Branching root of Mallow. 16. Conical tap-root of Bryony. 17. Spindle-shaped tap-root of Radish. 18. Succulent root of Turnip. 19. Fibrous root of Rib-grass. In figs. 16 to 19 the crown of the root is seen, which is a shortened stem, at the top of the root, bearing leaves.

and the lateral spreading of the roots. In this way the rain which falls on a tree drops from the branches on that part of the soil which is situated immediately above the absorbing fibrils of the roots. If the roots are not allowed to extend freely, they exhaust the soil around them, and do not receive a sufficient supply of food. The plants in such a case, deprived of their proper means of support, become stunted and deformed in their appearance.

Roots in general descend into the soil at once; but in some cases they proceed from different parts of the stem, and thus are in the first instance aerial. The Banyan tree of India (fig. 20), exhibits these roots in

Fig. 20.

a remarkable manner. They proceed from all parts of its stem and branches, and ultimately reach the soil, forming numerous stem-like roots which support this wide-spreading tree.

Fig. 20.—The Banyan-tree (belonging to the same genus as the Fig), sending out numerous adventitious or aerial roots, which reach the soil, and prop the branches.

When roots do not extend much, they are sometimes provided with reservoirs of nourishment which supply the means of growth during a certain period. This is seen in the case of the common orchis (fig. 21). These reservoirs or tubercules constitute the salep of commerce, which is used as food. In dry soils, roots are sometimes unable to spread from want of moisture, and form bulb-like appendages so as to lay up a store of nourishment. In seasons of drought also, a similar occurrence may take place. In the orchids of warm climates, in place of thickened roots there are large bulb-like stems which serve the same purpose (fig. 22). These orchids, which are often

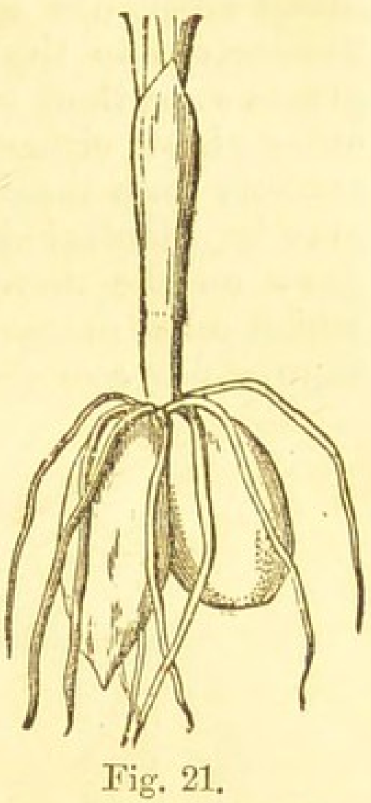


Fig. 21.

Fig. 22.

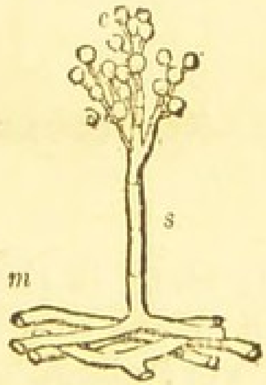


Fig. 23.

Fig. 21.—Roots of Orchis; some of them are slender and absorb nutriment, while two of them are thick, fleshy tubercules, which contain a reservoir of food, and constitute salep.

Fig. 22.—Orchideous air-plant, with its peculiar flowers and bulb-like stems.

Fig. 23.—A species of mould-fungus (*Botrytis*), magnified. There are below root-like filaments *m*, constituting the spawn. These

called air-plants, send out roots into the air, and attach themselves to the stems and branches of trees. Some plants send their roots or suckers into the substance of other plants either dead or living, and derive their food entirely from them. Such are called **Parasites**, and they may be illustrated by moulds (fig. 23); by fungi which grow on the decaying stumps of trees, and by those which cause diseases in growing crops; by dodder which injures flax and clover, and by the mistleto (fig. 24).

Fig. 24.

III.—Structure, Conformation, and Functions of the Stem.

The stem is the name given to that part of a plant which bears the leaves and the flowers. Some plants have very short and inconspicuous stems; others have long and conspicuous stems. In the cowslip, dandelion,

insinuate themselves into the tissues of living plants, and act as parasites, drawing nourishment from the tissues, and ultimately destroying the plants. *s*, Cellular stalk bearing fructification.

Fig. 24.—The Mistleto, a green-leaved parasite which derives nourishment from the plants to which it is attached.

and gentianella, the stem is so short that the leaves appear to arise from the root, and are hence called radical leaves. Some stems lie along the ground only partially covered by soil, as the iris (orris-root), and Solomon's seal (fig. 25); others are completely under ground, as ginger (fig. 26). The latter give off leaf-buds, which appear above ground. The banana has an underground stem pushing out shoots, which form temporary aerial stems or branches; so have also the asparagus, the bamboo, and arrow-root. Many subterranean stems are called, in common language, roots, from which, however, they are distinguished

Fig. 25.

Fig. 26.

by the leaf-buds which spring from them. Thus the potato is an underground stem or branch giving off buds in the form of **eyes**. The bulbs of lilies, leeks, (fig. 27), and tulips, with their fleshy scales, and the more solid bulb-like corms of crocuses and meadow-saffron (fig. 28), are in reality stems giving off buds, which are covered with different kinds of scales or

Fig. 25.—Rhizome, root-stock, or partially subterranean creeping stem of Solomon's seal. The scars left on the stem by the fall of the buds give rise to the English name of the plant.

Fig. 26.—Rhizome, or thickened creeping stem of ginger, producing flowering stems and roots. This rhizome or root-stock is the part used economically and medicinally, and called ginger-root.

modified leaves. The cloves of onions are the young buds formed at the points where the fleshy scales join the underground stem.

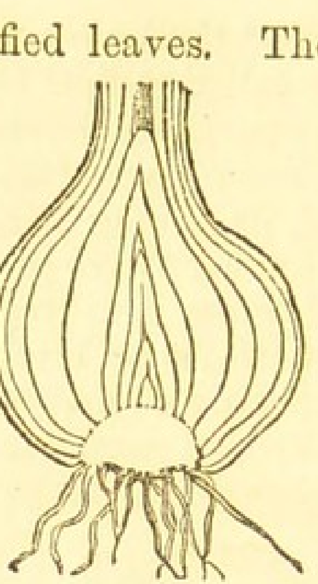


Fig. 27.

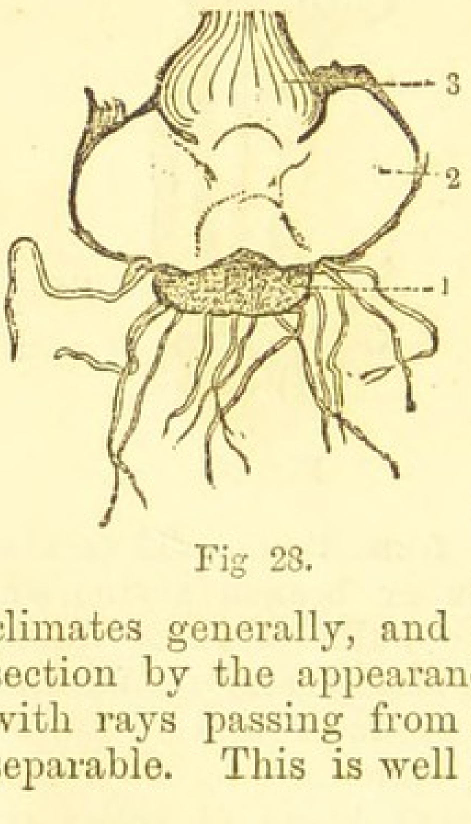


Fig 28.

Some stems are weak, and are supported by climbing on walls or rocks, as ivy (fig. 29), or by twining round some support, as convolvulus (fig. 30). These twining stems turn in certain definite directions. Thus the convolvulus (fig. 30), passion-flower, and French bean, twine from right to left, that is, to a person supposed to be in the centre of the coil, and the stem passing across his chest from his right to his left; while the hop, honeysuckle, and black bryony, twine from left to right.

Exogenous Stem. — Some stems die annually, others continue permanent. In flowering plants there are two marked kinds of stems. One occurs in the trees of temperate climates generally, and is recognized on a transverse section by the appearance of numerous woody circles with rays passing from the pith to the bark which is separable. This is well seen in the common oak (fig.

Fig. 27.—Bulb of leek, cut perpendicularly, showing the disc at the base whence roots proceed on one side, and scales with the growing point on the other.

Fig. 28.—Thickened bulb-like underground stem or corm of the Saffron, showing the mode in which new corms are produced above the old. No. 1 indicates the old corm now shrivelled; 2, the corm produced at the apex of it, in the form of a bud; 3, the young bud producing a flowering stem.

31), where the pith in the centre is composed of cells;

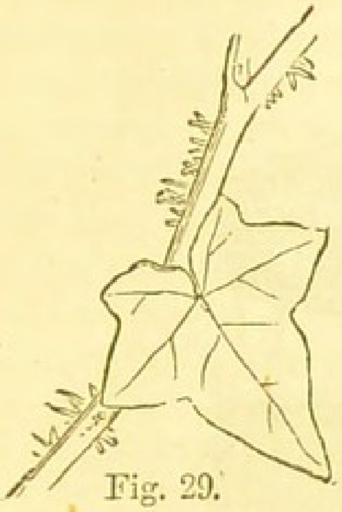


Fig. 29.

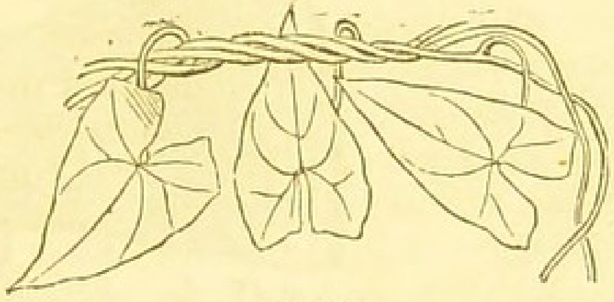


Fig. 30.

the circles of wood consist of fibrous vessels (fig. 4, p. 11),

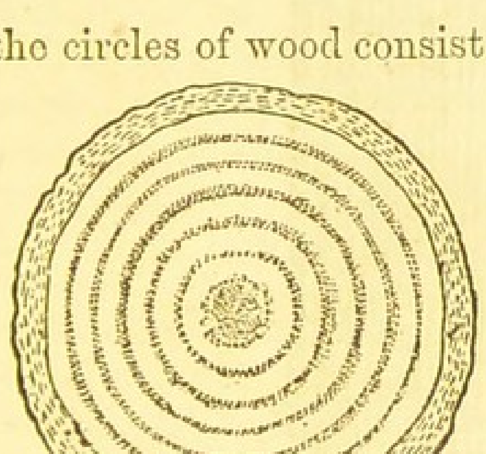


Fig. 31.

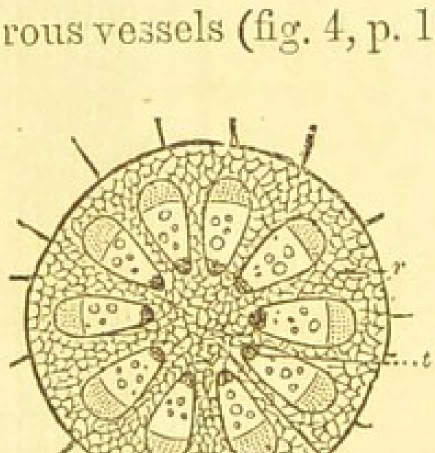


Fig. 32.

and pitted vessels (fig. 5, p. 12); cellular rays extend

Fig. 29.—Branch of Ivy, with root-like processes, by means of which it is attached to walls or trees.

Fig. 30.—Stem of Bindweed (convolvulus) twining from right to left.

Fig. 31.—Transverse section of the stem of an oak six years old —*i.e.*, having six concentric woody circles; cellular pith in the centre, surrounded by spiral vessels, and woody layers consisting of woody tubes and dotted or pitted vessels, layers of bark, both cellular and fibrous, on the outside.

Fig. 32.—Section of an Exogen during its first year of growth; *m* cellular pith, very large and occupying a considerable part of the stem; *t* spiral vessels forming a layer round the pith; *r* large cellular

from the pith to the bark—the latter being partly fibrous and partly cellular. A section of such a stem

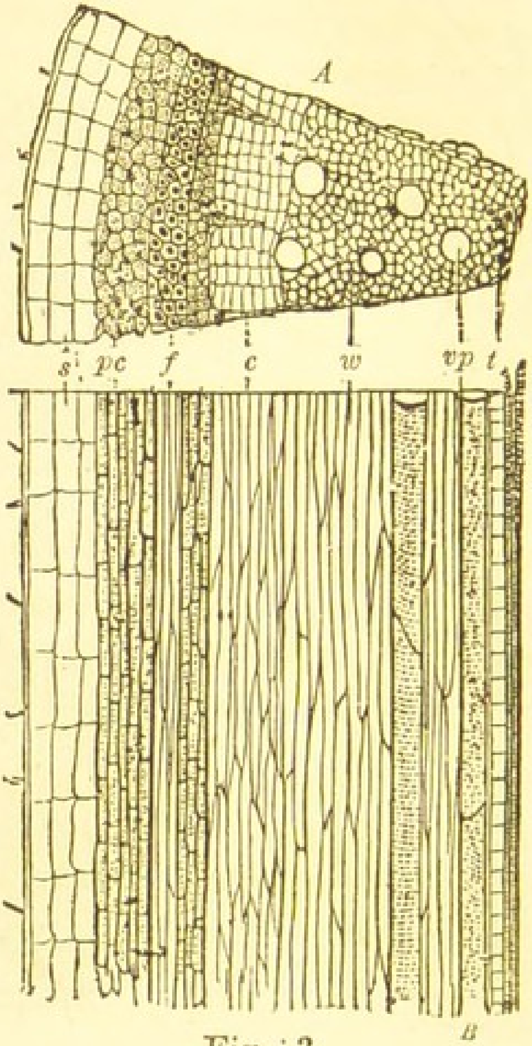


Fig. 33.

in the first year of growth exhibits the appearance presented in fig. 32, where *m* is the cellular pith, very

rays joining the pith and bark—the latter being represented by cells on the circumference. The woody and pitted vessels are placed between the pith and the bark, and are divided into ten wedges by the rays.

Fig. 33.—Stem of a maple at the commencement of its second year of growth. *A* transverse or horizontal section; *B* longitudinal or perpendicular section; *t* spiral vessels round the pith; *vp* dotted or pitted vessels with large apertures; *w* fibrous vessels of wood; *c* layer of sap-wood between bark and heart-wood; *pc*, inner cellular portion of bark separated from the layers of wood by the fibrous vessels of the bark *f*; *s* outer cellular corky layer of bark. Between the bark and wood a cellular layer called cambium occurs.

large; *r* large cellular rays proceeding from the pith and ending in the cellular bark, which forms the circumference. These rays divide the stem in the figure into ten wedges of woody and pitted vessels; while spiral vessels *t* occur round the pith. In the second year of growth a second set of vascular wedges is formed outside the first circle, and so on year after year, the stem increasing in diameter by circles of wood on the outside of those previously formed. The new wood is on the outside, the old wood within. Such trees are hence called Outward-growers or **Exogens** (the Greek word *exo* means outwardly), and they have their hard wood in the inside, their soft wood on the outside.

The structure of the different parts of such a stem is represented in fig. 33, where *A* is a transverse section, and *B* is a longitudinal one, of the stem of a maple one year old. In these figures, *t* indicates the spiral vessels (fig. 9, p. 12), round the cellular pith; *vp* are pitted vessels (fig. 5, p. 12), showing large round apertures; *w* fibrous vessels (fig. 4, p. 11); *c* a layer of new wood or alburnum next to the bark, which is composed of cells *s* and *pc*, and of fibres *f*.

The woody tubes in cone-bearing trees, as fir, spruce, larch, cedar, and cypress, exhibit markings called discs or punctations, which appear in the form of a circle and a dot in the centre (fig. 34).

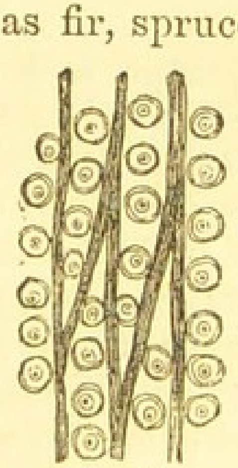


Fig. 34.

From the mode of growth in exogenous trees, it is obvious that we can ascertain the age of the tree by counting the number of woody circles or zones. Thus in fig. 31, p. 23, the oak is six years old. This calculation can be made with tolerable correctness in trees of temperate and cold climates, where during the winter there is a

Fig. 34.—Woody tubes of fir, with single rows of discs or punctations.

marked interruption to growth, and thus a line of demarcation is formed between the circles. In trees of warm climates this mode of estimating age may lead to error, for it would appear that in them there is often the appearance of two or more circles in one year. Even in the trees of this country, when full-grown, it is found that the different circles are so blended as to make it difficult to count them accurately.

The wood in the centre of exogens is often altered in colour by variously-tinted woody matter being deposited in the tubes. Thus the heart-wood of the ebony-tree is black, while that of the outer soft wood is pale. The latter is the part in which the active processes of life go on; and hence, if it is destroyed, the plant dies. A woody plant, such as honeysuckle, twining round the stems of such trees, causes strangulation and ultimate destruction. Grooved sticks are formed by the twining of the honeysuckle round neighbouring trees.

The size attained by the stems of many exogens, both as regards height and diameter, is sometimes very great. Trees belonging to the cone-bearing tribe attain heights varying from 100 to 200 feet. The oak sometimes attains the height of 120 feet; and forest trees in Europe and in America are met with 150 feet high. The celebrated mammoth pine of Oregon (**Wellingtonia**) has been seen 450 feet high. Some cedars of Lebanon have a girth of 40 feet.

Endogenous Stem.—Another marked type of stem occurs in some herbaceous plants, such as lilies and grasses, and is well seen in palms and certain trees of warm climates. In palms the increase of growth is by additions of woody and pitted vessels towards the centre. The stem is at first entirely cellular, but in the progress of growth bundles of vessels are formed among the cells. These gradually increase and distend the stem to a certain amount the first year. Next year new bundles are produed inside the last, which increase the diameter still more, until at length, by successive additions, the stem is distended to the utmost. The outer portion becomes hard, so as sometimes to resist the blow of a hatchet, while the inner part is comparatively soft. This mode of growth has given rise to the name of Inward-growers or **Endogens** (the Greek word *endon* means inwardly), applied to plants having stems of this

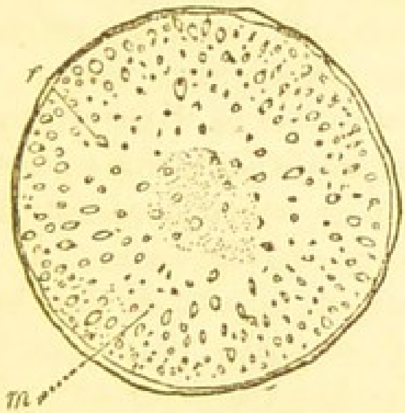


Fig. 35.

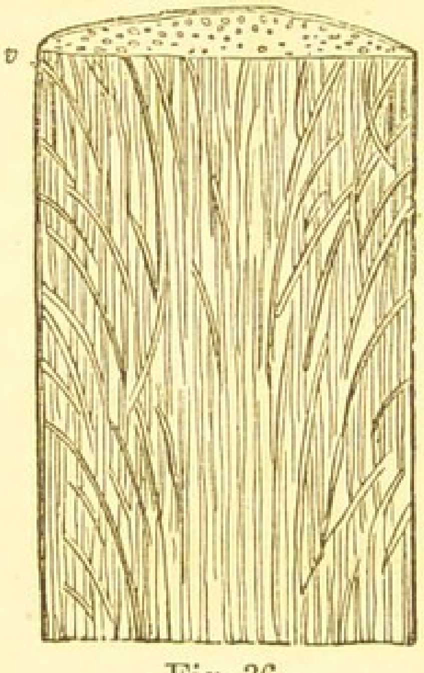


Fig. 36.

kind. On making a section of a palm-stem, the appearance presented is seen in fig 35. There is no distinct pith, no concentric circles, no rays, no separable bark. The outer part representing the bark is hard, and is incorporated with the fibrous tissue below. The interior consists of cells *m*, in which bundles of vessels, *f*, are dispersed irregularly. In tracing the vessels *v*, in the vertical section of a palm (fig. 36), it is found that they follow a curved course, and interlace with

Fig. 35.—Transverse section of a palm-stem, showing endogenous structure. Cellular tissue *m*; bundles of woody and other vessels *f*. No concentric circles, no rays

Fig. 36.—Longitudinal section of a palm-stem. Vessels *v*, descending in an oblique manner, and interlacing.

each other. Palms have straight trunks of nearly equal diameter throughout, bearing a cluster of leaves at the summit. This character is seen in fig. 37. They rarely branch, and grow chiefly in height, not much in diameter. The age of a palm may be estimated by measuring its height, for it is found that the growth in an upward direction is nearly uniform in each species. From the small increase in diameter, and the hardness of the exterior, a twining woody plant does not injure a palm-stem. When the tuft of leaves at the summit of a palm is completely destroyed, the plant dies, because there is no provision for lateral buds, as in our native trees.

Fig. 37.

Palms give a marked and distinctive character to the vegetation of tropical regions, and their umbrageous foliage, particularly in the case of those with fan-shaped leaves, affords an excellent shelter from the sun's rays.

Acrogenous Stem.—Another conspicuous permanent stem is that which occurs in ferns, especially in the tree-ferns of New Zealand, and of tropical countries. In these plants the stem is uniform in its diameter, hollow, and marked on the outside by the scars of the leaves (fig. 38). The stem increases by additions to the summit, and hence the plants are called Summit-growers or **Acrogens** (the Greek word *acros* means summit).

Fig. 37.—The Date palm, the Tamar of Scripture. Its leaves are compound and pinnate. The leaves are often called branches in ordinary language.

The stem is composed of parenchyma and irregular vascular bundles. The latter unite freely and form mesches, and they give off vessels to the fronds and to the adventitious roots. On making a transverse section of such a stem, the appearances seen are represented in fig. 39, where *e* is the outer portion, marked by the scars of fallen leaves, *f v* bundles of vessels of an irregular form, dark outside,

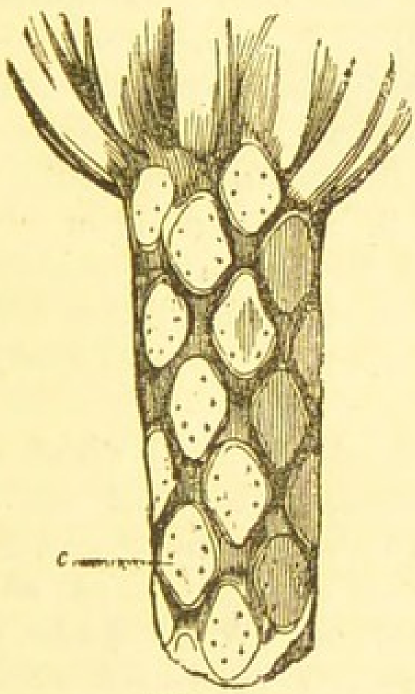


Fig. 38.

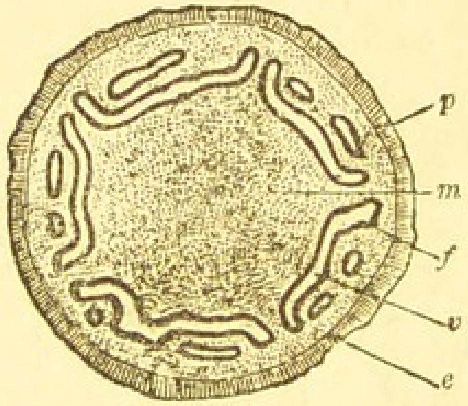


Fig. 39.

pale in the centre, *p* outer layer of cellular tissue, *m* central cells, which are often absorbed so as to leave a cavity. In the common brake or bracken of our pasture, the lower part of the stem, when cut, exhibits bundles of vessels which have the form of an oak or of a double spread-eagle. Ferns characterize mild and moist climates, and they give a peculiar feature to the landscape of New Zealand. At former epochs of the earth's

Fig. 38.—Stem of a tree-fern. It is acrogenous or increases at the top. The stem is uniform in diameter, marked by scars of fallen leaves *c*.

Fig. 39.—Transverse section of the stem of a tree-fern, showing the cellular portions *p m*, the irregular bundles of vessels *f v*, and the outer portions *e*.

history, they appear to have constituted a large part of its vegetation.

We have thus seen the structure of the three marked forms of permanent woody stems which are met with in the vegetable world:—1. Exogenous or Outward-growers, consisting of pith, concentric circles of wood, which increase by additions on the outside, separable bark, and rays connecting pith and bark; exemplified in the forest trees of Britain. 2. Endogenous or Inward-growers, consisting of a mass of cellular tissue with bundles of woody and other vessels scattered irregularly through the tissue, increasing by additions inside; exemplified in palms. 3. Acrogenous or Summit growers, stem increasing at the summit, consisting of cellular tissue and vascular bundles, the latter being irregular and formed simultaneously; exemplified in tree-fern.

Buds and Branches.—Stems produce buds, which are developed as leaves or as branches bearing leaves. Buds may thus be regarded as shortened leaf-bearing axes, capable of elongation so as to form stems and branches. Some buds are terminal (fig. 40 *a*), or are produced at the extremity of the primary axis. Other buds are lateral, or are produced at the sides of the axis (fig. 40 *b*). Exogenous stems have the power of forming both lateral and terminal buds, and if the terminal bud is destroyed, the functions of the plant are carried on by lateral buds, as in pollard trees. In palms and tree-ferns, the buds are terminal, and in their case when the top of the stem is cut off, the plants perish. In some of them we find two terminal buds in place of one, and then the stem divides in a forking manner. The Doom

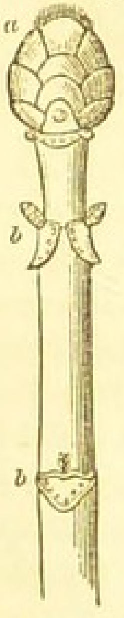


Fig. 40.

Fig. 40.—Branch ending in a terminal bud, *a*, covered with protecting scales. Lateral buds are seen at *b b*, produced in the axil of leaves which have fallen and left scars.

Palm of Egypt divides in this way. Buds are often protected by coarse leaves or scales (fig. 40 *a*), which are arranged spirally, and are occasionally covered with resinous or gummy matter for protection. Branches are connected with the centre of the woody stem. They occur especially in Exogens, and they have the same structure as the stems whence they proceed. Branches are arranged on the stem in a spiral manner, and follow the same law of spiral symmetry as will be noticed in the case of leaves. Branches spread out at different angles with the axis, and thus give rise to marked characters in the contour of trees.

Owing to various causes, it is rare to find all the buds properly developed. Many lie dormant, and do not make their appearance as branches, unless some injury has been done to the plant; others are altered into thorns (*Frontispiece*, fig. 1); others, after increasing to a certain extent, die and leave knots in the stem. That thorns are, in reality, undeveloped branches, is shown by the fact that they are connected with the centre of the stem, that they bear leaves in certain circumstances, and that under cultivation they often become true branches. Many plants are thorny in their wild state, which are not so under cultivation, owing to this transformation. Thorns, as seen in the hawthorn, differ totally from prickles, as seen in the rose. The latter are merely connected with the surface of the plant, and are considered as an altered condition of hairs, which become hardened in their structure.

QUESTIONS.

1. What is meant by the organs of plants?
2. Mention the nutritive organs of plants.
3. Mention the reproductive organs of plants.
4. What does the minute structure of plants consist of?
5. Describe a cell.
6. Describe a vessel.
7. What is meant by cellular plants? Give an example.

8. What is meant by vascular plants? Give an example.
9. Mention some varieties of cells.
10. Mention some varieties of vessels.
11. How are spiral cells and vessels formed?
12. Describe ladder-like vessels, and mention plants in which they occur.
13. How can the thread in spiral vessels be shown?
14. Of what tissue is the pith of plants composed?
15. What is the structure of cork, and whence is cork procured?
16. What is the structure of rice-paper, and how does it differ from common paper?
17. What tissue abounds in fleshy-fruits and in fleshy roots?
18. What is the structure of the shell in stone-fruits, such as the peach?
19. What are the tubes which constitute the wood of trees? Give their form.
20. What is the structure of flax and hemp?
21. What are the uses of cells and vessels? What functions do they perform?
22. Of what tissue does the young plant consist in its earliest state?
23. Describe the movements seen in the interior of some cells, and mention plants in which they are seen.
24. Mention some of the contents of cells.
25. What are raphides, and of what are they composed?
26. Why is the root called the descending axis?
27. Describe the parts of the young root.
28. What is meant by spongioles, and where are they seen?
29. What is the crown of the root?
30. What is meant by a tap-root? Give an example.
31. What is the function of roots?
32. What is meant by aerial roots? Give examples.
33. What kind of roots are met with in an Orchis?
34. What is salep?
35. What is meant by parasites?
36. Describe the stem or ascending axis.
37. Are stems always erect?
38. What is the essential character of a stem?
39. Describe the stem of Solomon's Seal.
40. To what part of the plant is the edible potato referred?
41. What is meant by the eyes of the potato?
42. Describe a bulb as seen in the lily and the onion.
43. What is meant by a rhizome or root-stock? Give an example.
44. What is meant by a corm? Give an example.
45. Describe the formation of buds in the crocus.

46. What is meant by ginger root?
47. What is meant by the term exogenous?
48. Mention the parts of an exogenous stem, proceeding from the centre to the circumference.
49. Give the structure of the different parts of an exogenous stem.
50. Mention a peculiarity in the wood of the fir-tree.
51. How is the age of an exogen determined?
52. What part of the ebony-tree is used for furniture?
53. Describe the effect of a twining woody plant, such as the honeysuckle, on the stem of an exogen.
54. Mention some exogens remarkable for the height and diameter of their stems.
55. Describe the structure of an endogenous stem, and give an example.
56. Why are some plants called Endogens?
57. Which is the hardest part of the stem of a palm?
58. In what respects does an endogenous differ from an exogenous tree as regards structure and aspect?
59. Contrast the effect produced by a woody twiner on an Exogen and on an Endogen, and explain the cause of the difference.
60. Describe the structure of an acrogenous stem, and give an example.
61. Why is a stem called acrogenous?
62. Contrast an endogenous and acrogenous stem as regards structure and appearance.
63. What are buds, and what positions do they occupy on the stem?
64. How do Exogens and Endogens differ as regards the production of buds?
65. How are buds protected?
66. Explain the connection between buds and the interior of the stem.
67. When palm-stems divide, what is the mode of division?
68. What are thorns?
69. What are knots in trees? How are they produced?
70. What is the use of the stem, and what function does it perform?
71. Describe the circulation of the sap in an ordinary exogenous tree.

IV.—Structure, Arrangement, Conformation, and Functions of the Leaves.

Structure of Leaves.—Leaves exhibit an arrangement of cells and vessels, as seen in fig. 41, where the dark lines indicate the vessels or veins of the leaf, and the intermediate spaces the cellular parts of it. On making a section of a leaf from the upper to the under surface, and examining it under the microscope, we see the texture more clearly. This is delineated in fig. 42. The upper epidermis or skin, is marked *a*, the lower epidermis *g*, and between these are the cells and vessels. The cells at the upper side *b* are placed close together, with occasional air-cavities *c*; those of the lower

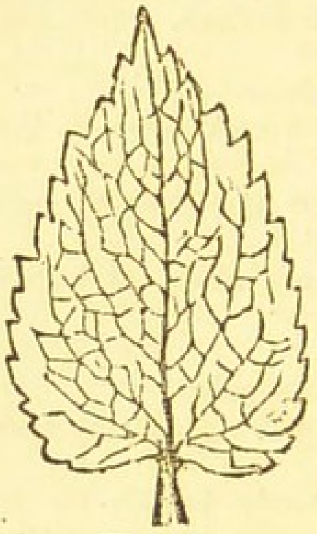


Fig. 41.

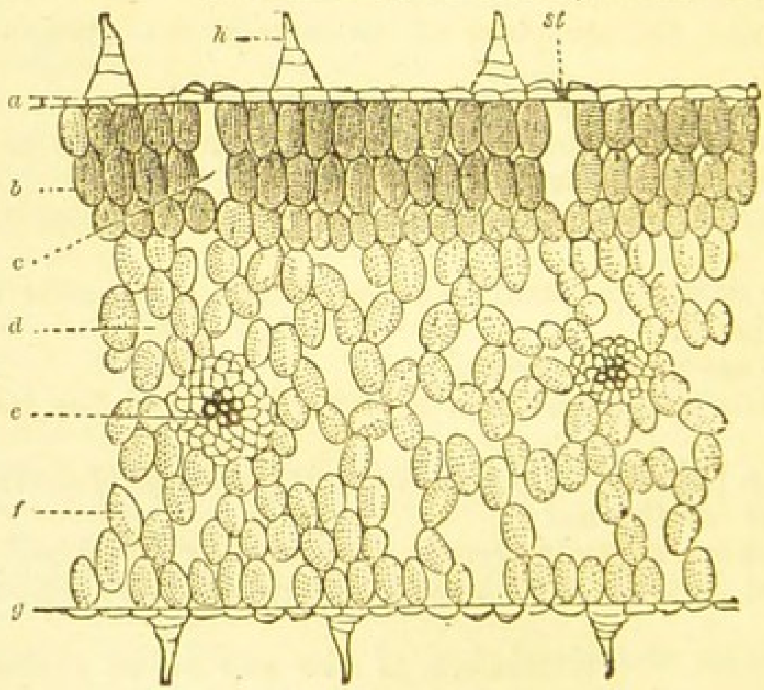


Fig. 42.

Fig. 41.—Reticulated (netted) leaf of the white dead-nettle, showing the distribution of the veins, or what is called venation. The edges of the leaf are serrate—*i. e.*, cut like the teeth of a saw.

Fig. 42.—Section of the leaf of a melon, perpendicularly to its surface; *a* upper integument; *g* lower integument; *b* cells of

side *f* are more loose, and have numerous air-spaces *d*. The bundles of vessels forming the veins are marked *e*, while *h* indicates hairs projecting from the surface, and *st* an opening (stoma, meaning mouth) through the skin into the cavity below. When leaves are left for a long time to macerate in water, the cellular part is destroyed, and the veins or vascular parts are left, forming the skeleton. How often have we seen leaves which have lain in ditches during the winter exhibiting a beautiful net-work of veins.

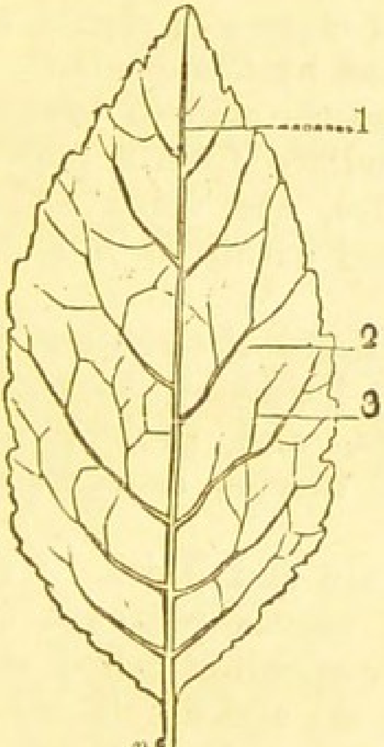


Fig. 43.

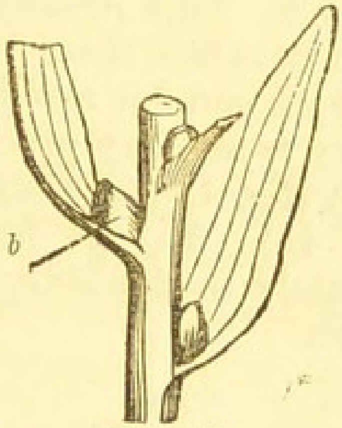


Fig. 45.

Fig. 44.

upper part of leaf; *f* cells of lower part of leaf; *e* bundles of vessels; *d* air cavities; *c* cavity below a stoma; *st* a stoma; *h* a hair.

Fig. 43.—Leaf of cherry, showing distribution of veins in the lamina or blade. 1 midrib; 2 primary veins, given off from the midrib; 3 secondary veins; *p* petiole or leaf-stalk; *s* stipules.

Fig. 44.—Palm-leaf, showing straight or parallel venation, the veins not being reticulated.

Fig. 45.—Stem of bulbiferous Lily, showing bulbels or bulblets *b*, produced in the axils of the leaves which exhibit parallel venation.

Venation.—As regards the distribution of veins in leaves (venation), flowering plants may be divided into two classes: those having reticulated leaves, or exhibiting an angular network of vessels, as in fig. 43, which represents the leaves of the ordinary trees of this country; and those having no proper network, but a set of parallel or diverging veins running from the base to the extremity, as in grass, lilies (fig. 45), and palms (fig. 44), or from the midrib to the margin, as in bananas. The first kind of leaf occurs in exogens, the second in endogens. This constitutes another means of discrimination between these two great classes of plants, and is one which can be easily detected by the student. The primary veins may proceed from the midrib toward the margin (fig. 43), or they may radiate from a point (fig. 61, p. 41). In the former case, the veins either go completely to the margin, or end within it in a curved manner.

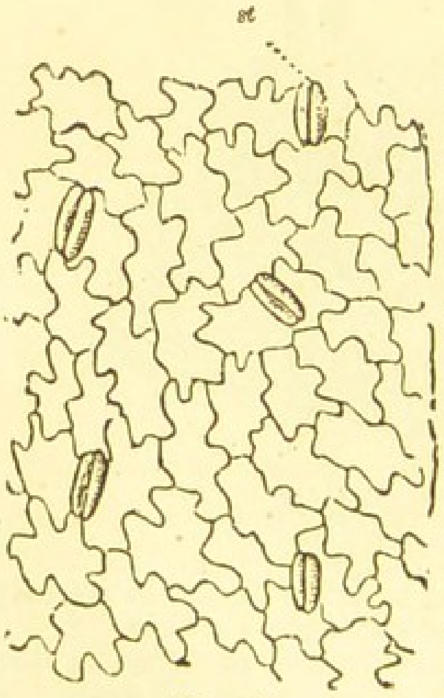


Fig. 46.

Sometimes the veins of leaves become hardened at their extremities, and project in the form of thorns, as seen in the holly.

Stomata and Hairs.—The surface of leaves presents certain pores or openings called stomata (fig. 46, *st*; and fig. 42, *st*). The cells surrounding these pores are so constructed that in dry weather they collapse, and close the opening; while in moist weather they have a crescentic margin, by which they open the orifice. They are connected with the passage of air and fluids to

Fig. 46.—Stomata *st*, or openings in the epidermis or skin of the leaf of Balsam. There are five of these represented in the figure, placed at regular intervals. They are concerned especially with the absorption and exhalation of fluids.

and from the leaf. In fig. 46 they are seen scattered

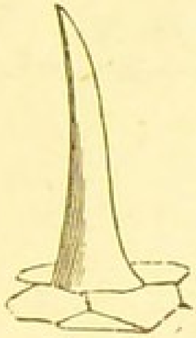


Fig. 47.

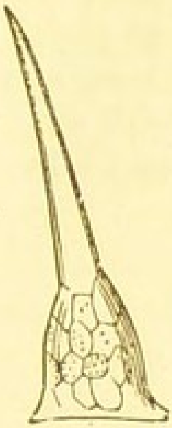


Fig. 48.

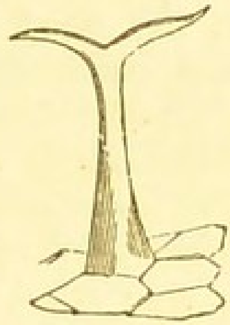


Fig. 49.

over the surface at regular intervals. They are easily observed in a very thin piece of the skin of the leaf of a hyacinth or lily placed under the microscope. They vary much in form and appearance in different plants.

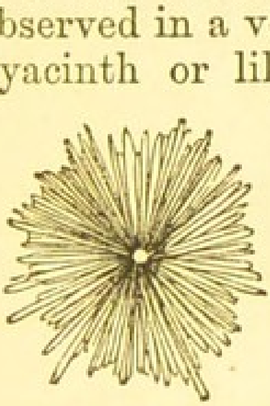


Fig. 50.

On the surface of leaves hairs are often produced (fig. 42, *h*). They are formed from the cells of the skin or epidermis, and they are composed either of single cells (fig. 47), or of several cells united (fig. 48). Sometimes hairs become forked (fig. 49), at the apex, while at other times they assume a star-like form and unite to form scales (fig. 50). The glandular hairs of the nettle are called stings (fig. 48).

Leaf-arrangement.—The mode in which leaves are arranged on the stem deserves notice. They are either placed opposite to each other, as seen in fig. 51, or

Fig. 47.—Hair of common Cabbage. It is composed of a single elongated conical cell.

Fig. 48.—Sting of Nettle. Its base is formed of numerous cells containing an irritating fluid. It is called a glandular hair.

Fig. 49.—Forked hair of Whitlow-grass, one of the cruciferous plants.

Fig. 50.—Radiating hairs, or scale in the Oleaster.

alternate with each other, as in figs. 52 and 53. When leaves are opposite, we frequently find that the different pairs cross each other at right angles. Thus in fig. 51 the two leaves at the base are placed to the front and back, the next two right and left, and so on. When several occur at the same level, they become whorled

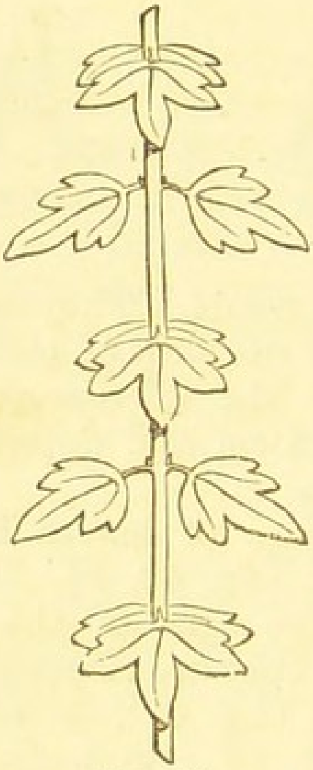


Fig. 51.

Fig. 52.

(verticillate) and then the leaves of the separate whorls alternate with each other. There is thus seen a law of alternation. In fig. 52 there are six leaves arranged at different heights on the stem, and it will be seen that the sixth leaf is directly above the first, and the same arrangement is seen in fig. 53, where the leaves

Fig. 51.—Opposite leaves on a stem; each pair is placed at right angles to that next it, thus following a law of alternation. In this case they are said to be decussate.

Fig. 52.—Alternate leaves. The sixth is placed directly above the first, and the fraction expressing the arrangement is $\frac{2}{5}$—viz., two turns round the stem and five leaves.

are numbered in succession 1, 2, 3, 4, 5, 6. Commencing with the lowest leaf in these figures, and proceeding regularly through all the leaves until we reach the one directly above the first, we follow a spiral direction, make two complete turns round the stem, and meet with five leaves. This arrangement is expressed by the fraction $\frac{2}{5}$. This means that there are five vertical rows of leaves, and that in passing from any one leaf to that directly above it, we make two turns round the stem, and meet with five leaves.

Fig. 53.

Vernation.—The arrangement of the leaves in the leaf-bud is called **Vernation**, and it furnishes important characters. Individual leaves in a bud may be folded from their midrib, as in fig. 54, or rolled outwards or


Fig. 54.


Fig. 55.

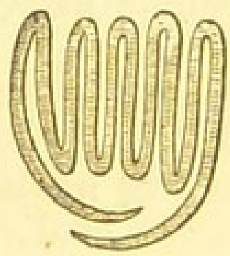


Fig. 56.

Fig. 53.—Alternate leaves, arranged in the same way as in fig. 52, the number expressing the arrangement being $\frac{2}{5}$. The sixth leaf is directly above the first, and there are five leaves in the cycle.

Fig. 54.—Two sides of the leaf folded in each other (conduplicate).

Fig. 55.—Edges of the leaf rolled inwards (involute); when rolled in the same way outwards they are revolute.

Fig. 56.—Leaf folded like a fan (plaited, plicate).

inwards at their margins (fig. 55), or from top to bottom, or they may be folded like a fan, as in the lady's mantle and in the vine (fig. 56). The leaves in the bud, taken collectively, may be applied to each

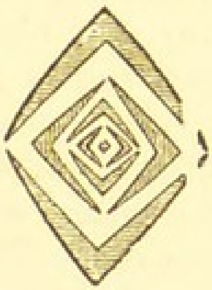


Fig. 57.

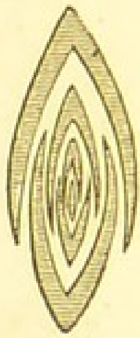


Fig. 58.

other at their edges, or they may overlap in various ways (figs. 57 and 58).

Conformation of Leaves.—The leaf consists of the blade or lamina, and the leaf-stalk or petiole (fig. 43). When there is no stalk, the leaf is called sessile (fig. 45). The leaf-stalk is usually rounded; but sometimes it is flattened, or forms a sheath round the stem. At the base of the leaf there are occasionally leaflets attached laterally, and called stipules (figs. 43 and 62, *s*). The presence or absence of these leaflets furnishes useful characters. Leaves are usually arranged under the heads of simple and compound; the former having a blade composed of one piece either perfectly entire or divided in various ways, and having no joint beyond the points where the leaves are united to the stem (figs. 59, 60, 61); the latter having a blade divided with separate parts or leaflets, which are united by joints to the petiole or leaf-stalk (figs. 62, 71).

The form of leaves depends upon the mode in which the ribs and veins are distributed and the margins are

Fig. 57.—Leaves in a leaf-bud folded, and their edges applied to each other in a decussate manner (accumbent).

Fig. 58.—Leaves in a leaf-bud folded, and overlapping each other (equitant).

divided. When a leaf or leaflet has no divisions on its

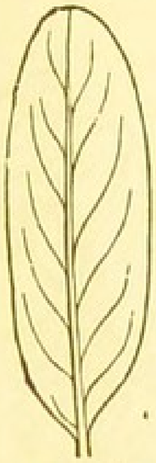


Fig. 59.

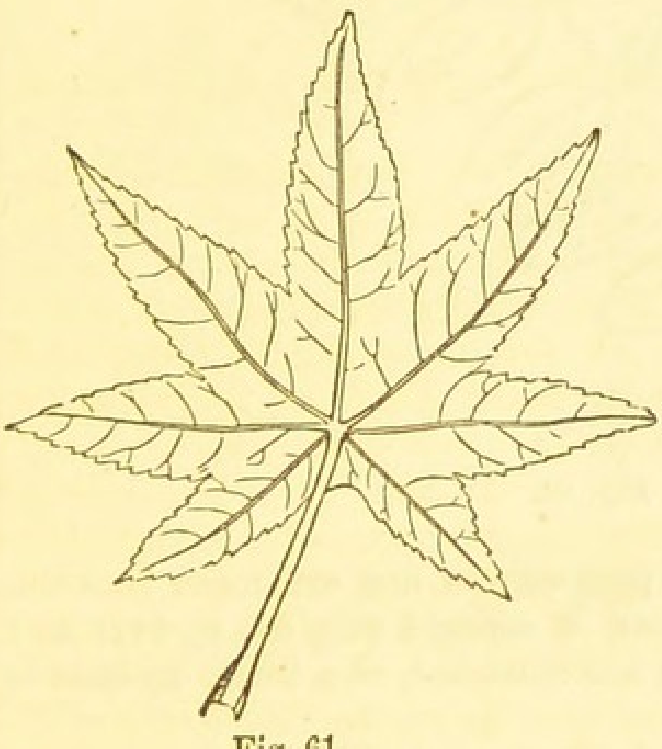


Fig. 61.

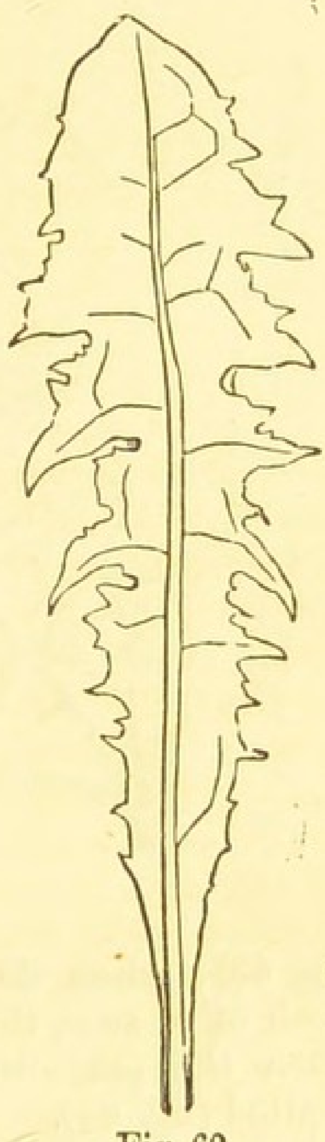


Fig. 60.

margin, it is called entire (fig. 59); when the margin

Fig. 59.—Simple oblong entire leaf of a species of Senna. The apex is obtuse or blunt, and the base is unequal.

Fig. 60.—Simple runcinate leaf of Dandelion. It is a pinnatifid leaf, with the divisions pointing towards the petiole (leaf-stalk).

Fig. 61.—Simple leaf of castor-oil plant. It is palmately cleft, and exhibits seven lobes at the margin. The petiole or leaf-stalk is inserted a little above the base, and hence the leaf is called peltate or shield-like.

presents small acute projections, the leaf is toothed

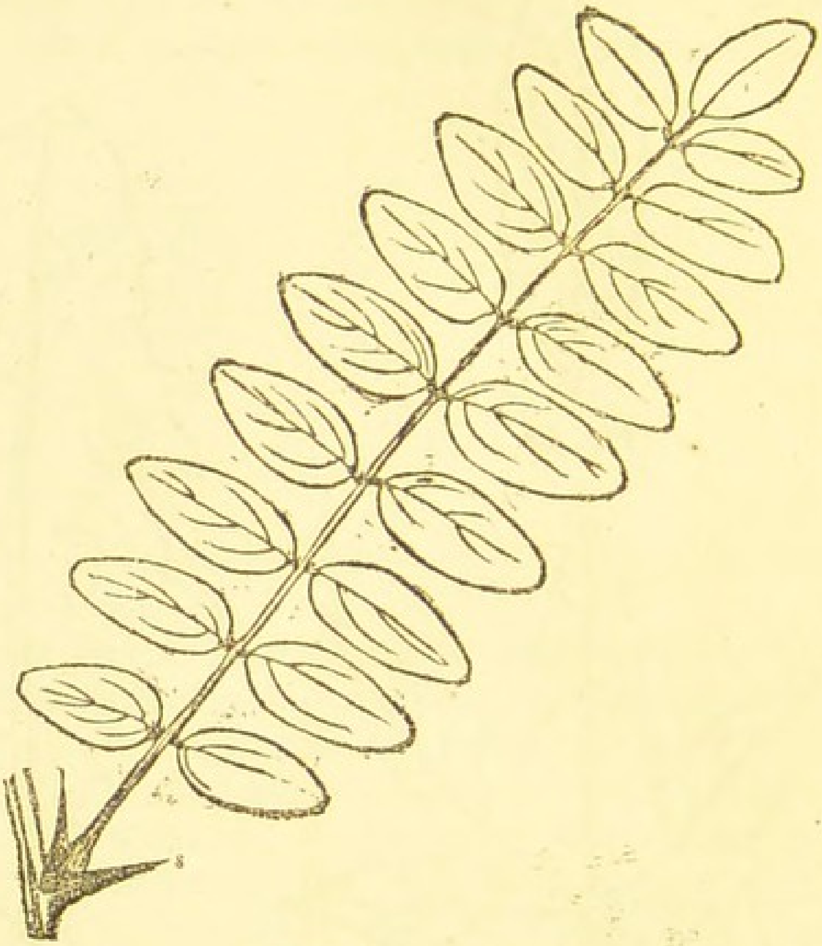


Fig. 62.

(fig. 63); when these projections are arranged like the teeth of a saw, the leaf is serrate (fig. 41, p. 34); and when the projections are rounded, the term crenate is applied (fig. 64).

When a simple leaf is divided deeply in a lateral direction—*i. e.*, from the margin towards the midrib—it is said to be pinnately-cleft or pinnatifid (fig. 60); if the divisions extend nearly to the midrib, then the term partite is used in place of cleft, and the leaf is pinnately-partite (fig. 65).

Fig. 62.—Compound unequally pinnate leaf of Robinia. There are nine pairs of shortly-stalked leaflets (pinnæ), and an odd one at the extremity. At the base of the leaf stipules *s* are seen.

When a simple leaf is divided deeply in a longitudinal

Fig. 63.

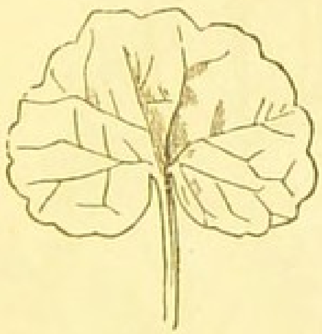


Fig. 64.

Fig. 65.

Fig. 66.

direction—that is, from the apex to the base—the terms palmately-cleft and palmately-partite are used, and the number of divisions is indicated by a numeral prefixed. Thus in fig. 61, there is a palmately-cleft leaf, and the divisions and lobes being seven, the name 7-cleft is also applied.

Various names are given to forms of simple leaves,

Fig. 63.—Margin of leaf, toothed (dentate).

Fig. 64.—Leaf of Ground-ivy, having a kidney-like form, and hence called reniform. Its margin is crenate.

Fig. 65.—Pinnately-partite leaf of a kind of Poppy. The segments of the leaf are pinnately-cleft.

Fig. 66.—Lanceolate leaf of willow, narrow and tapering to each end.

such as lanceolate, meaning narrow and tapering to each end (fig. 66); oblong, meaning narrow, but not

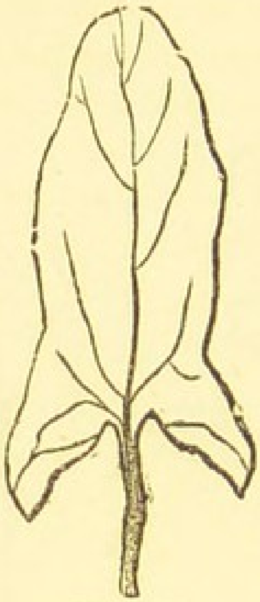


Fig. 67.

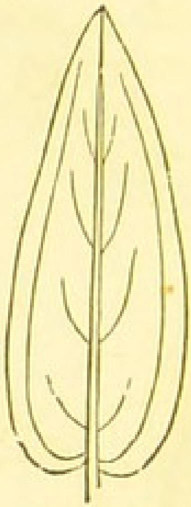


Fig. 68.

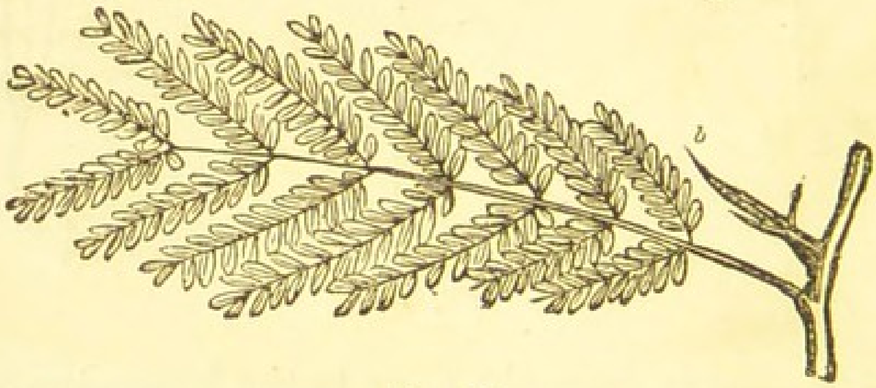


Fig. 69.

tapering to each end (fig. 59); cordate, like the heart on cards; sagittate, like an arrow (fig. 67); ovate, or egg-shaped (fig. 68). When a heart-shaped leaf has the division of the heart at the point farthest from the stalk, it is obcordate; and when an ovate leaf has the broad part of the egg similarly placed, it is obovate.

Fig. 67.—Arrow-shaped leaf (sagittate) of Scammony.

Fig. 68.—Entire egg-shaped (ovate) acute leaf of Coriaria. It is also three-ribbed (tricostate).

Fig. 69.—Doubly pinnate (bipinnate) leaf; *b*, a spiny bud arising from the stem.

In a compound leaf the divisions vary in a similar manner—taking place either laterally or longitudinally. In this case, however, the divisions consist of separate leaflets usually articulated to the petiole or midrib. A compound leaf having leaflets placed laterally along the midrib is called pinnate (fig. 62 and fig. 77). The leaflets are in pairs, and the leaf may end in a pair of leaflets, or in one leaflet as in fig. 77. In the former case it is equally, in the latter unequally-pinnate. The

Fig. 70.

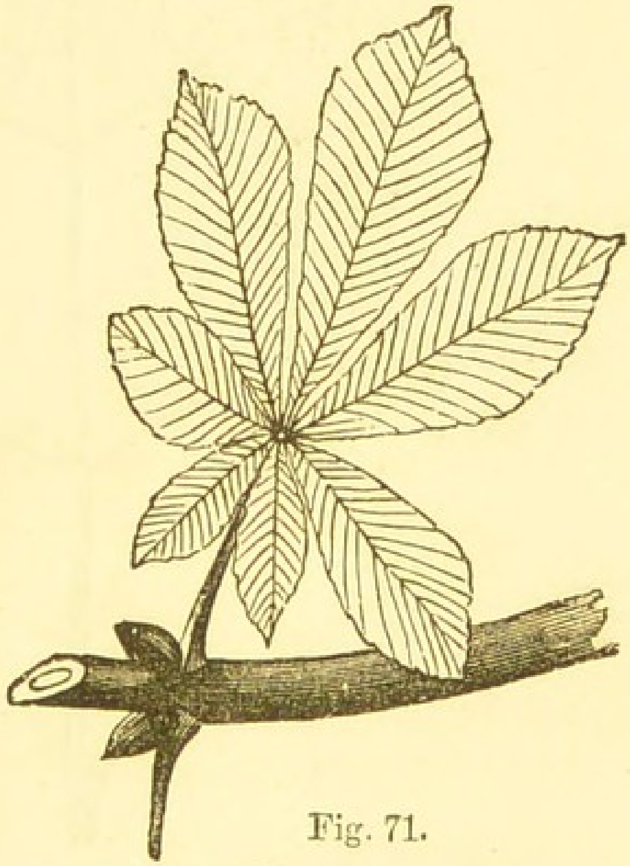


Fig. 71.

leaflets themselves may be divided into a series of smaller leaflets in pairs, and then the leaf is twice pinnate (bipinnate) (fig. 69). Further division on a similar plan will make it thrice pinnate (tripinnate), and so on.

Fig. 70.—Wood-sorrel, with its compound ternate leaves.

Fig. 71.—Compound septenate leaf of the horse-chestnut. Such leaves are sometimes called digitate (fingered).

A compound leaf formed of leaflets jointed to the top of the leafstalk (the divisions being thus longitudinal) is named according to the number of the leaflets—ternate, when they are three (fig. 70); quinate, when they are five; septenate, when seven (fig. 71); and digitate when they are numerous. When a ternate

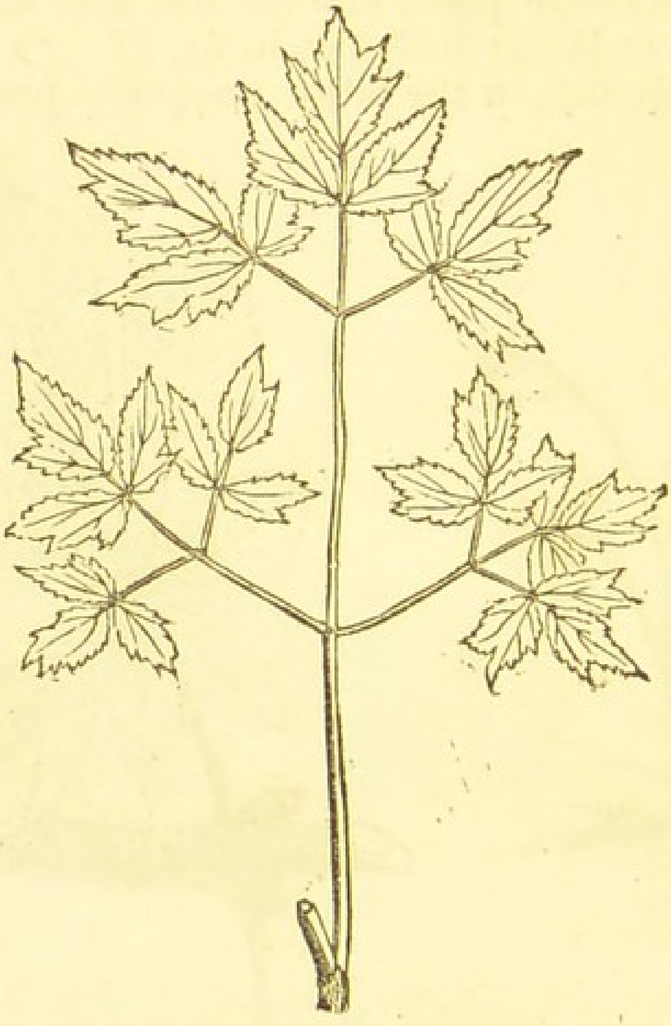


Fig. 72.

leaf divides twice into three, it becomes biternate; when thrice, triternate (fig. 72).

Petiole or Leaf-stalk.—The petiole or leaf-stalk is usually rounded in its contour, and it is either articulated to the stem, as in the case of ordinary trees when the leaves fall in winter, or it is continuous with the

Fig. 72.—Triternate leaf of Baneberry.

stem, as in lilies and hyacinths, and then withers without falling off. The petiole is flattened from side to side in the aspen, and it is broadened out into a leaf-like body in the orange (fig. 73, *p*) and in some Acacias (fig. 75, *p*). In many Acacias of Australia the petiole serves the purpose of leaves, and no true leaves are produced (fig. 74). In some aquatics the leaf-stalk

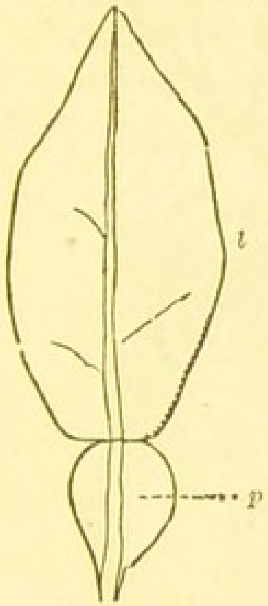


Fig. 73.

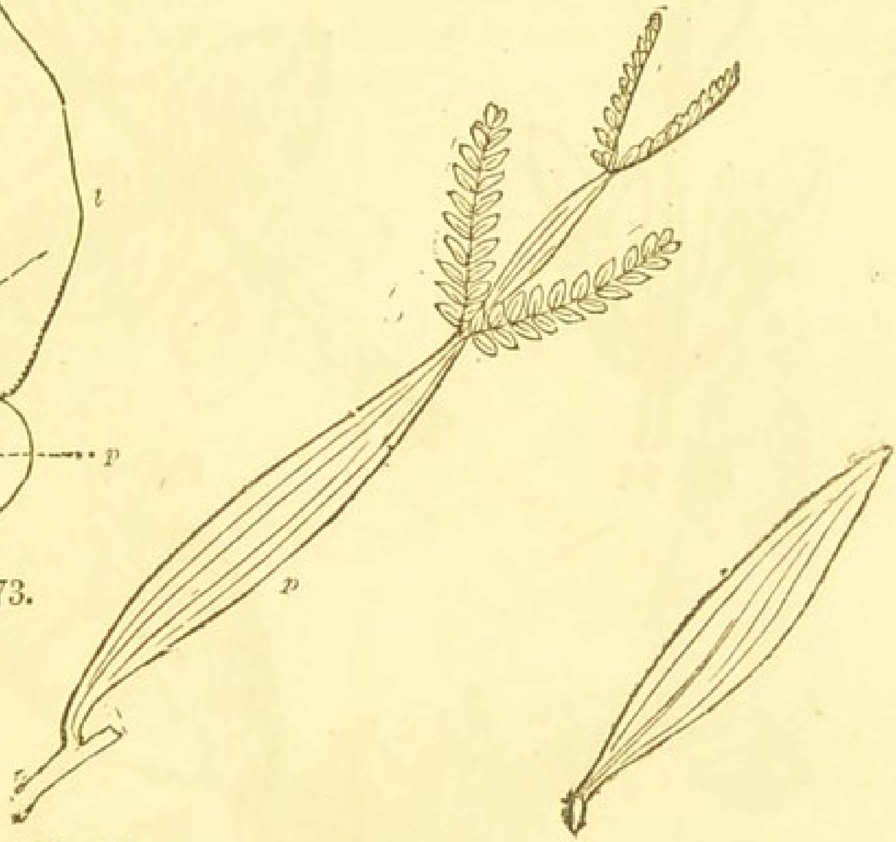


Fig. 75. Fig. 74.

is full of air, so as to enable the leaves to float on the surface of the water, or to rise above it.

Stipules.—These are small leaf-like bodies situated at the base of the leaf-stalks, and having in their normal

Fig. 73.—Leaf of orange, showing a winged petiole *p*, which is articulated to the blade (lamina) *l*. It is a compound leaf with only one leaflet.

Fig. 74.—Broadened leafstalk (phyllodium) of an Acacia, without any true leaves.

Fig. 75.—Leaf-stalk of the same Acacia bearing leaflets.

state a lateral position as regards the leaves. In some

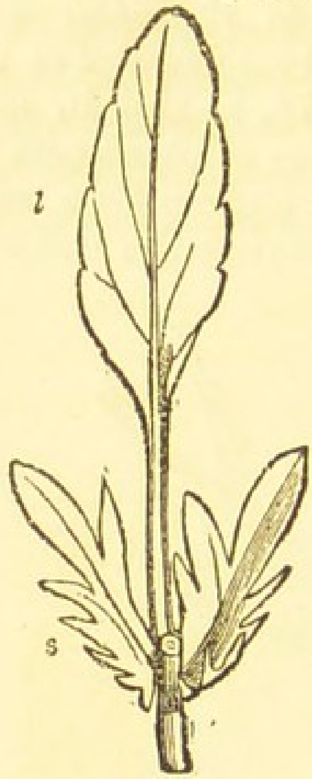


Fig. 76.

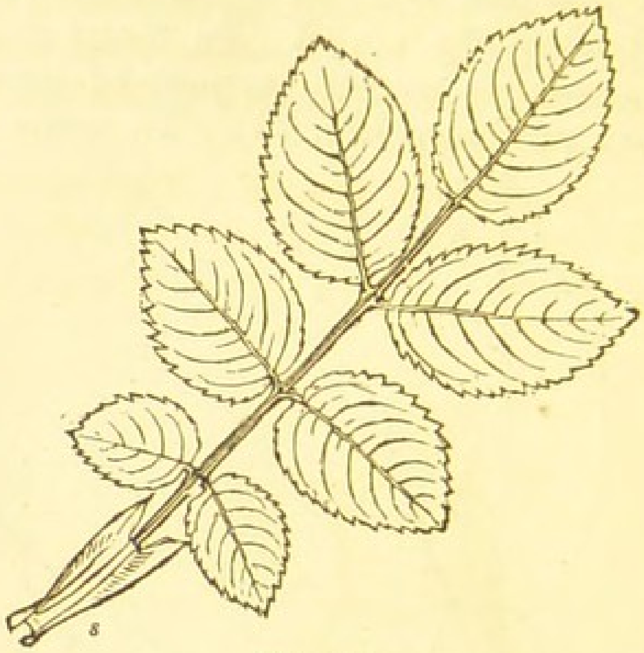


Fig. 77.

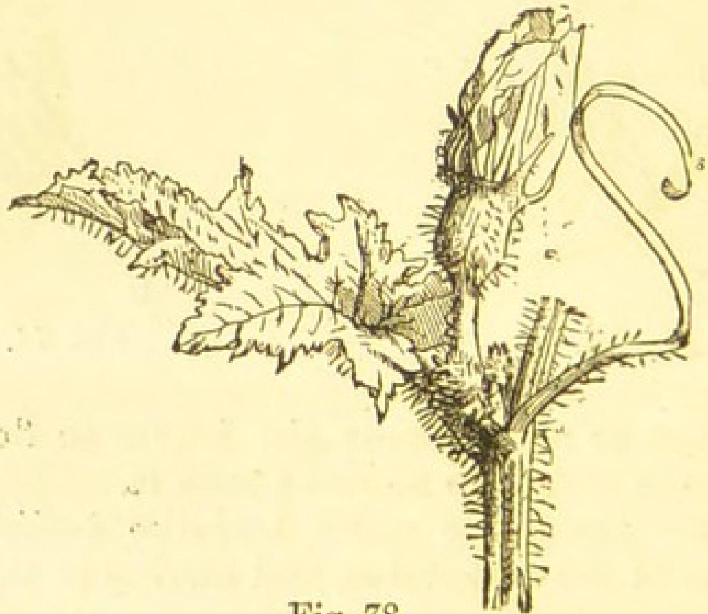


Fig. 78.

Fig. 76.—Leaf of Pansy, *l*, separated from the plant; the pinnatifid stipules, *s*, are distinctly visible, and their lateral position is seen.

Fig. 77.—Compound pinnate leaf of rose, with two stipules *s*, at its base united to the leaf-stalk and to each other.

Fig. 78.—Wavy leaf of melon, with a stipule, *s*, in the form of a tendril.

plants they occupy the place of the true leaves. They are well seen in the common pansy (fig. 76). In the rose the two stipules are united together so as to form a broad expansion at the base of the petiole (fig. 77). In rhubarb the stipules form a sheath round the stalk, and in the cucumber tribe they are in the form of tendrils (fig. 78).

Anomalous Leaves.—Leaves exhibit peculiar shapes in consequence of being folded so as to form bags or pitchers. There are various kinds of pitcher-plants.

Fig. 79.

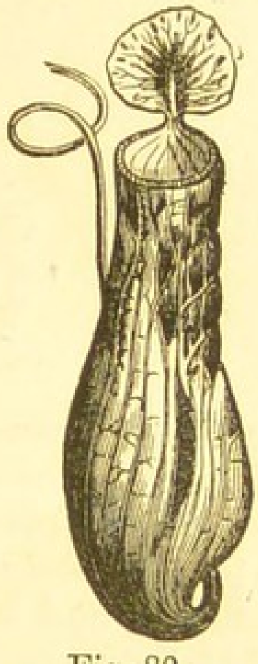


Fig. 80.

The pitcher of an American pitcher-plant is represented in fig. 79, while that of an East Indian plant is seen in fig. 80. In the latter there is a distinct lid, which is folded over the mouth of the pitcher at first, but ultimately rises, as shown in the woodcut.

Irritable Leaves.—An interesting phenomenon exhibited by the leaves of plants, is irritability. This

Fig. 79.—Pitcher of Sarracenia, a North American marsh plant.

Fig. 80.—Pitcher of Nepenthes from the Indian Archipelago. It hangs by a narrow portion from the end of the leaf or leaf-stalk, and has a distinct lid which closes the orifice at first.

is manifested by certain movements which they display either spontaneously or under the influence of mechanical and chemical stimuli. In the plant called Venus's fly-trap (fig. 81), the leaf is furnished with three projecting hairs on its blade, as seen in the expanded leaf on the figure, which, when touched,

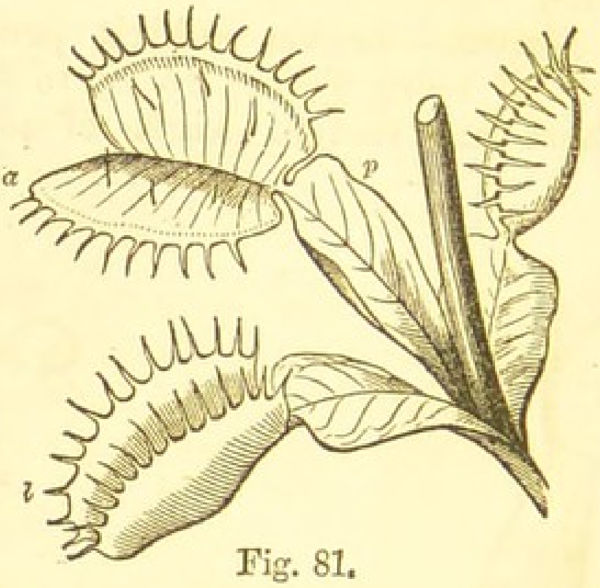


Fig. 81.

immediately cause the leaf to fold upon itself, and thus enclose any insect that may have alighted on it. In the sensitive-plant (fig. 82), the slightest touch causes the little leaflets to fold together in the way shown in the figure, and if the irritation is continued, the whole leaf *l* falls down. During the night, the leaflets close and the leaf is depressed. In the moving-plant of India (*Desmodium gyrans*), as shown in fig. 83, there are two little leaflets *l l* which are in constant motion, jerking from one side to the other in a remarkable manner, both during light and darkness. The large leaf at the end of the stalk also exhibits slow movements, rising and

Fig. 81.—Venus's fly-trap, a North American marsh plant, which displays irritability of its leaves. One leaf, *a*, is expanded, showing the two parts of the blade with three projecting hairs on each, which, when touched, cause the parts of the blade to fold, as shown in the other two leaves. The petiole, *p*, is broad, and is said to be winged. A partially-closed blade of the leaf is marked *l*. Electrical currents are produced during these movements.

falling, and moving from one side to the other. During darkness, the large leaf always hangs down.

Functions of Leaves.—In the form and size of leaves we may perceive many interesting adaptations. Thus the large fan-shaped leaves of palms are fitted for shade and shelter in the warm countries in which they grow; while the narrow linear leaves of pines and firs, fit them for the Alpine districts in which storms and blasts prevail.

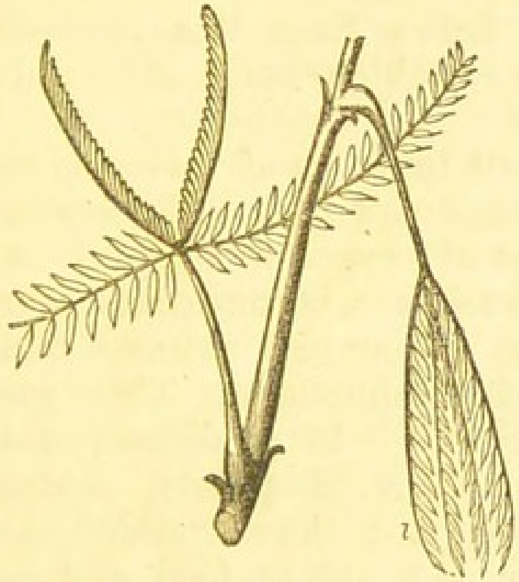


Fig. 82.

Fig. 83.

The function of leaves is to expose the juices of the plants to light and air, and thus to aid in forming the woody matter of the stem, and the various secretions. Unless the leaves are freely exposed to air and light, the wood is not properly formed. Hence the reason why the wood is deficient both as regards quantity and

Fig. 82.—Sensitive plant. The stem with two leaves. Each leaf is composed of numerous leaflets on a common stalk. In the lower leaf, the leaflets are expanded at one part and closed at the other. In the other leaf all the leaflets are closed, and the whole leaf *l* has fallen down.

Fig. 83.—The moving-plant of India. The large leaf moves slowly and imperceptibly from side to side, as well as upwards and downwards. The little leaflets *l l* are constantly jerking so as to meet in the middle and then separate again.

quality in trees grown in crowded plantations. The same observations apply to all the secretions of plants. Thus potatoes grown in the shade, by which the functions of their leaves are impeded, become watery, and produce little starch in their tubers. Leaves also give off a quantity of watery fluid. This constitutes what is called exhalation. The amount of fluid exhaled varies according to the structure of the leaves and the nature of the climate. Plants exhale fluid from their leaves, in the first place, for their own benefit. But various important secondary effects follow from this process. One of these is maintaining a suitable portion of humidity in the air.

Another and most important function of leaves is to keep up the purity of the atmosphere; in other words, to keep up a sufficient amount of oxygen in the air. A poisonous gas, called carbonic acid gas, is constantly sent into the air by the breathing of man and animals, and by the various processes of combustion. This gas consists of carbon and oxygen. It is decomposed by leaves and the green parts of plants, under the influence of light. They are thus enabled to separate the carbon for their own use as food, and to give out oxygen gas, which constitutes the part of the air necessary for breathing.

In preparing certain delicacies for the table, the gardener blanches plants—that is, he makes them grow in darkness, or at least partially covered from the light. In this way the plants lose their green colour, and they do not form their proper secretions. In place of fibrous matter, only delicate cells and spirals are produced, and the plants are rendered tender. Thus the leaf-stalks of celery and sea-kale, and the shoots of asparagus, are made fit for use. The heart of the cabbage is rendered white and delicate by the outer leaves screening it from light. By the same process the odours of plants are weakened or destroyed.

The fall of the Leaf (Defoliation).—The leaf, after performing its functions, dies, and either falls off at once, leaving a scar, or remains for a certain time attached to the plant. In the case of lilies and hyacinths the leaves decay gradually, and remain for a long time as withered unsightly appendages. Provision is made for the fall of the leaf. Long before this a plane of separation begins to form at the base of the leaf-stalk, and it reaches its full development just at the time when the leaf ought to fall. A scar is left at the point of the stem where the leaf was attached.

The parts of the plant which we have now considered—the root, stem, and leaves—constitute what are called the organs of nutrition or nourishment. Fluid matters are taken up by the cells of the roots from the soil, they are conveyed to the leaves, and there under the influence of air and light, they are fitted for the purposes of plant-life, and for the production of various secretions, such as starch, gum, sugar, woody matter, gluten, oils, and resins. The nature of the soil has a material influence on the nourishment of the plant, and the process of manuring is conducted with the view of supplying certain substances which the plant requires for its vigorous growth, and which it cannot get from the particular soil in which it is placed. Some plants require ingredients which others do not need; and it is upon this principle that a certain rotation or change of crop is adopted.

QUESTIONS.

1. Describe the structure of an ordinary leaf, from the upper to the under surface.
2. What is meant by venation?
3. Divide leaves according to their venation.
4. How are spines in leaves formed? Give an example.
5. Give an example of a spiny leaf.
6. Describe stomata.

7. What is the structure of hairs?
8. What is meant by glandular hairs? Give an example.
9. What is meant by forked hairs?
10. What is meant by epidermal scales? Explain their formation.
11. Mention a peculiarity in the hairs of the leaves of the nettle.
12. Describe the mode in which leaves are arranged upon the stem.
13. What is meant by opposite and alternate leaves?
14. What is meant by whorled (verticillate) leaves?
15. What is meant by decussate leaves?
16. What is the series of numbers exhibited in the leaf-arrangement?
17. Explain the meaning of the fraction $\frac{2}{5}$, applied to the leaf-arrangement.
18. Explain the term vernation.
19. Describe some of the modes in which the leaves are folded in the bud.
20. What is meant by the conformation of leaves?
21. What is the meaning of the terms lamina and petiole?
22. What are stipules?
23. Explain the meaning of a simple and of a compound leaf.
24. Give an example of each.
25. Explain the terms entire, toothed, serrate, and crenate, as applied to leaves.
26. Explain the terms pinnatifid (pinnately-cleft) and pinnately-partite.
27. Explain the terms palmately-cleft and palmately-partite.
28. Explain the terms lanceolate, oblong, cordate, and ovate.
29. Explain the terms obcordate and obovate.
30. Explain the term sagittate.
31. Explain the terms pinnate, bipinnate, and tripinnate.
32. Explain the terms ternate, biternate, and triternate.
33. Explain the terms quinate, septenate, and digitate.
34. What is meant by a sessile leaf?
35. Describe the petiole of the orange.
36. Describe a peculiarity in the leaf-stalk of some Australian acacias.
37. Describe the position of stipules.
38. What kind of stipules are seen in the pansy and in the rose?
39. How are vegetable pitchers formed?
40. Mention two kinds, and describe the difference between them.
41. What is meant by irritable leaves? Give an example.
42. Describe the movements in the leaf of Venus's fly-trap.
43. Describe the movements in the leaves of the sensitive-plant.

44. Describe the movements in the leaves of the moving-plant of India.
45. What are the functions of leaves?
46. What changes take place in plants when grown in the dark? Give an example.
47. What is meant by the exhalation of leaves?
48. What is meant by leaf-absorption?
49. What effect do leaves produce on the atmosphere?
50. What poisonous gas is absorbed by the leaves of plants?
51. What is meant by defoliation?
52. What is meant by a leaf-scar?

CHAPTER II.

THE ORGANS OF REPRODUCTION.

The flower, or the floral organs concerned in the production of seed containing the young plant, are called the Organs of Reproduction. In exogens and endogens these organs are usually obvious, and hence these plants are called Flowering or Phanerogamous—that is, with reproductive organs conspicuous (the Greek word *phaneros* means conspicuous). In acrogens, on the other hand, these organs are obscure, and hence the plants are called Flowerless or Cryptogamous—that is, having concealed organs of reproduction (the Greek word *kryptos* means concealed). We shall consider, in the first place, these organs as seen in flowering plants.

I.—Bracts, Flower-stalks, and the Arrangement of the Flowers on the Axis, or Inflorescence.

The arrangement of the flowers on the flowering stem or branch is called Inflorescence. Flowers are produced from flower-buds, which arise like leaf-buds from the axil of leaves—that is, from the angle formed by leaves coming off from the axis. Leaves which give origin to flower-buds are called Bracts. They are sometimes similar to the ordinary leaves of the plant, at other times they are altered and modified in various ways. In fig. 84 is seen the common scarlet pimpernel, with each of the sessile (not stalked) leaves or bracts producing a flower; in this case the bracts are like the ordinary leaves of the plant. Such is also the case in the ivy-leaved speedwell, but in it the leaves are alternate in place of being opposite. In other cases, however, the bracts differ from the ordinary leaves. Sometimes they are beautifully coloured like the leaves of the

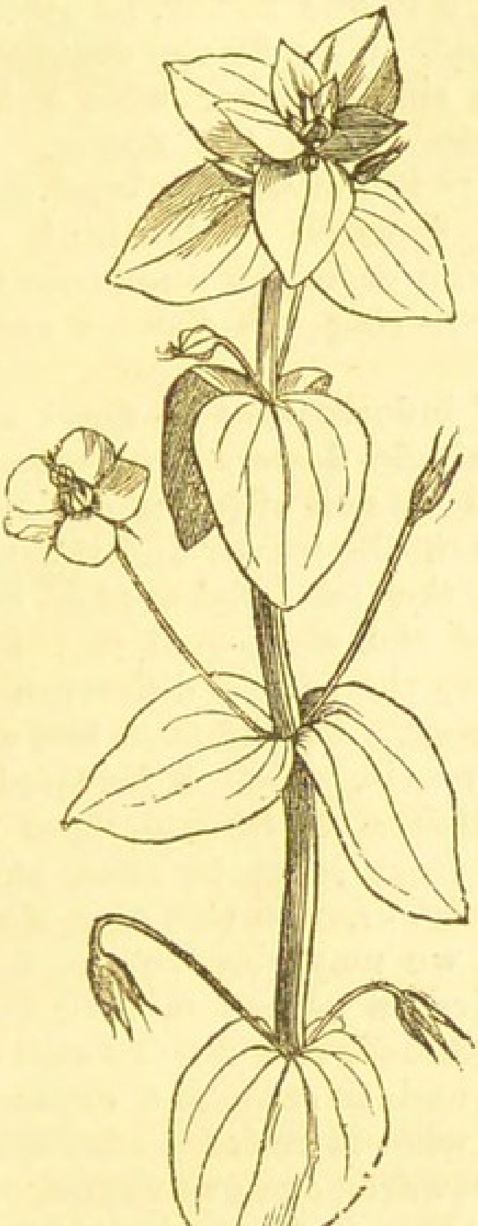


Fig. 84.

Fig. 85.

Fig. 84.—Flowering stem of the Scarlet Pimpernel or Poor-man's Weather-glass. The floral stem or axis goes on lengthening and producing flowers at the points where the leaves (called floral) join the axis or stem. The lowest flower expands first, and the others in succession upwards. The bracts (floral leaves), in this case, are like the ordinary leaves of the plant, and each bract gives rise to a flower.

Fig. 85.—Flower of Spring Snow-flake, supported by a peduncle *p*, called a scape, and coming out from a sheathing bract *b*. The flower is drooping and solitary, and the perianth is above the ovary *o*.

flower, sometimes they are mere scales. While in some instances they give origin to one flower, in others they give rise to many flowers. In fig. 85 the common snow-flake is seen bearing a single flower with a bract *b*, which in the early state covers the flower. In the polyanthus-narcissus there is a sheathing bract enclosing many flowers. In the common cuckoo-pint, and in palms, large bracts are seen enclosing numerous flowers. In grasses the bracts covering the flowers are called glumes.

The simplest kind of inflorescence or floral arrangement is that in which single flowers are supported on flower-stalks arising from the axil of leaves (that is, from the angles formed between the leaves and the branch), as in the gentianella, the snow-flake (fig. 85), the common periwinkle, and the pimpernel (fig. 84). In these instances, however, there is a difference in the mode of floral development. In the first two a single flower ends the primary axis, which is arrested in its growth, and does not elongate. Should more flowers be produced, they rise from separate axes, and they expand after the central flower. In this case, if clusters of flowers are produced, we may observe one flower in the centre fully expanded, a second farther from the centre only partially expanded, and a third still farther off in the state of bud, and so on. The expansion of the flowers is, therefore, what is called centrifugal—*i.e.*, going from the centre outwards or downwards. Again, in the latter two instances—viz., the periwinkle and the pimpernel—the floral expansion is different; the flowers are produced laterally on the axis, which elongates and continues to produce flowers in regular succession from below upwards, so that the lowest flowers are first expanded, and the whole inflorescence is on one axis. This development is called centripetal, because the expansion is from below upwards, or, in the case of shortened clusters, from without inwards, always towards the centre of the axis. There are, then, two kinds of inflorescence—one called Determinate or Definite, with centrifugal opening of the flowers; and the other Indeterminate or Indefinite, with centripetal opening of the flowers.

Figs. 86, 87, and 88 show the different modes of

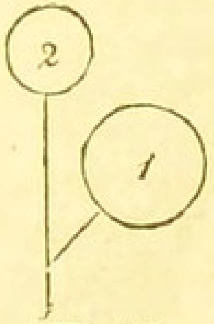


Fig. 86.

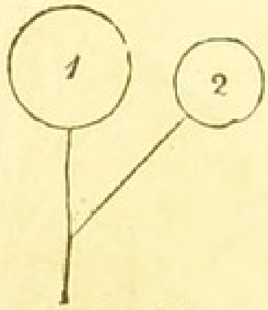


Fig. 87.

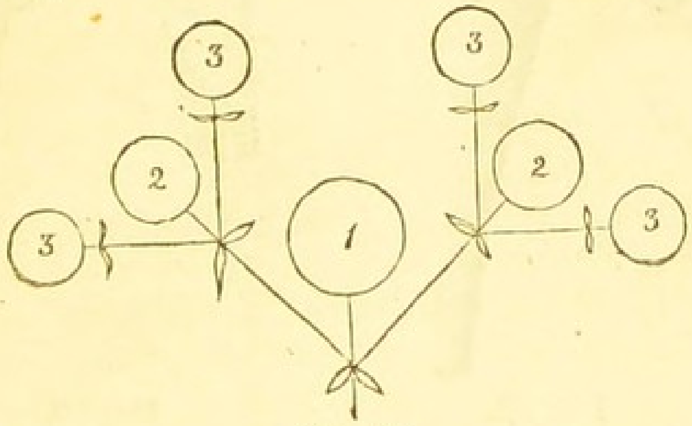


Fig. 88.

inflorescence. Fig. 86 shows the indefinite inflorescence, in which the lower floret (1) expands first, and then the upper floret (2). Fig. 87 shows definite inflorescence, where the terminal floret (1) opens first, and then the lower floret (2). Fig. 88 shows definite inflorescence with numerous floral axes. The first floral axis bears a flower (1), which opens first; then come off two floral axes (2 2), the flowers of which expand next; then each of these gives off two floral axes (3 3, 3 3), which expand third in order, and so on.

In the dandelion, daisy, and marigold, the heads of

Figs. 86, 87, 88.—Forms of indefinite and definite inflorescence.

flowers are surrounded by a set of bracts arranged in a whorl called an involucre (figs. 91 *b*, 89 *i*). A similar arrangement of bracts is observed in the hemlock tribe.

Fig. 89.

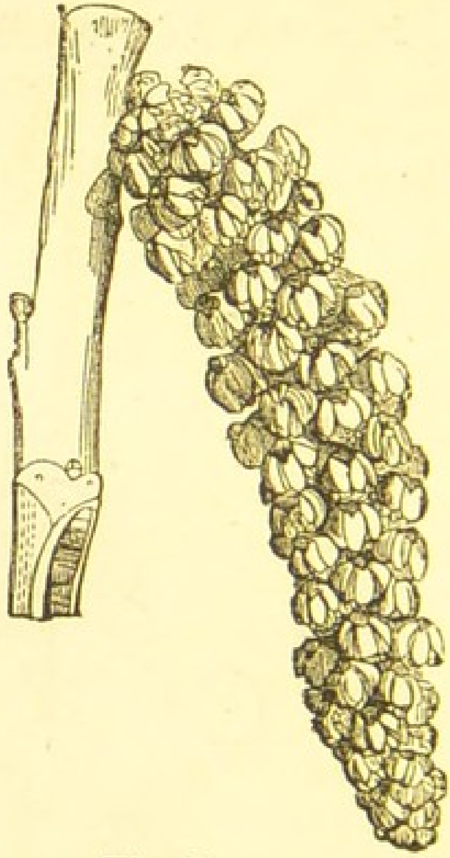


Fig. 90.

In the willow, the hazel, the oak, the walnut, and other trees which bear catkins, each flower has a scaly bract covering it (fig. 90). Bracts sometimes continue attached to the fruit, as in the oak, hazel, hop, and fir. The cup of the acorn, the husk of the common filbert, and the scales of the cone, are bracts.

Some flowers are supported on a stalk called a peduncle, while others have no stalk and are called

Fig. 89.—Head of flowers of Marigold, consisting of numerous flowers, *f*, enclosed by bracts, *i*, which form an involucre or general covering outside the mass of flowers.

Fig. 90.—Catkin of the Walnut, bearing numerous flowers, each of which has a scaly bract at its base.

sessile. A flower-stalk may support one flower, as in

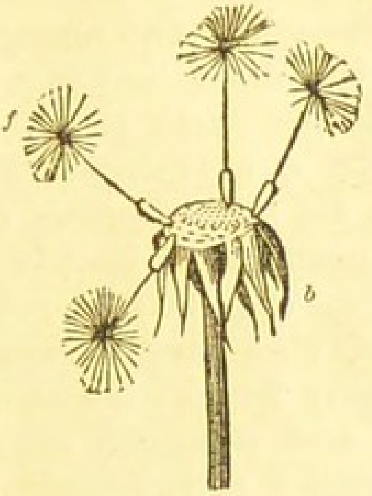


Fig. 91.

Fig. 92.

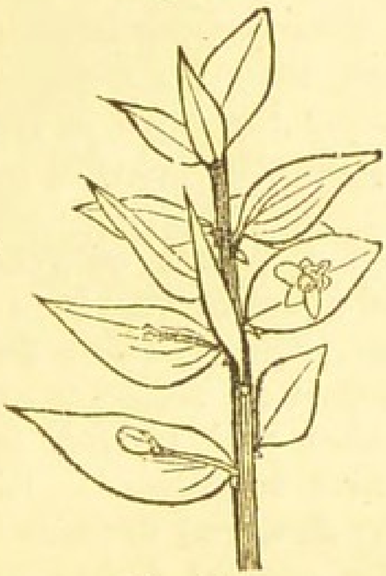


Fig. 93.

Fig. 91.—Receptacle (thalamus) or part of the Dandelion on which the flowers are placed. It is represented in the dry state when the plant is in fruit, and the leaves (bracts) *b* surrounding the head of flowers are turned back so as to allow the fruit to be easily scattered by the wind. The fruit *f* is seen with the calyx attached, which appears above in the form of hairs or pappus.

Fig. 92.—Peduncle or floral axis of Fumitory, bearing numerous flowers. Each flower is attached to the floral axis by a short stalk called a pedicel, at the base of which a leaflet called a bractlet *b* is produced.

Fig. 93.—Butcher's-broom, showing leaf-like flower-stalks bearing clusters of flowers.

the pimpernel and snowflake (figs. 84 and 85), or it may support many flowers, as in the narcissus and the marigold (fig. 89). In the dandelion (fig. 91), the top of the peduncle is flattened, so as to form a receptacle for many flowers. In the common red currant, in germander speedwell, and in fumitory (fig. 92), we have instances of elongated flower-stalks having many flowers borne on short stalklets, and arranged alternately. Flower-stalks are broadened like leaves in the butcher's broom (fig. 93), and they become large and succulent in the cashew, where they constitute what is called the cashew-apple, bearing the fruit or nut. The fruit of the fig is a hollow peduncle bearing numerous flowers inside (fig. 94).

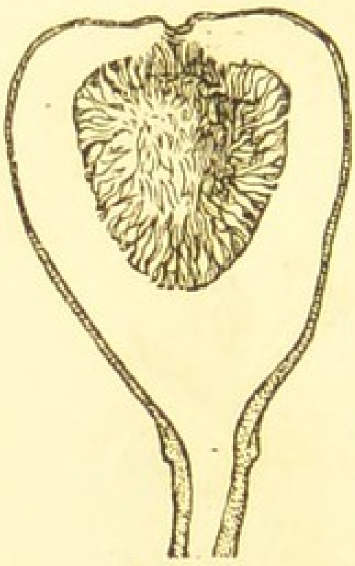


Fig. 94.

In fig. 95, there is shown a flower of gentianella, which terminates the axis and is solitary. It is a simple instance of definite flowering. Should other flowers be produced, they will be developed on separate axes in a centrifugal manner—*i.e.*, farther and farther from the central flower, which is the first to expand. In fig. 96 there is an instance of a many-flowered definite inflorescence in the carnation. The central flower is shown fully expanded. It terminates the primary axis. The second flower, *b*, is not yet expanded fully. It is produced on a secondary axis farther from the centre; while the flower, *c*, is still less expanded, and is produced on a tertiary axis still farther from the centre. These are two cases of definite inflorescence—the first being one-flowered, the second many-flowered.

Fig. 97 is an example of indefinite inflorescence in

Fig. 94.—Fruit of Fig. This is a succulent stalk, or peduncle, curved so as to form a hollow receptacle, on which numerous flowers are placed, each bearing a single-seeded seed-vessel.

which the axis elongates and the lower flowers are first

Fig. 95.

Fig. 96.

expanded—the others being developed in regular succession from below upwards. In fig. 98 there is another

Fig. 95.—Flowering stem of Gentianella. The plant produces a single flower. The termination of the axis, *a*, bears two leaves or bracts, *b*. The flower, *c*, with its calyx and corolla, terminates the axis. This is the simplest form of definite inflorescence. If other axes are produced in such a case, they arise from the axil of the bracts, *b*, and the flowers expand after the central one, *c*, or in what is called a centrifugal manner. Each axis ends in a solitary flower.

Fig. 96.—Flowering stalk of Clove-pink. The inflorescence is definite and centrifugal—the central flower expanding first, afterwards those at *b* and *c*. It is a cyme.

form of indefinite inflorescence, in which the axis is shortened and the outer flowers expand first, while the

Fig. 97.

Fig. 98.

inner ones expand in succession from without inwards towards the centre—*i.e.*, centripetally.

Certain kinds of inflorescence have received names

Fig. 97.—Spike of Verbena, consisting of sessile flowers, which expand from below upwards (centripetally).

Fig. 98.—Head of flowers of Scabious. The outer flowers open first, and the inflorescence is centripetal—*i.e.*, from without inwards, to the centre.

which are much used in the description of plants, and which it is necessary to explain. Numerous stalked flowers placed alternately on a common floral axis constitute a **raceme**, as in the currant (fig. 99). A similar arrangement, in which the flowers have no stalks, is a **spike**, as in common verbena (fig. 97). When the floral axis is shortened, and numerous stalked flowers come off from the end of a common peduncle, like the radii of a circle, an **umbel** is formed (fig. 100). The umbel is

Fig. 99.

Fig. 100.

often compound—that is, there is a second umbel formed at the end of each of the stalks (pedicels) coming from the common peduncle, as in many umbelliferous plants (fig. 101). When flowers arise from the end of the common peduncle and have no stalks, but are sessile,

Fig. 99.—Raceme of Red Currant. Stalked flowers on a lengthened axis. Inflorescence centripetal.

Fig. 100.—Simple umbel of cherry. Stalked flowers arising from a common point. Stalks of nearly equal length.

then a head is formed, as in the dandelion, daisy, marigold (fig. 89, p. 60), and thistle.

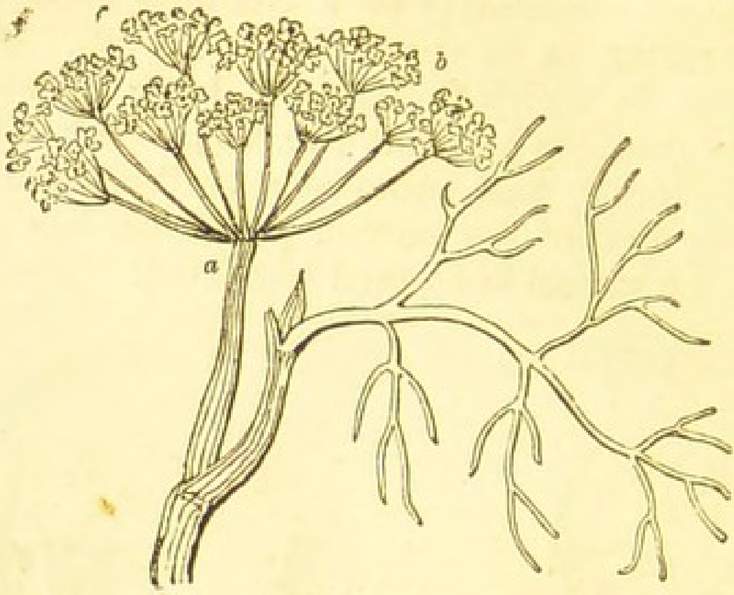


Fig. 101.

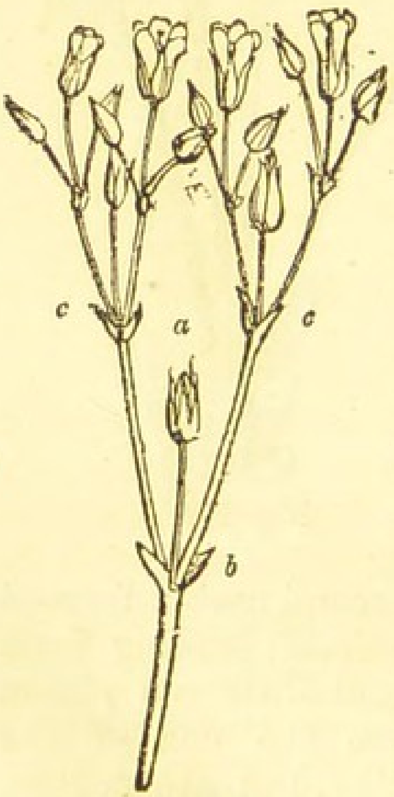


Fig. 102.

A variety of raceme called a **corymb**, is produced by the lower flowers having longer stalks than the upper ones on the axis, so that all the flowers are nearly on a level at the summit. The spike, when the axis is fleshy and all the flowers are enclosed in a sheathing bract (spathe), is called a **spadix**, as in cuckoo-pint and palms; and when the flowers are covered by scaly bracts, as in the willow, hazel, beech, and walnut (fig. 90, p. 60), the name **catkin** is applied.

In the determinate inflorescence, when there are numerous floral axes arising from a common point and assuming umbellate or corymbose forms, a **cyme** is produced, as in the elder and chickweed (fig. 102).

Fig. 101.—Compound umbel of Common Dill. One primary umbel, *a*,. and numerous secondary umbels, *b*.

Fig. 102.—Inflorescence (cyme) of the Mouse-ear Chickweed. First

II.—The Flower and its Parts.

Floral Symmetry.—The parts of the flower are usually arranged in four series, or whorls—that is to say, in four sets of leaves or modified leaves arranged in alternating rows,—1. The calyx; 2. The corolla; 3. The stamens; 4. The pistil. (See *Frontispiece*, fig. 1.) These parts are seen in figs. 103 and 104, in which *c* is the calyx; *p*, the corolla; *s*, the stamens; and *b*, the pistil. In fig. 103, the different series of the flowers are com-

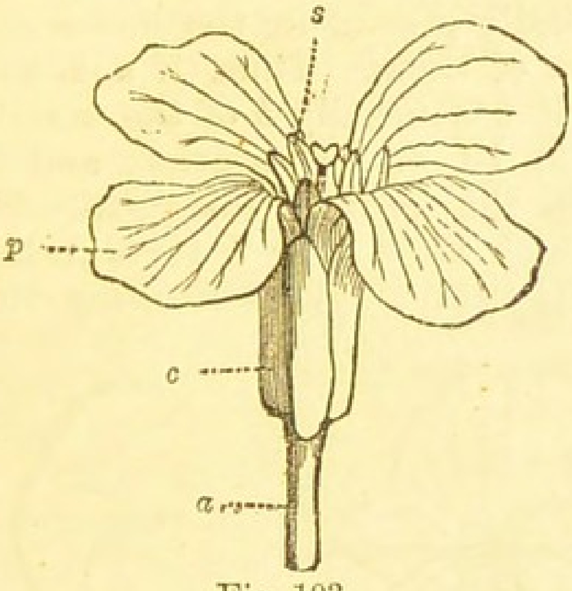


Fig. 103.

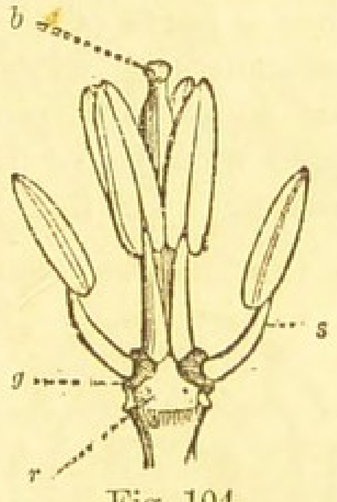


Fig. 104.

plete; in fig. 104 the calyx and corolla are removed. These parts are looked upon as leaves altered to suit the particular functions which each row performs, and sometimes appear in the form of true leaves without

axis ends in a single flower, *a*, which opens first. This axis bears two bracts, *b*, each of which gives origin to a secondary axis, each ending in a single flower and bearing two bracts *c c*, which in their turn give rise to tertiary one-flowered axes. There are thus one primary flower, two secondary, four tertiary, eight quaternary, and so on.

Fig. 103.—Flower of Common Wallflower. *a*, The flower-stalk; *c*, the calyx; *p*, the corolla; *s*, the stamens.

Fig. 104.—Same flower with calyx and corolla removed. Stamen *s*, pistil *b* (its upper part called the stigma), *r*, the receptacle (thalamus), to which the parts of the flower are attached; *g*, a small gland at the base of the stamen.

any marked modification. The inner two of the series are essentially connected with the production of seed, and are called essential organs (fig. 104). The outer two are protective and nutritive organs, and are called floral envelopes. When flowers become double, the stamens and pistil are more or less completely changed into parts resembling the outer series, and when the alteration is complete, no seed is produced.

The parts of each series or whorl are arranged like leaves on the principle of alternation, and there is an evident symmetry as regards the number of the parts. The numbers which generally prevail in the flower are 2, 3, and 5, or multiples of them. Thus, if a flower has 5 parts of the calyx, it has usually 5 of the corolla alternating with them; 5, 10, or 20 stamens; and 5, or some multiple of 5, in the parts of the pistil. So also with those flowers which have 2 or 3 parts in the calyx. In fig. 105 a diagram is given showing the

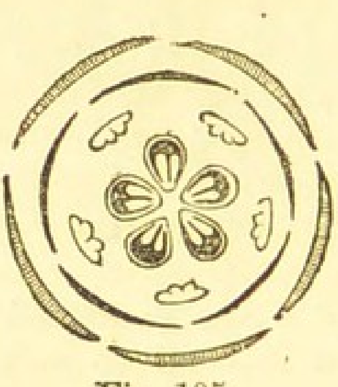


Fig. 105.

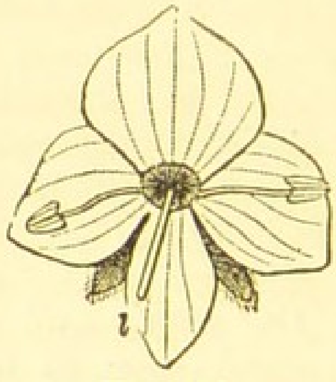


Fig. 106.

Fig. 107.

Fig. 105.—Diagram to show the arrangement of the parts of the flower. There are four whorls, each consisting of five parts, which alternate with those next them.

Fig. 106.—Irregular gamopetalous (united petals) wheel-like corolla of Speedwell. The irregularity consists in the different sizes of the lobes of the corolla, especially the lower lobe *l*, which is much smaller than the rest. The stamens are two, and the style one.

Fig. 107.—Irregular gamopetalous (united petals) labiate corolla of the white Dead-nettle. The upper lip, *u*, is composed of two petals united, the lower lip, *l*, of three. Between the two lips (labia) there is a gap. The throat is the part where the tube and the labiate limb join. On account of the arching of the upper lip, this corolla is called ringent.

alternation of the 5 parts of each whorl of the flower. It is worthy of notice that flowers exhibiting 2 or 5, or multiples of these numbers, in their whorls, usually belong to plants having two seed-lobes or cotyledons, and which, when they form permanent woody stems, exhibit distinct zones or circles, and are exogenous; while flowers having 3, or a multiple of 3, in their whorls, present only one seed-lobe, and when they form permanent woody stems exhibit no distinct zones or circles, and are endogenous. The number 2, or a multiple of it, is seen also in the parts of fructification of flowerless plants which have so seed-lobes, such as ferns, mosses, and seaweeds.

The parts forming the individual flower are arranged in a whorled manner, but in reality each whorl is a complete spiral cycle, the coloured leaves of which are placed closely together. Each separate whorl, or whorled cycle, alternates with that next to it. The arrangement of the parts of the flower of a plant does not always correspond with that observed in the leaves.

There is frequently an interference with the law of symmetry in the flower by adhesion, by abortion, or by non-development of parts. The symmetry of a flower must be viewed to a certain degree independently of its regularity or irregularity of form. Symmetry has reference to number and arrangement of parts, regularity to size and appearance. A flower may be irregular in its form, and yet its parts may be symmetrical. Thus the common speedwell (fig. 106), is irregular in its corolla, some parts being larger than others, yet the number 2 prevails in the flower—viz., 4 parts of the calyx, 4 of the corolla, 2 stamens, and 2 parts of the pistil. We often notice, however, that any cause which gives rise to want of symmetry also causes irregularity in form. By cohesions of various kinds there appears to be sometimes an interference with the proper number of parts in a whorl. Thus, in labiate or lipped plants there are 2 lips of the corolla, and thus apparently only 2 parts, but in reality there are 5, of which 2 cohere to form the upper lip, and 3 the lower (fig. 107). In slipperwort there are 2 in place of 3 parts of the calyx, in consequence of the cohesion of 2. Non-development is a constant cause of want of symmetry. The corolla is sometimes absent, and then the flower has

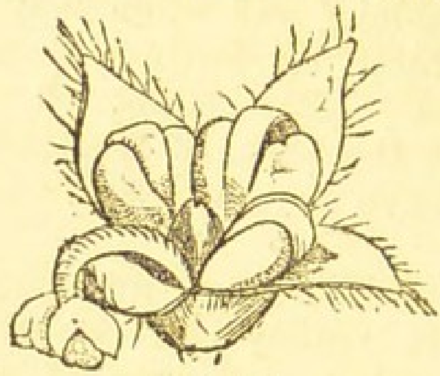


Fig. 108.

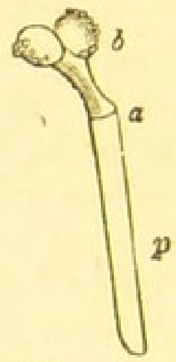


Fig. 109.

only one covering, which is the calyx (fig. 108). In such a case the stamens are placed opposite to the parts of the whorl next them, in place of being alternate. A

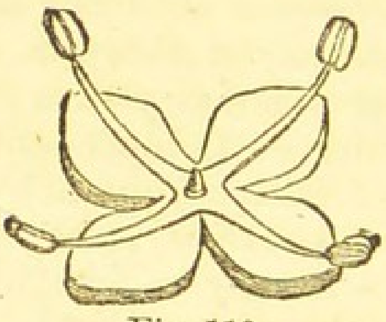


Fig. 110.

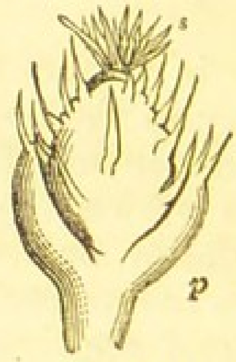


Fig. 111.

Fig. 108.—Flower of Pellitory. It consists of a four-divided calyx, with four stamens and a rudimentary pistil.

Fig. 109.—Flower of Euphorbia. The whole flower consists of a stamen *b*, supported on a peduncle *p*, to which it is united by a joint at *a*. The flower is naked, that is, has neither calyx nor corolla.

Fig. 110.—Staminate or staminiferous flower of Mulberry, showing a four-partite calyx, and four stamens with long filaments and two-lobed anthers. The flower has one covering or calyx.

Fig. 111.—Pistillate or pistilliferous flower of the Nettle, consisting of a two-leaved floral envelope or calyx, *p*, with a single pistil. The pistil consists of an ovary, and a sessile tufted stigma, *s*.

scale or scales may occupy the place of calyx and corolla; and sometimes there is a complete want of both these parts (fig. 109). In a perfect flower, stamens and pistil are present, but if these organs are in separate flowers, we have a flower bearing stamens and no pistil, and called staminate (fig. 110), or a flower bearing a pistil and no stamens, and called pistillate (fig. 111).

In the coco-nut the symmetry is represented by the number 3; in the ripe fruit, however, there is a single cavity and one seed, the other two being abortive. This abortion is proved by examining the shell of the coco-nut, in which there are three evident ridges indicating the three original parts.

Times of Flowering.—The flowering of plants takes place at different periods of the year, and thus a calendar of the seasons may be constructed. By observing the exact time when plants in the same garden flower in different years, an indication will be given of the nature of the season. The mezereon and snow-drop, hepatica and winter aconite, put forth their flowers in February in this country, the primrose and crocus in March, the cowslip and daffodil in April, the hawthorn in May, the great mass of plants in May and June, many in July and August, the ivy in September, the meadow-saffron and strawberry-tree in October and November, and the Christmas rose in December. Some plants, like the daisy, produce their flowers throughout the whole season.

Besides annual periods, some flowers exhibit diurnal periods of expansion and of closing. On this fact, Linnæus constructed what he called a floral clock, in which each hour of the day was marked by the opening of some flower. While most flowers open during the day, there are some which expand their flowers in the evening, and are called night-bloomers. To that class belongs the night-flowering cereus, a kind of cactus which unfolds its flowers about nine or ten o'clock at night.

The closing of flowers also follows a periodical law. Most flowers close during darkness. Some close even in daylight. Thus the salsafy shuts up its heads of flowers about mid-day, and the chicory about four in the afternoon. Many flowers are affected by the nature of the day as regards moisture, dryness, cloudiness, or clearness, and are called meteoric. In cloudy and rainy weather the flowers of the scarlet or "pink-eyed pimpernel," called poor man's weather-glass (fig. 84, p. 57), remain closed. So also do the heads of flowers of the daisy, dandelion, and other composite plants. By this means the essential organs of the flower are protected from injury. The direction of the flowers of some plants seems to be influenced by the sun's rays; and the name girasole, or sunflower, was given from an impression that the heads of flowers inclined towards the part of the heavens where the sun was shining. This does not, however, appear to be the case with the sunflower as grown in this country. One of the species of girasole is the plant called Jerusalem artichoke. The first part of the name is a corruption of girasole, and the latter is given from the taste of the roots being like that of the common artichoke.

Æstivation.—The arrangement of the parts of the flower in the flower-bud is called æstivation, and it follows the same law as we have already seen to regulate the leaves in the leaf-bud—the parts being either applied laterally to each other, or folded or rolled up in different ways. Sometimes the parts overlap each other like the tiles of a house, at other times they are twisted upon each other, as in the mallow. Each flower has its own kind of æstivation.

The Calyx.—This is the outer covering or envelope of the flower. It is usually of a greenish hue like leaves. Sometimes, however, it is coloured, as in the fuchsia and Indian cress. It consists of a certain number of parts called sepals, which are either distinct from each other, when the calyx is polysepalous (Greek word *polys*, means many), as in the common buttercup and wallflower (fig. 103, p. 67), or are united together more or less completely, when the calyx is gamosepalous (Greek word *gamos*, means union), as in the harebell, gentianella, dead-nettle, and campion (fig. 112). The calyx is either regular—that is, has all its parts or sepals equal, as in

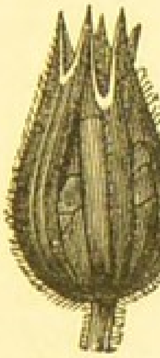


Fig. 112.

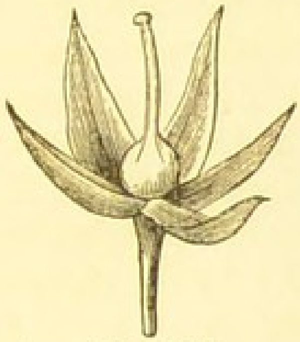


Fig. 113.

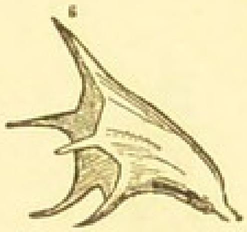


Fig. 114.

the pimpernel (fig. 113); or it is irregular—that is, has its parts unequal, as in the dead-nettle (fig. 114), in larkspur where it is spurred, and in monkshood where it is like a hood. The calyx, in the case of the gooseberry, currant, cucumber, pear, apple, pomegranate, sunflower (fig. 115), and many other plants, forms a covering of the fruit, and remains attached to it when ripe. In such cases the limb of the calyx is placed above the ovary (superior). In some instances the calyx falls off very early, as in the poppy. In some plants the calyx is inconspicuous, and is reduced to a mere rim or slight projection, as in hemlock, and in certain rhododendrons, and in madder (fig. 116). In plants, such as the thistle and dandelion, which belong to the large division called composites, having numerous small flowers on a common

Fig. 112.—Gamosepalous (monosepalous) five-toothed calyx of Campion.

Fig. 113.—Gamosepalous five-partite calyx of Pimpernel, placed below the pistil, which is composed of ovary, style, and stigma.

Fig. 114.—Bilabiate gamosepalous calyx of the Dead-nettle, placed below the pistil (inferior). It is composed of two lips, the upper lip formed by three sepals, the lower by two. One of the upper sepals, *s*, stands prominently out from the rest. The tube is formed by the united sepals.

head, the calyx is united to the fruit, and appears at the upper end of it in the form of hairs or pappus (fig. 117).

The Corolla.—This is, generally speaking, the showy part of the plant, in which the gay colours of the flower reside. It is sometimes wanting, as in the mulberry

Fig. 115.

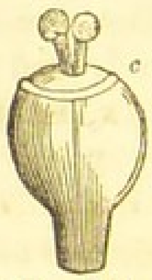


Fig. 116.

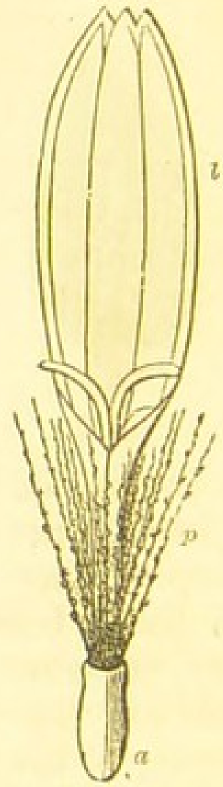


Fig. 117.

(fig. 110), nettle (fig. 111), and catkin-bearing trees, such plants having only a calyx or bracts covering the essential organs. When present it consists of a number of leaves

Fig. 115.—One of the central flowers of the Sunflower. The corolla, *a*, is gamopetalous, five-toothed at the apex. The calyx, *c*, is called superior, because it is above the fruit. Extending beyond the corolla are seen the stamens and pistil, *b*.

Fig. 116.—Calyx, *c*, of Madder adherent to the pistil, its limb appearing in the form of a rim. The calyx is called obsolete.

Fig. 117.—Irregular (strap-shaped) ligulate flower of Ragwort. It may be said to be a tubular floret, split down on one side, with the united petals forming a strap-like projection, *l*. The lines on the flat portion indicate the divisions of the five petals. From the tubular portion below, the bifid style projects slightly. The fruit, *a*, is surmounted by hairs (pappus), which are the changed calyx, *p*.

called petals, which are either distinct from each other, when the corolla is polypetalous, as in the buttercup, wallflower, cinquefoil, rose, and stonecrop (fig. 118); or united together in various ways by cohesion when the corolla is gamopetalous, as in the gentian (fig. 95, p. 63), foxglove, frogsmouth, dead-nettle, and harebell (fig. 119). A corolla is regular when its parts or petals are of equal size, as in the strawberry (fig. 120); and it

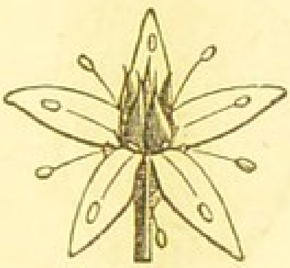


Fig. 118.

Fig. 119.

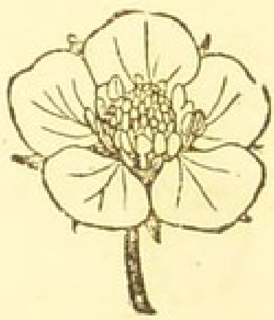


Fig. 120.

is irregular when the petals are of unequal size, as in speedwell and dead-nettle (figs. 106, 107, p. 68). Some irregular corollas, especially those of orchids, present curious forms, resembling insects, such as butterflies, bees, and spiders.

The petals are composed of a congeries of minute cells, each containing colouring matter, and delicate spirals interspersed, all being covered by a thin epidermal coat or skin. The coloured cells are distinct from one another, and thus a dark colour may be at one part and a light colour at another. One of the most

Fig. 118.—Polypetalous corolla of Biting Stonecrop. It is composed of five separate petals, and hence is pentapetalous. There are ten stamens in two rows, and five carpels.

Fig. 119.—Regular gamopetalous bell-shaped corolla of Harebell. It is composed of five petals united. *c*, Calyx superior, that is, above the ovary.

Fig. 120.—Corolla of the Strawberry, composed of five petals without claws. The points of the calyx are seen alternating with the white petals.

beautiful objects under the microscope is the petal of a pelargonium.

Petals assume various forms; some are flat, others folded, or hollowed in various ways. In the carnation there is a long narrow portion called the claw; in mignonette the petal is divided into segments (fig. 121); in columbine the petals are hollow, and form a long spur at the base (fig. 122); in monkshood two of them are hollow and raised on long stalks (fig. 123, *p*); they are concealed under the hood-like sepal. There are

Fig. 121.

Fig. 122.

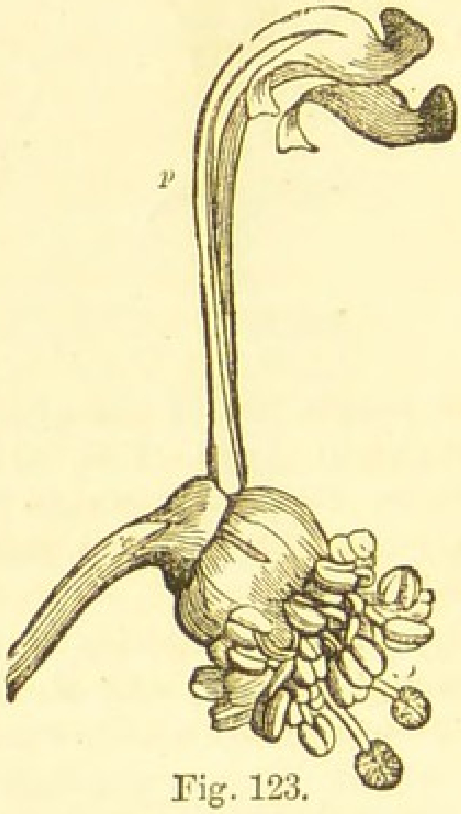


Fig. 123.

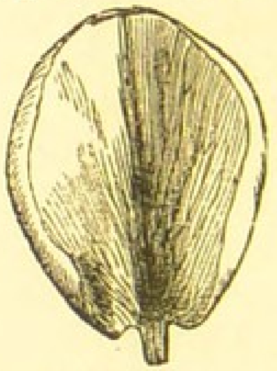


Fig. 124.

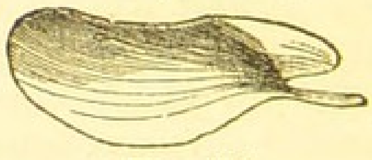


Fig. 125.

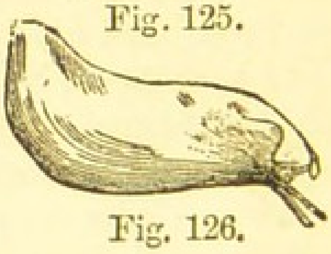


Fig. 126.

Fig. 121.—Petal of Mignonette divided at the apex into numerous narrow segments.

Fig. 122.—Horn-like hollow petal of Columbine.

Fig. 123.—Two peculiar horn-like stalked petals, *p*, of Monkshood. Below the petals are seen numerous stamens attached to the receptacle.

Fig. 124.—Standard or upper petal of a papilionaceous flower (blossom like that of the pea).

Fig. 125.—One of the wings or side petals of a papilionaceous flower.

Fig. 126.—Keel of papilionaceous flower. It is formed of two petals.

certain forms of corolla which deserve notice. Among polypetalous corollas some are regular, as the rose and strawberry (fig. 120); others are irregular, as the pea. In the wallflower (fig. 103, p. 67) there are four petals arranged like a cross, and hence the corolla is called cruciate. In the pea the flower is called papilionaceous (butterfly-like); it consists of a large upper enveloping petal called the standard (fig. 124), two side ones called wings (fig. 125), and a boat-shaped body called the keel (fig. 126), formed by two slightly-cohering petals which enclose the essential organs.

In orchids the floral envelopes are in two rows, both coloured, each consisting of three parts, the outer being the calyx, and the inner the corolla. One of the petals of the latter has usually a marked form, and is called the lip or label.

Among gamopetalous (monopetalous) corollas there are also regular and irregular forms. In the harebell, the corolla is regular and bell-shaped (fig. 119, p. 75); the central yellow flowers in the head of the daisy are regular and tubular, while the outer white flowers are irregular and ligulate or strap-shaped, *i.e.*, with the cohering petals spread out above in a flattened form (fig. 117, p. 72). In the pimpernel, the corolla is regular and wheel-shaped (fig. 84, p. 57); in the speedwell, irregular and wheel-shaped (fig. 106, p. 68). In the dead-nettle, there is an irregular lipped corolla (fig. 107, p. 68).

Appendages to the corolla are seen in the fringes of the passion-flower, in the crown of the narcissus, and in the scales of the comfrey.

QUESTIONS.

1. What are the organs of reproduction in flowering plants?
2. What is meant by phanerogamous plants?
3. What is meant by cryptogamous plants?
4. What is the meaning of inflorescence?
5. What are bracts?

6. Mention some of the forms which bracts assume.
7. Describe indefinite inflorescence.
8. What is meant by the centripetal expansion of flowers?
9. Describe definite inflorescence.
10. What is meant by the centrifugal expansion of flowers?
11. What kind of bracts occur in palms?
12. What are glumes?
13. What arrangement of bracts is seen in the dandelion and the daisy?
14. What is meant by the term involucre?
15. What is a peduncle?
16. What is meant by the receptacle of the flowers?
17. What kind of flower-stalk occurs in the butcher's-broom?
18. Describe the peduncle of the cashew and of the fig.
19. Describe a raceme and a corymb, and give an example of each.
20. Describe an umbel, and give an example.
21. Describe a head of flowers, and give an example.
22. Describe a spike and a spadix, and give an example of each.
23. Describe a catkin, and give an example.
24. What is meant by a cyme?
25. What are the parts of the flower?
26. What is meant by the essential organs of the flower?
27. What is meant by the floral envelopes?
28. How do flowers become double?
29. What numerical series do the parts of the flower follow?
30. What number prevails in the flowers of endogens?
31. What numbers prevail in the flowers of exogens?
32. What number is conspicuous in flowerless plants?
33. What is meant by symmetry in flowers?
34. How is floral symmetry interrupted?
35. What is meant by a symmetrical flower?
36. What is meant by an unsymmetrical flower?
37. What is meant by a regular flower?
38. What is meant by an irregular flower?
39. What is meant by a staminate flower?
40. What is meant by a pistillate flower?
41. How is a floral calendar formed to indicate the months of the year?
42. How is a floral clock formed to indicate hours of the day?
43. Give an instance of a plant expanding its flowers late in the evening.
44. What is meant by meteoric flowers?
45. Whence does the sunflower derive its name?
46. What is meant by æstivation?
47. What kind of æstivation occurs in the mallow?
48. What is the calyx? Of what parts is it composed?

49. What is meant by a gamosepalous calyx?
50. What is meant by a polysepalous calyx?
51. What is meant by a regular and an irregular calyx?
52. If there is only one floral envelope, which part does it represent?
53. What is meant by a coloured calyx?
54. What is meant by pappus?
55. In what plants is it observed?
56. What is meant by an inferior, and what by a superior calyx?
57. What is the inner floral envelope?
58. What are petals?
59. When is a corolla called gamopetalous or monopetalous?
60. When is a corolla called polypetalous?
61. When the corolla is wanting, what is the flower called?
62. What is meant by a regular corolla?
63. When is a corolla called irregular?
64. What is the claw of the petal?
65. What is meant by a spurred petal? Give an example.
66. What kind of petals are seen in monkshood?
67. What are the parts of a papilionaceous corolla? Give an example.
68. What is meant by a cruciate corolla? Give an example.
69. What is meant by a labiate corolla? Give an example.
70. What is the part of the corolla called a label in orchids?
71. Describe a ligulate corolla, and give an example.

The Stamens.—These form the third series of parts in the flower (fig. 105, p. 68). In fig. 127 they are

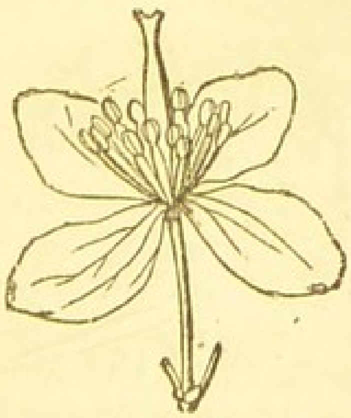


Fig. 127.

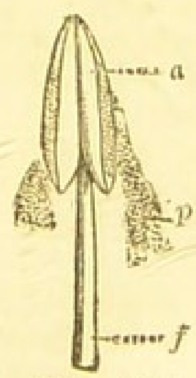


Fig. 128.

Fig. 127.—Flower of Celandine. The calyx has fallen off, the four petals are seen, numerous stamens and one pistil in the centre.

Fig. 128.—A stamen consisting of filament *f*, anther *a*, and pollen *p*, discharged from slits in the anther-lobes.

numerous, and surround the central pistil, which is longer than the stamens. Like the other parts of the flower, they are considered as a modification of leaves. In double flowers they are converted into petals. They consist usually of two parts, a stalk or filament (fig. 128, *f*) supporting two small cellular bags at the top (fig. 128 *a*), which are called the anther-lobes; when there is no stalk the anther is sessile. The anther contains a powder (fig. 128, *p*), often of a yellow colour, called pollen, which is essential to the production of perfect seed in flowering plants. At a certain period of growth, this powder is discharged from the anther, which opens by slits (fig. 128), or by hinges, as in the barberry and laurel, or by holes, as in the heath, rhododendron, and potato, to allow its escape. The anther has two coverings, the inner of which often contains elastic spirals,

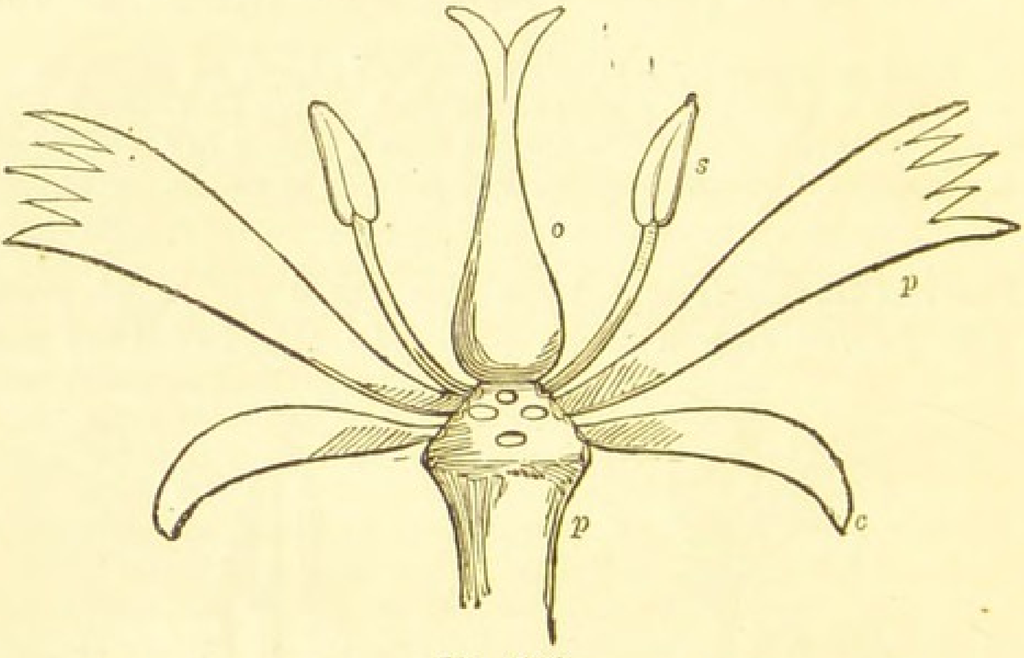


Fig. 129.

which seem to assist in the opening of the lobes. The pollen, or the dust of flowers, when examined by the microscope, presents multiplied forms. It must be

Fig. 129.—End of peduncle, *p* (receptacle or thalamus), bearing sepals *c*, petals *p*, and stamens *s*, all separate and all below ovary *o*. Stamens hypogynous.

applied to the pistil or central part of the flower, in order that the seed may be perfected.

The position of the stamens in relation to the ovary requires special attention. Sometimes they are attached to the receptacle—*i.e.*, the upper part of the flower-stalk —and are then placed below the ovary and free from it, as well as from the calyx. In that case they are called hypogynous, which means under the ovary (fig. 129).

Again, the stamens are attached to the calyx to a greater or less extent, but free from the ovary—*i.e.*, not adhering to it—and then they are perigynous, which means around the ovary (fig. 130).

A third variety is that in which the stamens appear above the ovary, and are called epigynous, which means upon the ovary. In this case the calyx is also epigynous (fig. 131).

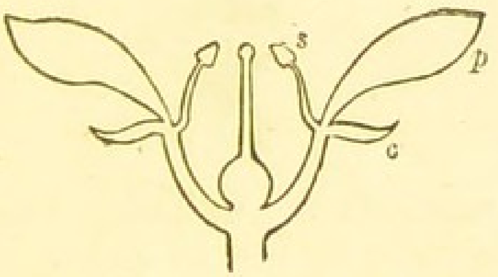


Fig. 130.

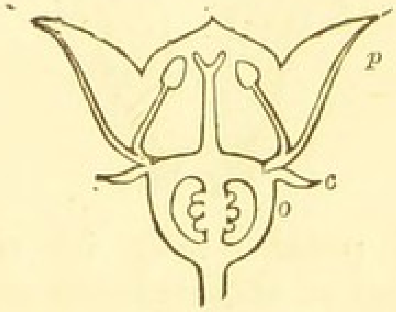


Fig. 131.

The stamens, as regards number, bear a relation to the other parts of the flower. They are either equal to the number of parts in the calyx or corolla, or some multiple of them. When there is a want of correspondence as regards number, it will be found that this depends usually on something abnormal. Thus, in irregular lipped flowers (fig. 107, p. 68), there are five

Fig. 130.—Figure showing two stamens *s*, united to the calyx *c*, and thus surrounding the ovary, which is free in the centre. Stamens perigynous. Petal, *p*.

Fig. 131.—Figure showing two stamens placed above the ovary *o*, and therefore epigynous. Calyx *c*, is also epigynous. *p*, Corolla.

The word gynous is applied to the pistil, and the words epi, peri, and hypo mean upon or above, around, and below.

parts of the calyx and five of the corolla, but frequently only four stamens, on account of one stamen being undeveloped. The stamens in such cases are usually of different lengths—two being long and two short, as in dead-nettle (fig. 132). In cruciform plants, as wallflower there are four long and two short stamens (fig. 104, p. 67). The number of the stamens is taken into account in the Linnæan or artificial system of classification, the Greek numerals being prefixed to the term *andria*, meaning stamen. The stamens like the sepals

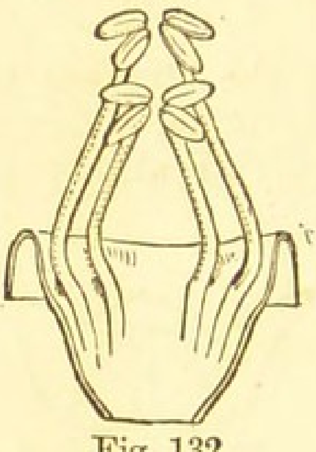


Fig. 132.

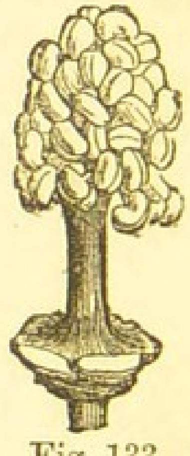


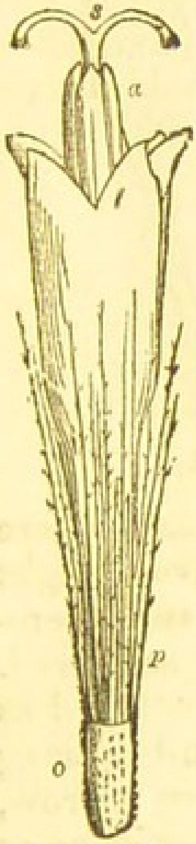
Fig. 133.

and petals, may be either separate or united. The union of the stamens may take place by means either of their filaments or of their anthers. The stamens are sometimes united by their filaments so as to form one bundle as in the mallow (fig. 133); at other times they form two bundles, as in the sweet pea (fig. 134), and in the fumitory (fig. 92, p. 61); the union sometimes takes place by the anthers, as in the dandelion, and in composite plants generally (fig. 135); the stamen and pistil are at times united on a column, as in orchids and in birthwort (fig. 136). The filament may be long and thread-like, as in grasses (fig. 137); or short and thick; or elastic; or irritable.

Fig. 132.—Two long and two short stamens of Foxglove. They are said to be didynamous, and are attached to the corolla.

Fig. 133.—Stamens of Mallow united by their filaments so as to form one bundle (monadelphous). The anthers are not united.

The pollen consists of minute cells contained in the anther-cases. Sometimes they are united in fours, at other times in masses, as in orchids (fig. 138). The pollen must be applied to the pistil in order to insure the formation of perfect seed containing the embryo plant inside.



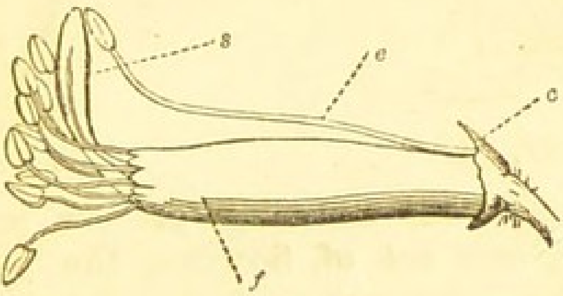


Fig. 134.

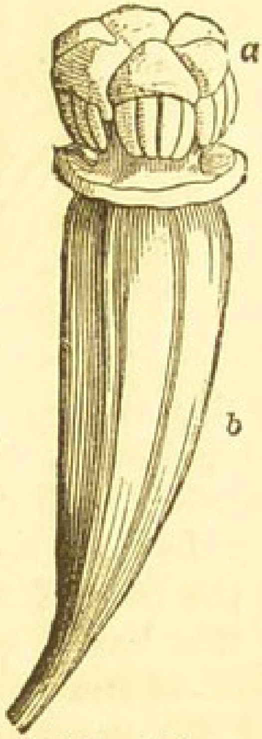


Fig. 135.

Fig. 136.

Many beautiful arrangements are made for insuring the proper application of the pollen to the upper part of the pistil. The agency of winds, of elasticity, of irritability, and of insects, is called into operation in

Fig. 134.—Stamens of Sweet Pea united in two bundles by their filaments. There are ten stamens, nine of which *f*, are united, and one, *e*, is free. They are called diadelphous. Top of style, *s*; calyx, *c*.

Fig. 135.—Tubular corolla of Ragwort showing united anthers *a*, surrounding the style (syngenesious or synantherous). The single-seeded ovary, *o*, is surmounted by the hairy limb of the calyx, *p* (pappus). Bifid stigma *s*.

Fig. 136.—The stamens and pistil *a*; the former placed below the part of the latter called the stigma; *b*, the inferior ovary.

different cases. In the common nettle, and in the pellitory of the wall, the stamens have elastic filaments, which are at first bent down, so as to be covered by the calyx; but when the pollen is ripe, the filaments jerk out and scatter the powder on the pistils, which, in the

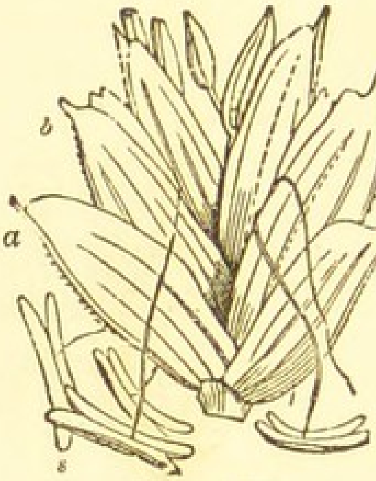


Fig. 137.

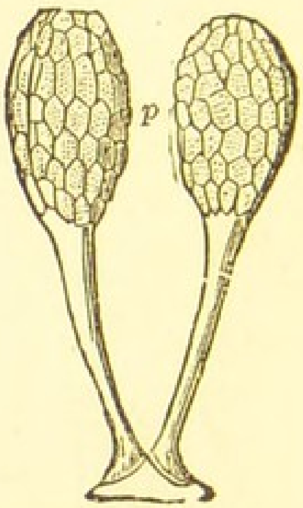


Fig. 138.

nettle, occupy separate flowers. In the hazel, where the pollen is in one set of flowers, the leaves might interfere with the application of the pollen, and therefore they are not produced until it has been scattered. In the case of firs, which have their flowers arranged as in the hazel, stamens at one place and fruit-bearing cones at another, the evergreen leaves are very narrow, and the quantity of pollen produced is very great, so as to insure its reaching the young cones.

Insects are often, in the arrangements of Providence, made the means of securing the production of seed. How often do we see the bees collecting the yellow powder of plants, and, while providing for the food of their young, aiding in dispersing the pollen!

Fig. 137.—Spikelet of Wheat, consisting of two bracts (glumes) *a a*, enclosing several flowers *bb*; stamens *s*, having long slender filaments which are attached to a part of the anther. The latter are very movable.

Fig. 138.—Pollinia, or pollen-masses, separated from the point above the stigma, with viscid matter attaching them at the base. The pollen-masses *p*, are supported on stalks. These masses are easily detached by the agency of insects, which convey them to the stigmas of the flower and thus ensure fertilization.

The Pistil.—This is the central part of the flower (fig. 1, *Frontispiece*), and is composed of one or more leaves called carpels (figs. 139, 140). It may consist of a single carpel, as in the pea and vetch (fig. 158, p. 93); or of several, either distinct from each other, as in the pæony

Fig. 139.

Fig. 140.

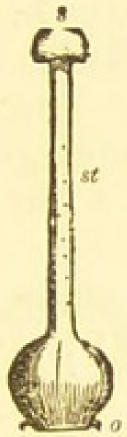


Fig. 141.

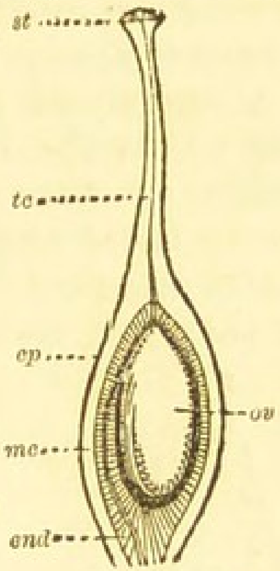


Fig. 142.

and stonecrop (fig. 143, p. 86), or combined, as in the tulip and lily (fig. 144, p. 86). In the double-flowering cherry, in which the stamens are changed into petals, the pistil appears in the form of a flat leaf, as represented in fig. 139, or of a folded leaf, as in fig. 140. The plant does not produce fruit, on account of the change which has taken place in the stamens and pistil. The parts of the pistil are seen in fig. 141. The rounded top, *s*, is the stigma, the stalk below, *st*, is the style, and the lower swollen portion, *o*, is the ovary, containing the cellular ovules which become seeds. These parts are better seen in fig. 142, which represents the pistil of the apricot-tree laid open longitudinally, *st* being the stigma,

Figs. 139 and 140.—The pistil of the double-flowering cherry, composed of a leaf (carpel) either flat, as in 139, or folded, as in 140.

Fig. 141.—Pistil of Primrose, showing the ovary, *o*, below, the stigma, *s*, at the top, and the style, *st*, between them.

Fig. 142.—Pistil of Apricot-tree cut vertically. *ep*, Outer coat of ovary, *me*, middle coat, *end*, inner coat, which becomes the stone, *ov*, young seed or kernel, *tc*, style and its canal, *st*, stigma.

tc the style, with a canal through it, *ep*, *me*, and *end*, the three coverings of the ovary, and *ov* the young seed. When there is no style the stigma is sessile.

The carpels or leaves forming the pistil are sometimes separate, as in the common stonecrop (fig. 143), at other times they are united together, as in the primrose (fig. 141), so as to appear one. The number of carpels forming such a compound pistil can usually be ascertained by cutting across the ovary, as in fig. 144, where it is seen that there are three cavities containing seeds, and consequently three carpels. The ovules or young seeds are generally attached to the edge of the carpels; but sometimes they are united to the axis, as in the primrose,

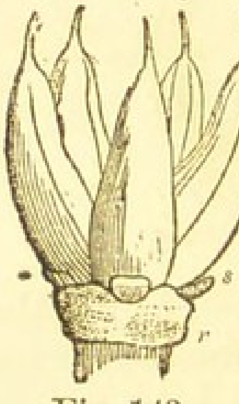


Fig. 143.

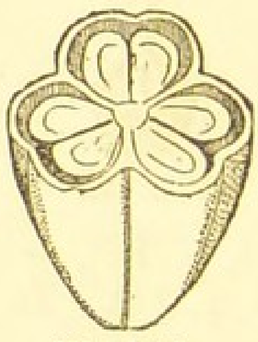


Fig. 144.

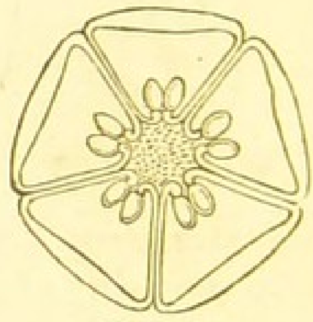


Fig. 145.

without any apparent attachment to the carpels. In certain cases, as in cycads and conifers, the ovules are not covered by carpels, and are called naked, because the pollen is at once applied to them without the inter-

Fig. 143.—Pistil of Stonecrop (*Sedum*). It consists of five carpels, which are separate and distinct. Each carpel has its own ovary, style, and stigma. The pistil is composed of separated carpels. At the base of the carpels are seen scales, *s*. Below the pistil is the part of the receptacle, *r*, to which the other whorls were attached.

Fig. 144.—Ovary or lower part of the pistil of the Lily cut transversely. There are three cavities containing seeds, indicating the union of three carpels. The divisions in the ovary are formed by the sides of the carpellary leaves. Each division is double, and the number of divisions corresponds with the number of the carpels. The ovules are attached to a central point called placenta.

Fig. 145.—Pistil formed of five carpels. Section of ovary showing five partitions and five cavities, with ovules attached to central placenta.

vention of a stigma. The number of styles in a flower was used by Linnæus as a mode of distinguishing certain divisions in his system called orders; the Greek numerals being prefixed to the term *gynia*, meaning pistil.

Divisions are formed in ovaries by the folded edges of the contiguous carpels uniting with each other, at the same time being attached to the central axis where the placentas and ovules are situated. In fig. 144 there are three carpels, the edges of which meet together, and thus three partitions are produced, and three cavities containing ovules. In fig. 145 there are five carpels united. Sometimes the partitions do not extend to the centre, and then there is only one cavity in the ovary,

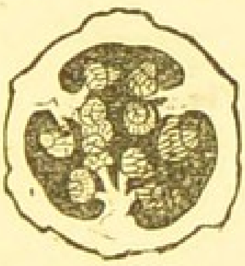


Fig. 146.

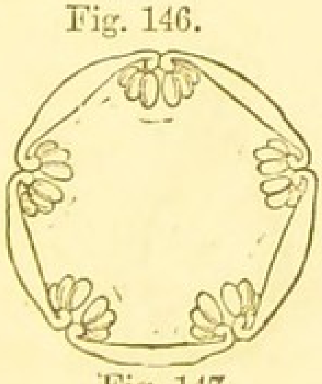


Fig. 147.

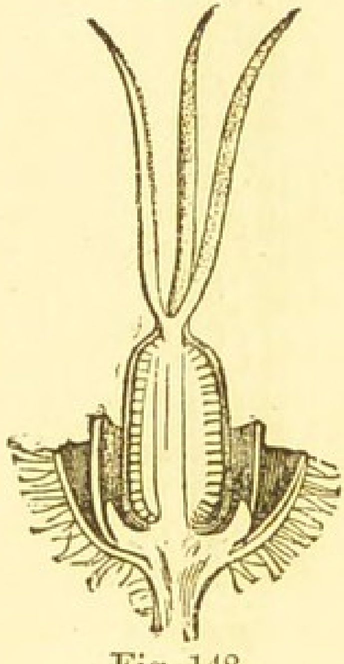


Fig. 148.

although there may be several carpels, as in the poppy, and the mignonette and orchis (fig. 146). In fig. 147, the ovules appear on the walls of the ovary. Occasionally

Fig. 146.—Ovary of an Orchid cut transversely, showing three parietal placentas bearing ovules.

Fig. 147.—Section of ovary formed by five carpels, with the ovules attached to the points where the carpels meet each other. The placentas are five and parietal.

Fig. 148.—Pistil of Rose-campion cut vertically, showing a free placenta in the axis bearing numerous ovules.

no partitions whatever are seen, and the ovules are attached to the central axis directly, as in the red campion (fig. 148), and in the primrose (fig. 149). Spurious partitions are formed in ovaries by the folding in of the back or front of the carpels, as in some papilionaceous flowers and in flax, or by a prolongation of the placentas, as in wallflower (fig. 150, *cl*). Carpels

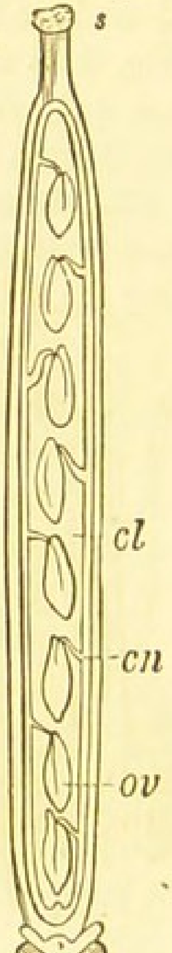


Fig. 150.

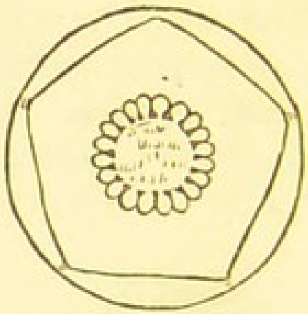


Fig. 149.

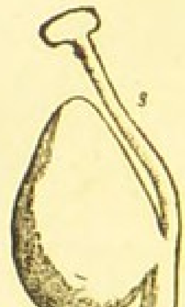


Fig. 151.

are sometimes united together completely, at other times the ovaries only are combined, while the style and

Fig. 149.—Ovary formed of five carpels, and the ovules attached to a free placenta in the centre. There are no partitions.

Fig. 150.—Pistil of Wallflower, consisting of two carpels, between which is a spurious partition (replum) *cl*, formed by the placentas *cn*; ovules *ov*, style *s*.

Fig. 151.—Pistil of the Lady's-mantle with the style, *s*, arising from the apparent base of the ovary.

stigma are separate (fig. 148), or the ovaries and styles are united to each other and the stigmas are free, or the styles are united while the ovaries are free, as in the dead-nettle and comfrey. The number of carpels forming a pistil may be determined by the number of styles, or by the divisions seen on cutting across the ovary. The style is usually at the apex of the ovary, but sometimes

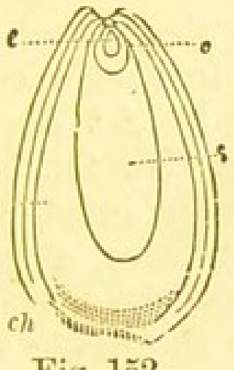


Fig. 152.

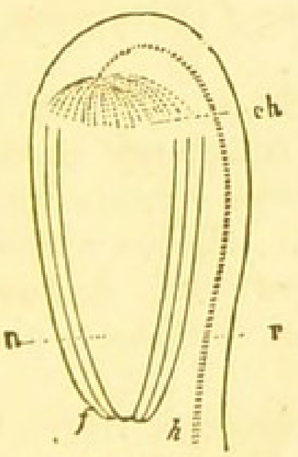


Fig. 153.

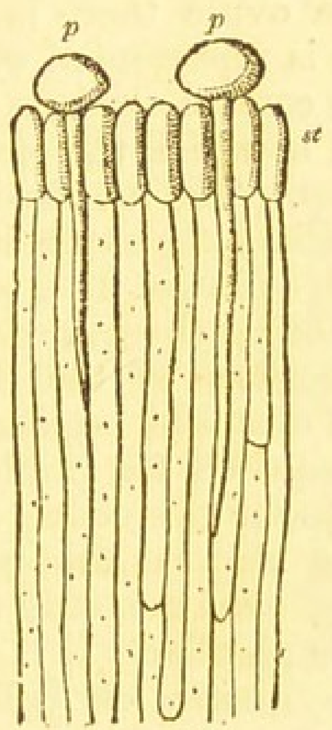


Fig. 154.

Fig. 152.—Straight ovule of Polygonum, showing the coats of the ovule on the outside of the nucleus *n*, the embryo-sac *s*, containing a vesicle *ce*, in which the rudimentary embryo *e* is seen close to the hole. The base of the nucleus is marked *ch*.

Fig. 153.—Inverted ovule of Dandelion, showing the coats of the ovule surrounding the nucleus *n*, which is inverted, so that its base *ch* is removed from the base of the ovule *h*, while the hole *f* is near the base. The connection between the base of the ovule and the base of the nucleus at *ch* is kept up by means of the cord *r*.

Fig. 154.—The style and stigma laid open. Two grains of pollen *p p* on the top of the stigma *st*, protruding tubes which descend through the stigma and style to the ovules.

it arises below the apparent apex, as in lady's-mantle (fig. 151). The stigma is a viscid spot at the upper end of the style, or, if there is no style, on the top of the ovary, formed of loose cells, to which the pollen is applied after the bursting of the anthers. The stigma may either be simple (fig. 141, *s*) or divided (fig. 135, *s*, p. 83).

The Ovule.—The ovule is the young seed contained in the ovary. There may be one or more ovules. Each ovule is covered by at least two coats, which inclose a central part in which the young plant is formed. At one part of the ovule there is a small opening. In fig. 152 an ovule is represented with its two coverings, inside which is the central nucleus *n*, the sac *s*, containing a minute cell *c*, in which the embryo *e* is seen near the opening at the top. The nourishing vessels enter the ovule at *ch*. Sometimes the ovule, in place of being straight, is turned round, as in fig. 153, where the opening *f* is represented as pointing downwards.

Functions of the Stamens and Pistil.—These are called essential organs of the flower, inasmuch as they are required for producing perfect seed containing in its interior the young (embryo) plant. Hence a flower having stamens and pistil is called perfect. A flower having stamens only is staminate; one having a pistil only is pistillate.

The grains of pollen, when discharged from the anther, are applied to the stigma (fig. 154, *st*), and after lying on it for a certain length of time, they send out tube-like prolongations, as shown in fig. 154, where two pollen-grains are seen lying on the top of the stigma, which is split open, along with part of the style, to show the pollen-tubes. In fig. 155 there is a magnified representation of a pollen-grain giving out three tubes, one of which is considerably elongated. These tubes reach the ovule in the ovary (fig. 156 *ve*), and by this means the embryo plant is formed (fig. 157 *e*). After this process has taken place, the pistil undergoes marked changes, by which it becomes the fruit containing the seed, in the interior of which is the young germ.

By taking the pollen of one species of plant, and applying it to a different species, seeds are produced, which, when they sprout, give origin to what are called hybrids.

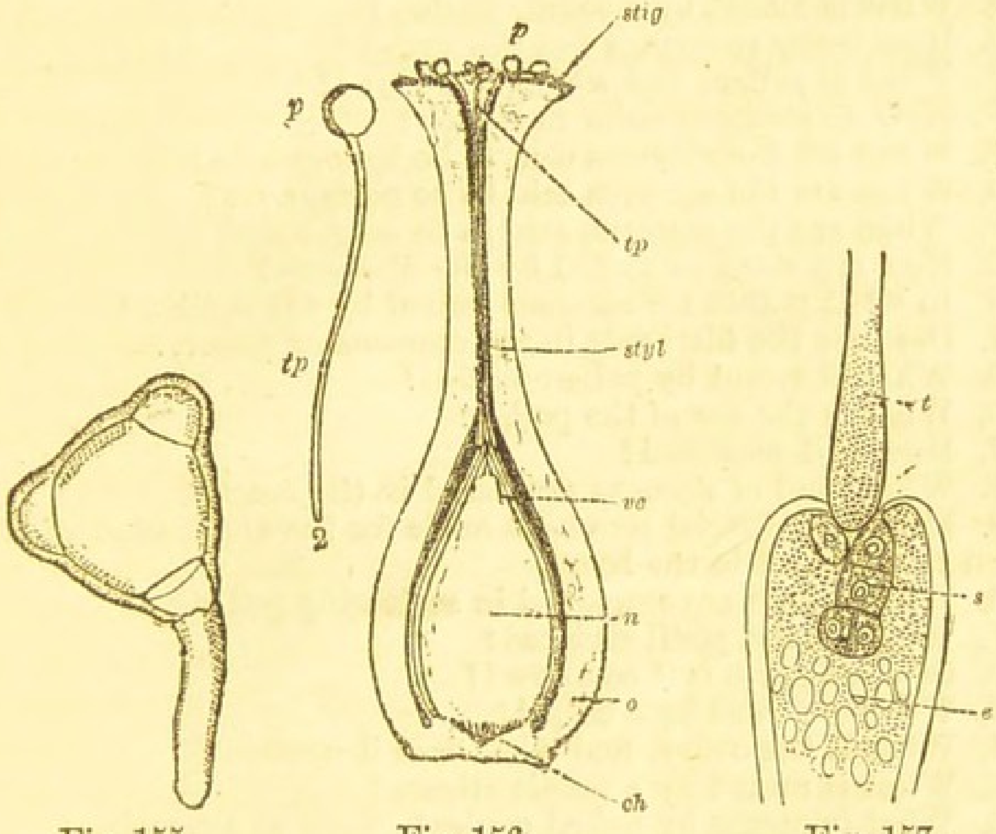


Fig. 155. Fig. 156. Fig. 157.

Fig. 155.—Pollen grain, much magnified, showing three points where tubes come out. One of the tubes is considerably elongated.

Fig. 156.—Pistil and pollen of Polygonum. 1. Stigma, *stig*, with pollen-grains, *p*, adherent to it, sending tubes, *tp*, down the conducting tissue of the style, *styl*; the ovary, *o*, containing the ovule with its coverings and central cellular mass or nucleus, *n*, enclosing a rudimentary embryo-sac, *vc*, in which ultimately the embryo is developed. The base of the ovule which was attached to the placenta is marked *ch*. 2. Pollen-grain, *p*, separated; tube, *tp*.

Fig. 157.—Section of the ovule of Œnothera, showing the pollen-tube *t*, with its enlarged extremity applied to the end of the embryo-sac, and introverting it slightly; the germinal vesicle in the sac has been fertilized, and has divided into two parts, the upper part forming a suspensor, *s*, and the lower dividing into four parts, which form a globular mass — the rudimentary embryo, surrounded by cells, *e*. Pollen grains may be wafted to the stigma by the wind, or carried by insects;

QUESTIONS.

1. Which whorl of the flower is formed by the stamens?
2. What relation do the stamens bear to the floral envelopes as regards their position?
3. In double flowers, what change do the stamens undergo?
4. What are the parts of a stamen?
5. What is meant by a sessile anther?
6. How many coverings has the anther?
7. What is pollen, and where is it found?
8. How do stamens differ in length?
9. When are the stamens said to be hypogynous?
10. When are the stamens said to be perigynous?
11. When are the stamens said to be epigynous?
12. How are stamens united by the filaments?
13. In what plants are stamens united by the anthers?
14. Describe the filaments in the stamens of grasses?
15. What is meant by pollen-masses?
16. What is the use of the pollen?
17. How is it scattered?
18. What kind of stamens are found in the nettle?
19. Mention a special provision made for the application of the pollen to the pistil in the hazel.
20. What agents are employed in scattering pollen?
21. Where is the pistil situated?
22. Of what parts is it composed?
23. What is meant by a carpel?
24. What is the ovary, and what does it contain?
25. What is meant by a sessile stigma?
26. What is meant by naked ovules? Give an example.
27. How are divisions (septa) in ovaries formed?
28. What is meant by a placenta?
29. How are spurious divisions in ovaries formed?
30. How can the number of carpels forming a pistil be ascertained?
31. What is the ovule?
32. How many coverings exist in the ovule?
33. Is there any opening in the ovule?
34. What are the functions of the stamens and pistil?
35. What is meant by a staminate, and what by a pistillate flower?
36. To what part of the pistil is the pollen applied?
37. Describe the changes which take place on the pollen after its application to the pistil.

The Fruit.—The term fruit, in botanical language, is applied to the mature perfect pistil, whether dry or succulent. When we examine fruits, however, we find them formed in various ways. Some, as the pea, bean, and vetch (fig. 158), consist solely of the pistil, slightly altered; others, as the grape, peach, and plum, consist of the pistil, changed so as to assume a succulent character, either entirely, as in the grape, or partially, as in stone fruit; others, as the gooseberry, currant (fig. 159),

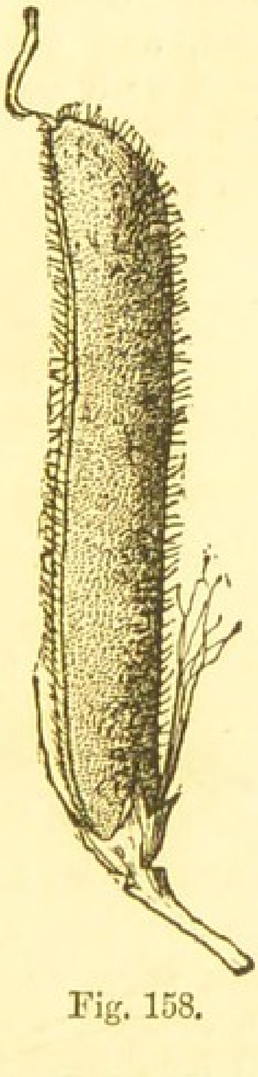


Fig. 158.

Fig. 159.

Fig. 158.—Pod of Vetch, composed of the pistil, with style and stigma at the summit. The fruit in this case is composed of a single carpel containing numerous seeds.

Fig. 159.—Fruit of Currant, composed partly of the pistil and partly of the calyx; the withered remains of part of the calyx are seen at the summit of each currant.

apple, pear, are formed not only by the pistil, but also by the calyx, a portion of which is seen at the top of these fruits in the form of brownish scales. The hazel-fruit (fig. 160), consists of the pistil developed into the nut, with a covering of bracts, called the husk, outside; and the fruit of the oak (the acorn) has a cup-like covering formed by bracts (fig. 161 *a*). In the strawberry (fig. 162), the succulent part, which is eaten, consists of the enlarged growing point, bearing on its surface numerous small carpels or fruits, which are often called seeds. The grain of wheat, and other cerea grains, consist of seeds incorporated with seed-vessels

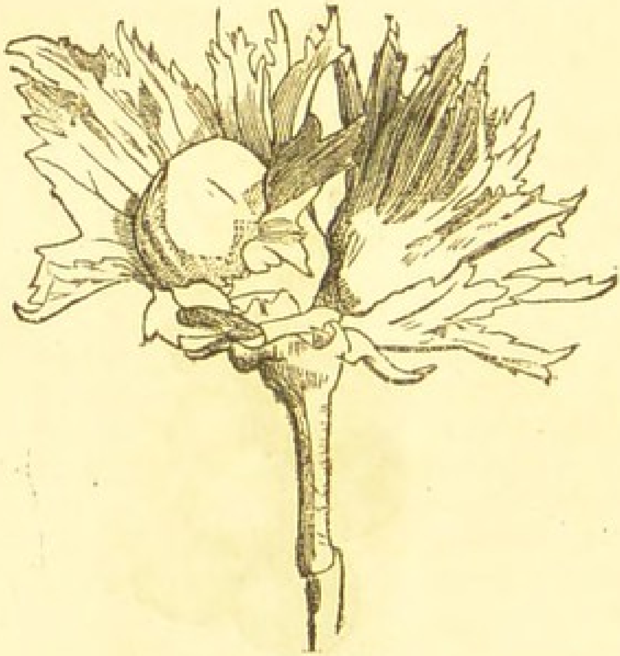


Fig. 160.

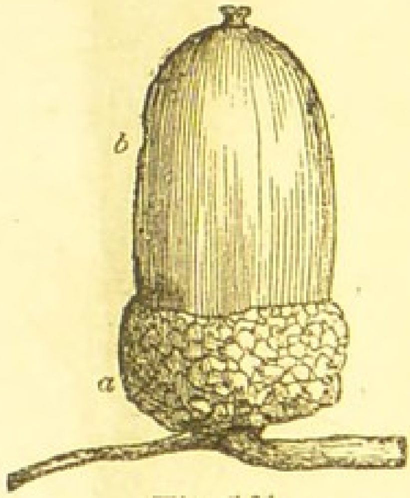


Fig. 161.

and are in reality fruits, although they appear like seeds The mulberry (fig. 163), as well as the pine-apple (fig 164), the bread-fruit, the cone (fig. 165), and the fig (fig. 94, p. 62), are made up of a congeries of pistils formed by separate flowers, and all combined into one

Fig. 160.—The fruit of the Hazel, consisting of the nut, with the husk outside. The husk is composed of floral leaves or bracts.

Fig. 161.—Fruit of the Oak (acorn), *b*, with its cup or outer covering of altered leaves or bracts, *a*.

mass. In the first four, the flowers are on the outside of a common receptacle or axis; while in the fig the

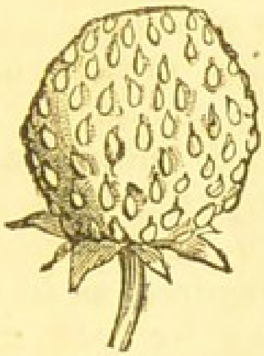


Fig. 162.

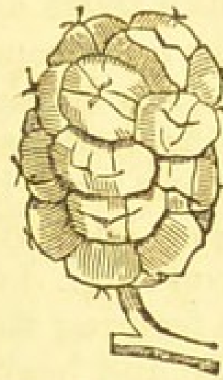


Fig. 163.

succulent receptacle is curved upwards and inwards, so

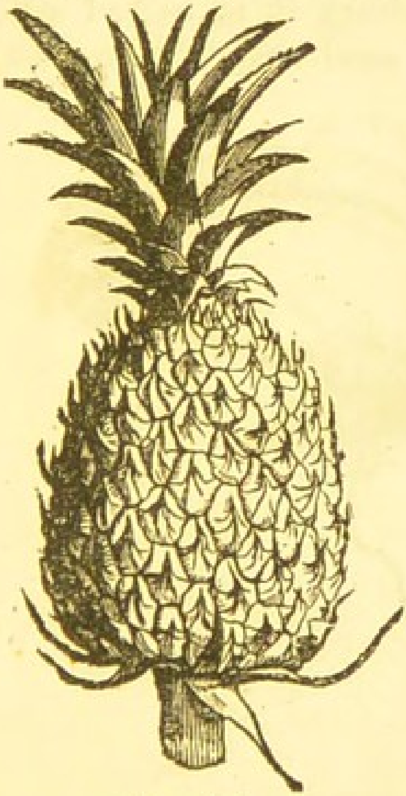


Fig. 164.

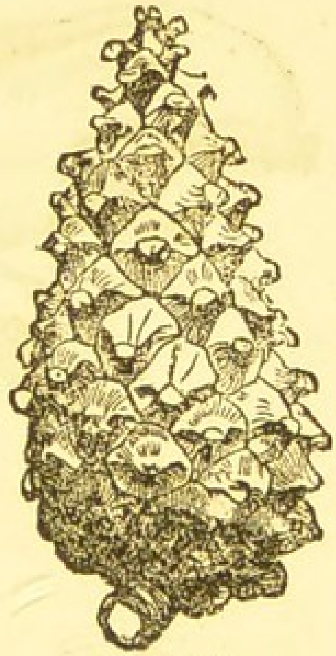


Fig. 165.

Fig. 162.—Strawberry fruit, consisting of a succulent receptacle, on which are scattered numerous fruits or achenes, resembling seeds.

Fig. 163.—Fruit of Mulberry, composed of several flowers united into one succulent mass.

Fig. 164.—Pine-apple, a fruit consisting of several succulent fruits formed by different flowers, and all united into one. The scales outside are modified leaves, while the crown is a series of leaves unaltered.

Fig. 165.—Cone of Fir, a fruit consisting of scales or hardened

as to be hollow, and thus bears the flowers inside (fig. 94, p. 62). In the fig, what are called seeds are in reality fruits, like those on the top of the strawberry, but produced by numerous flowers in place of one.

Fruits are divided into those which open in order to scatter the seeds, and those which do not open. Among the former may be noticed—1. The follicle, a carpel opening on one side, as in the pæony (fig. 166), and the stone-crop (fig. 143, p. 86), where there are several follicles forming the fruit; 2. The legume, as in the pea (fig. 167), and bean, a carpel opening by both sides; 3. Siliqua, a pod formed of the two united carpels opening along each edge in the form of two valves, as in wall-flower (fig. 150, p. 88)—when short it is called silicula (fig. 168); 4. The capsule, a seed-vessel composed of

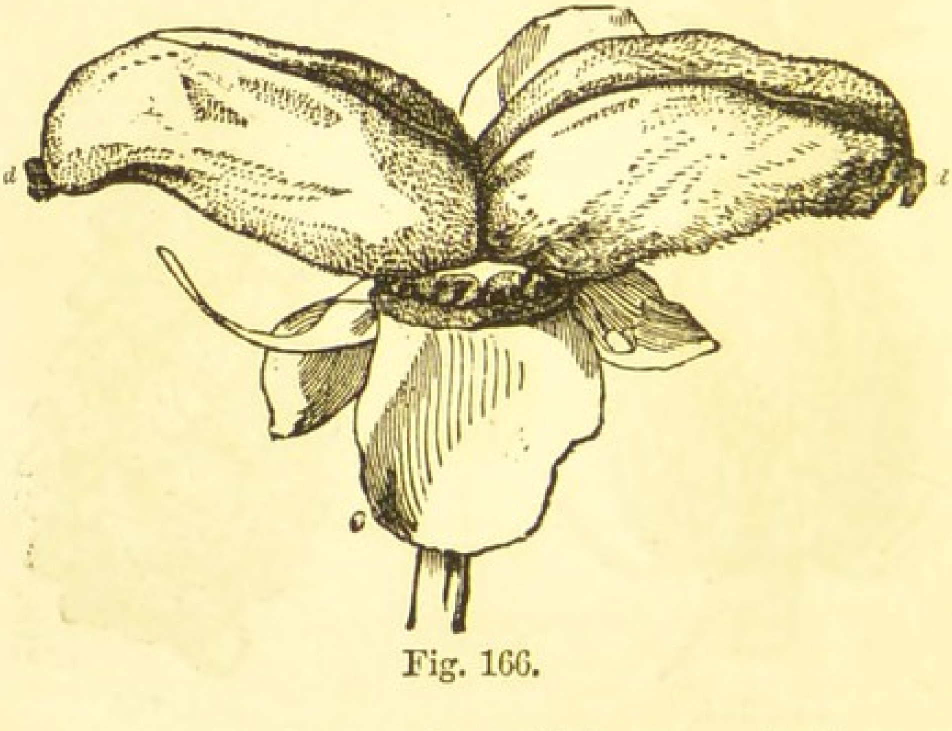


Fig. 166.

several dry united carpels, which separate from each other in various ways, opening by teeth as in the

leaves, each representing a separate flower. The fruit is made up of numerous flowers united.

Fig. 166.—Fruit of Pæony, consisting of two carpels, *d d*, opening on their inner side, and called follicles. Calyx, *c*, below the fruit.

campion (fig. 169), by valves as in the violet (fig. 170), by a lid as in henbane (fig. 171) and the monkey-pot

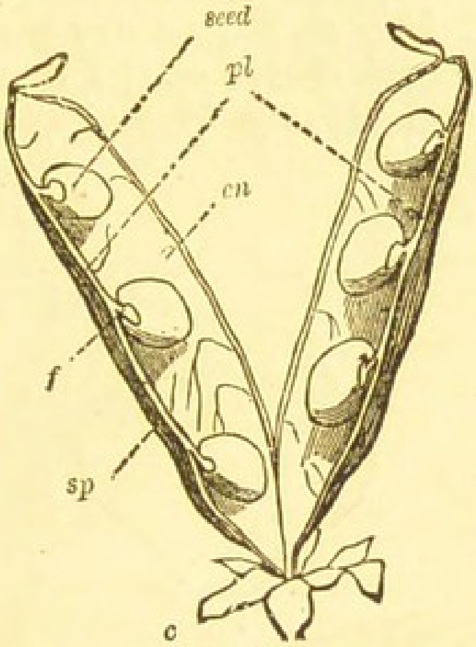


Fig. 167.

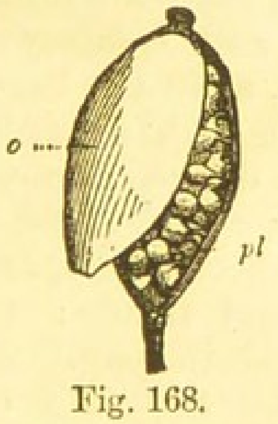


Fig. 168.

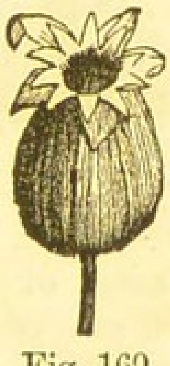


Fig. 169.

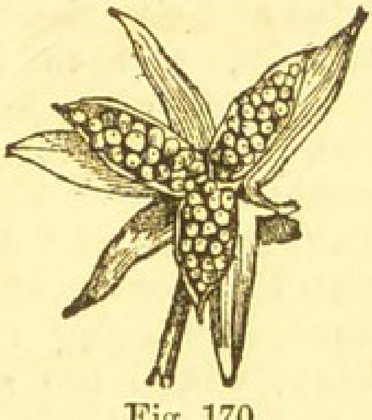


Fig. 170.

Fig. 167.—Legume of Pea opening on both sides. It is formed by one carpel, and the seeds are attached along one side, *pl.* Outer coat of seed-vessel, *sp*; inner coat, *en.* Placenta, *pl.* Stalk of seed, *f.*

Fig. 168.—Silicula of Whitlow-grass opening by two flat valves, *o*, from below upwards, having parietal placentas, *pl*, united by a membrane or replum. The seeds are attached to the placentas on either side of the seed-vessel.

Fig. 169.—Seed-vessel or capsule of Campion opening by ten teeth at the apex. The calyx is seen surrounding the seed-vessel, but not adherent.

Fig. 170.—The capsule of the Pansy, opening by three valves through the back of the carpels. The placentas and seeds are placed on the middle of the valves.

(fig. 172), by pores below the stigma as in the poppy (fig. 173).

Among fruits which do not open may be noticed—1. The achene (fig. 151, p. 88)—a dry single-seeded fruit, such as that of each floret of the dandelion and sunflower (figs. 91 and 115, pp. 61 and 74),—in the ranunculus and strawberry (fig. 162, p. 95) there are numerous achenes, and in the dead-nettle and comfrey four; 2. The nut, a single-seeded dry fruit, as in the hazel (fig. 160, p. 94) and oak (fig. 161, p. 94), with a hard shell outside covered by bracts; 3. The drupe, a succulent fruit, such as the cherry and peach, called stone-fruits, with three coverings—the skin, the fleshy part, and the stone containing the seed or kernel inside; 4. The berry, where the seeds are enclosed in pulpy matter within a covering formed either by the wall of the mature ovary alone, as in grape and potato-apple, or by the wall of the ovary in combination with the calyx, as in the gooseberry and currant (fig. 159, p. 93); 5. The apple, where there are usually five cavities in the centre containing seeds, and the outer part consists of fleshy

Fig. 171.

Fig. 172.

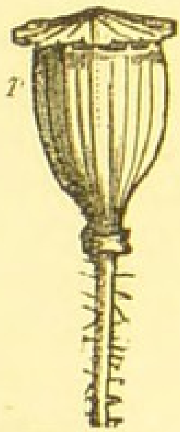


Fig. 173.

Fig. 171.—Seed-vessel of Henbane, opening by a lid.

Fig. 172.—Fruit of the Monkey-pot, opening by a lid. The seeds are the Sapucaya nuts of the shops.

Fig. 173.—Capsule of Poppy, opening by pores, *p*, under the broad stigma.

cells covered by a skin formed partly by the calyx, as in the apple and pear.

In common language we apply the name fruit chiefly to that which is succulent and eatable.

The Seed.—The seed is usually contained in the seed-vessel, or, in other words, in the fruit (fig. 167, p. 97). In some cases the seed is naked, that is, not contained in a seed-vessel, as in the fir. In order that it may be complete, it must contain the rudiment of the young plant, or what is called the embryo. On removing the skin of the seed, it is sometimes found that the embryo occupies the whole of the interior. This is the case in the bean, pea (fig. 13, p. 16), and lupin, the fleshy cotyledons of which form the great bulk of the seed; so also in the common stock (fig. 174), and other plants of the cabbage order. At other times the embryo forms only a part of the seed, as in palms (fig. 175) and lychnis (fig. 176). In these instances there is a separate store

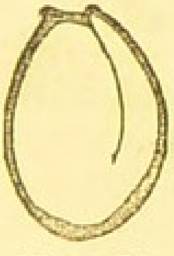


Fig. 174.

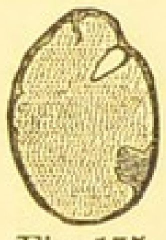


Fig. 175.

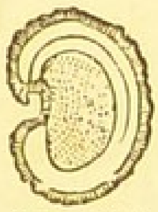


Fig. 176.

of nourishing matter called albumen, which, after the seed has been sown, is gradually dissolved, so as to be taken up by the plant in the early stages of growth.

Fig. 174.—Seed of Common Stock Gillyflower, cut open in a vertical manner, showing the embryo plant, of a white colour, occupying the whole of the interior. The coverings of the seed are dark, and a black line indicates the folding of the young root on the cotyledon.

Fig. 175.—Seed of a palm, cut vertically, showing the minute white embryo occupying only a small part of it. The bulk of this seed is made up by a separate store of nourishing matter.

Fig. 176.—Seed of Red Campion, cut vertically, showing the embryo curved round the store of nourishment, which is in the centre.

The mode in which seeds are scattered is deserving of notice. In some cases, as in the gooseberry, grape, apple, and coco-nut, the fruit falls without opening, and gradually decays, forming a sort of manure with the soil in which the plant sprouts. In other cases, the seed-vessels open and scatter the seeds. In the common broom, the pod, when ripe, opens with considerable force; so also the fruit of the sandbox-tree, and the balsam, which is called Touch-me-not, on account of its seed-vessel bursting when touched (figs. 177, 178). The squirting cucumber, when handled in its ripe state, gives way at the point where the fruit joins the stalk,

Fig. 177.

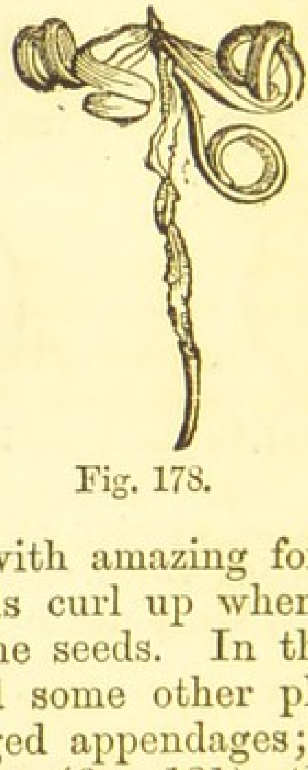


Fig. 178.

and the seeds are sent out with amazing force. The common geranium seed-vessels curl up when ripe, as seen in fig. 179, and scatter the seeds. In the case of firs (fig. 180), bignonias, and some other plants, the seeds are furnished with winged appendages; while in the cotton-plant and asclepias (fig. 181), they have hairs attached to them, by means of which they are wafted to a distance.

In the case of composite plants, such as the dandelion

Fig. 177.—Ripe fruit of Balsam, in its unopened condition.
Fig. 178.—Fruit of the same plant opening by five recurved valves.

(fig. 91, p. 61), thistle, and ragwort (fig. 135, p. 83), what is commonly called the seed is in reality the fruit with the calyx attached in the form of hairs. The down of the thistle consists of calycine hairs. Each

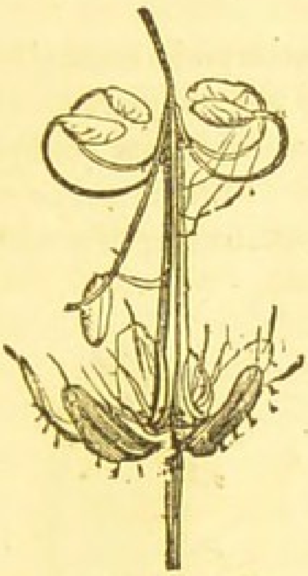


Fig. 179.

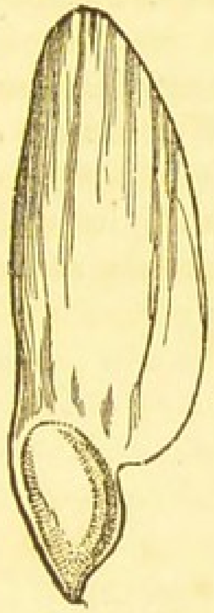


Fig. 180.

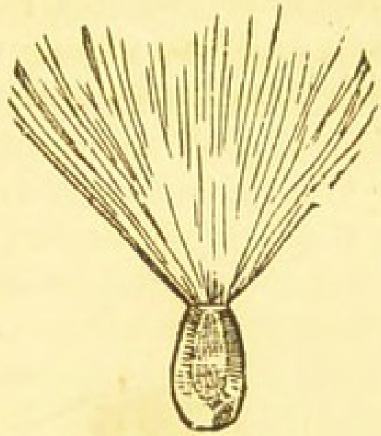


Fig. 181.

fruit contains a single seed, and it is interesting to know the process by which this single-seeded fruit is deposited in the soil. In these plants there are numerous flowers on a common receptacle, which is at first succulent and nutritive, as in the artichoke. In the young state this receptacle contains much starch, which is gradually changed into sugar, so as to be easily taken up in the form of a saccharine solution by the flower. As the flower grows, and the fruit is perfected, the receptacle loses its sugary matter and becomes dry. The hairy calyx which is attached to the fruit of most of these plants increases so as to be ready to waft it to a distance. In the dandelion, the leaves which surround the clusters or

Fig. 179.—Fruit of Geranium, showing the different parts of which it is composed curling upwards, so as to scatter the seed.

Fig. 180.—Naked winged seed of Common Fir.

Fig. 181.—Seed of Asclepias, with a cluster of hairs arising from the edges of the opening in the seed.

heads of flowers (fig. 91, p. 61) are turned downwards, the receptacle becomes convex and dry, the hairs spread out so as to form a parachute-like appendage to each fruit, and collectively to present the appearance of a ball. In this way the fruit is prepared for being dispersed by the winds.

The Embryo.—The young plant or embryo is contained in the perfect seed. It consists of three parts—the young root (radicle), the seed-leaves or seed-lobes (cotyledons), and the young stem (plumule). These parts are easily seen in the common pea after removing the skin,

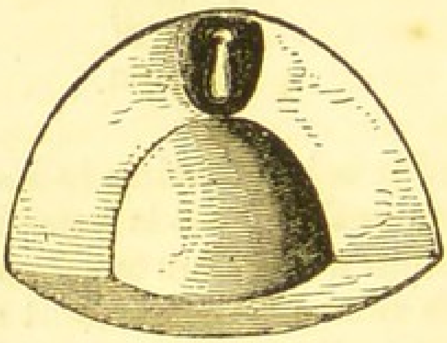


Fig. 182.

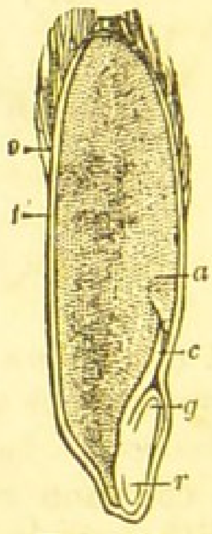


Fig. 183.

as shown in fig. 13, p. 16, where *r* is the radicle, *c c* the cotyledons, and *g* the plumule.

In flowering plants there are two kinds of embryos: one in which there is only a single cotyledon, and the other in which there are two. The embryo consists at

Fig. 182.—Section of part of the Coco-nut seed, showing the young plant in a cavity at one end, quite separate from the nourishing matter around.

Fig. 183.—Grain of Oats; *o t*, its coverings; *c g r*, young plant; *c*, being its seed-leaf; *g*, the young bud of the stem; and *r*, part of the axis whence the root proceeds; *a*, store of nourishment, called albumen.

first entirely of cells. In the case of flowering plants, it is contained in the seed, and along with it there is a store of nourishment for its future growth. This nutritive matter is in some cases incorporated with the young plant, as in the pea, the large fleshy lobes of which are part of the young plant (fig. 13, p. 16); in other cases it is separate from the young plant, as in the coco-nut and wheat. In fig. 182 there is a representation of part of the eatable portion of the coco-nut, with the small embryo plant lying in a cavity at the top. This cavity is in the flesh of the nut, immediately below the hole in the hard shell. The little plant weighs only a few grains, while the nourishing matter weighs many ounces. In palms generally the young plant occupies a small part of the seed, and the nourishment is abundant, and sometimes, as in the date and the ivory palm, very hard. In the grains of wheat, barley, and oats, the young plant is minute, while the starch and glutinous matter stored up along with it is large. Fig. 183 represents a grain of oats, *o t* being its covering, *c g r* the young plant, with its root, stem, and leaves, and *a* the mass of nourishment laid up for the use of the young plant, and not incorporated with it.

Sprouting of the Seed, or Germination—Seeds when ripe fall from the plant into the soil, or they are transported in various ways by means of winds and streams, or by the agency of man and animals, and are deposited in situations fitted for their growth. When the seed is placed in favourable circumstances, the little plant begins to sprout or germinate. In order that this process may take place, it is necessary that moisture, heat, and air should be present, and it is also important that the plant at first should be excluded from direct light. The supply of these requisites must be properly regulated, and in doing so the nature of the soil must be attended to. One of the most important operations for enabling grain to grow and give abundant produce is draining. Undrained soil, from having much moisture, is cold, is deficient in the supply of air, and prevents the constant renewal of food to the roots. Draining carries away superabundant moisture, allows a constant supply of fresh fluid nourishment to penetrate through the soil at the roots, permits the access of air and heat, and thus materially contributes to the health and vigour of the crops. The soil must therefore be prepared and fitted for the seed, otherwise, as far as regards useful and nutritious plants, the sowing will be unproductive.

When seeds are sown naturally, they have only a slight covering of soil, and if they happen to become deeply buried, the proper access of air is prevented, and their sprouting is retarded. In sowing seeds, we should imitate what occurs in nature. They should be placed at a moderate and equal depth. Seeds often lie long dormant, especially when placed too deep in the earth, and it is only when the soil is turned up and air admitted that they spring up. Many are the instances of seeds retaining vitality long, when buried in the ground, under certain conditions.

The various phenomena connected with the sprouting of the seed are well seen in the malting of barley. The grain is exposed to moisture, heat, air, and is kept in comparative darkness. It is placed in circumstances fitted for its sprouting. A marked change takes place in the contents of the grain. The starch, which is insoluble in water, and unfit for the nourishment of the plant, is converted into sugar, which is soluble, and easily taken up by the cells of the plant as food. The young roots are first protruded, and then the stem rises, surrounded by a leaf called a cotyledon, or seed-leaf. If the barley were allowed to grow, the whole of the sugar would be used by the plant. But man wishes to get the sugar, and he therefore stops the plant in its growth by drying it, and thus makes malt. The progress of growth in the oat is seen in fig. 184, which represents the embryo at one end of the grain, the curved dotted lines marking the dimensions of the grain. The letter *r* indicates the young roots passing through sheaths, *co*, and covered with little cellular hairs, ready to take up fluid nourishment; *c*, is the cotyledon—*i.e.*, the seed-lobe or seed-leaf; *g*, is the young stalk or stem rising upwards.

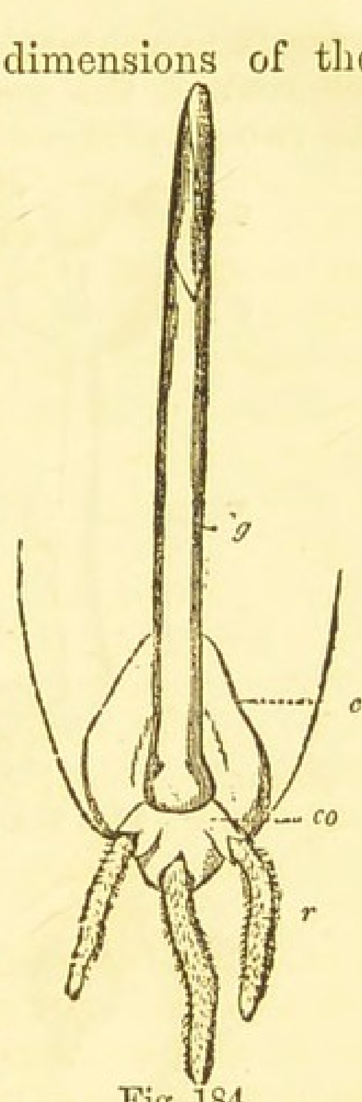


Fig. 184.

"Except a corn (grain) of wheat fall into the ground and die, it abideth alone; but if it die, it bringeth forth much fruit." We see an apt illustration here. The great bulk of the grain of wheat is composed of nutritious matter, separate from the little plant or embryo. This matter must all be changed and dissolved, in order that the plant may spring. Unless it dies, and undergoes solution, there can be no nourishment conveyed. Again, the sprouting of the grain is taken by St. Paul as an emblem of the resurrection. The bare or naked grain which is sown is not quickened except it die; and out of the corruption and dissolution which it undergoes, there springs up by a wondrous metamorphosis, the blade of wheat, or of some other grain.

In many plants the embryo, in place of having only one cotyledon, as in grasses and palms, has two. These cotyledons, during the sprouting of the plant, either rise above ground, and appear as temporary leaves of a peculiar form, as is seen in the lupin; or they remain below ground as fleshy lobes, and are gradually absorbed, as in the bean and pea (fig. 13, p. 16). Fig. 185 repre-

Fig. 184.—Germination or sprouting of the grain of Oats. *r*, Roots passing through sheaths, *co*; *c*, cotyledon; *g*, the first leaves of the plant. The plant is monocotyledonous, or has only one cotyledon.

sents the germination of the common haricot, where *r* is the root of the young plant, *t* is the stalk supporting the two cotyledons *c c*, and *g g* are the first proper leaves

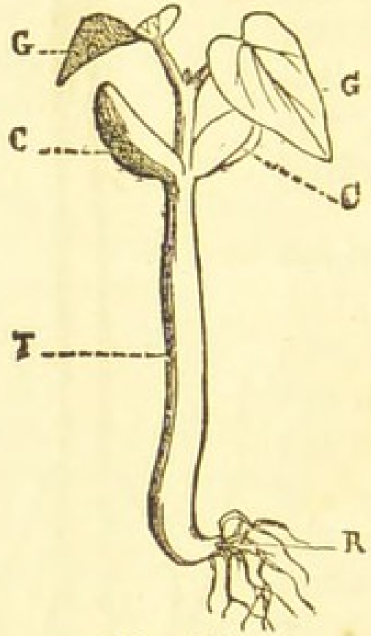


Fig. 185.

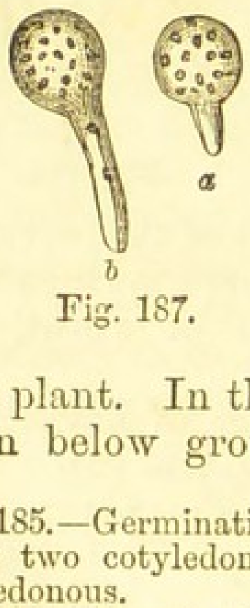


Fig. 187.

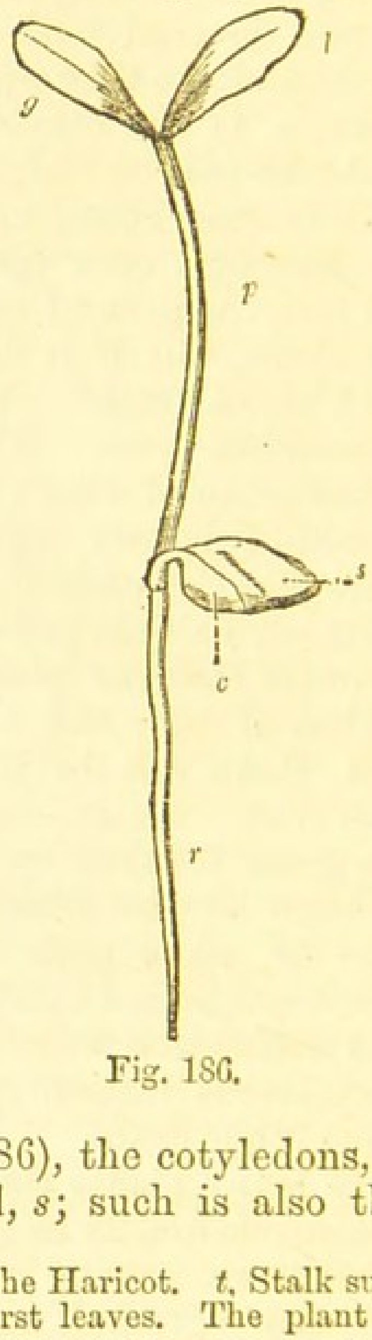


Fig. 186.

of the plant. In the orange (fig. 186), the cotyledons, *c*, remain below ground in the seed, *s*; such is also the

Fig. 185.—Germination or sprouting of the Haricot. *t*, Stalk supporting two cotyledons, *c c*; *g g*, the first leaves. The plant is dicotyledonous.

Fig. 186.—Germination or sprouting of the Orange. *c*, The two cotyledons enclosed in the seed, *s*, and remaining under ground; young root, *r*. The plant is dicotyledonous.

Fig. 187.—Germinating spores or germs of a species of Liverwort in different stages of growth. A small cellular protuberance first appears, *a*, which ultimately elongates, as seen at *b*. The plant is acotyledonous.

case in the bean and pea, in which the cotyledons form the great bulk of the seed. In plants which have no flowers, as ferns, mosses, sea-weeds, and fungi, the little germs are simple cells without any cotyledon, which send out cellular roots from various parts of their surface. In fig. 187 there is a representation of the germs of a flowerless plant, consisting of single cells, with tapering projections forming the roots. There is here no distinction of parts, as in the embryo or germ of flowering plants.

It will thus be seen that, according to the nature of the embryo or young plant, the whole vegetable kingdom can be divided into—1. Flowering plants having one cotyledon, called monocotyledonous plants (fig. 184); 2. Flowering plants having two cotyledons, called dicotyledonous plants (figs. 185 and 186); 3. Flowerless plants without cotyledons, called acotyledonous plants (fig. 187). Dicotyledonous plants have exogenous stems (figs. 31, 32, p. 23). Monocotyledonous plants have endogenous stems (figs. 35, 36, p. 27). While acotyledonous plants have acrogenous stems (fig. 38, p. 29).

QUESTIONS.

1. What is meant by the term fruit in botanical language?
2. Give an instance of a fruit formed by one carpel.
3. Give an instance of a fruit formed by several separate carpels.
4. Give an instance of a fruit formed by several carpels cohering together.
5. Describe the parts which form the fruit of a peach.
6. Describe the parts which form the fruit of a gooseberry, and explain in what respect it differs from a grape.
7. Describe the fruit of the hazel.
8. Describe the fruit of the oak.
9. What is the nature of a grain of wheat?
10. Describe the fruit of a strawberry.
11. What kind of fruit is the pine apple?
12. Describe the fruit of the Scotch fir.

13. Describe a mulberry, and point out the difference between it and a strawberry.
14. Describe the fruit of the fig-tree.
15. What is essential for a perfect fruit?
16. How is the seed scattered?
17. How do some fruits open to scatter the seed?
18. Describe a follicle, and explain how it differs from a legume. Give examples.
19. Describe a siliqua and silicula. Give examples.
20. Describe a capsule.
21. Describe the mode of opening in the fruit of the henbane, the rose-campion, the violet, and the poppy.
22. What is an achene? Give an example.
23. Describe a nut. Give an example.
24. Describe a drupe. Give an example.
25. In what respect does the pulp of the berry differ from the flesh of the peach?
26. Describe the parts of an apple.
27. What organ contains the seed?
28. What is meant by naked seeds?
29. What is the essential part of a seed?
30. What is meant by an exalbuminous seed? Give an example.
31. What is meant by an albuminous seed? Give an example.
32. How are seeds scattered?
33. What kind of seeds are seen in the common fir?
34. What is the use of hairs attached to seeds? Give an example.
35. Describe the nature of the fruit and seed in the dandelion.
36. What is the thistle-down?
37. Describe the mode in which the fruit of the dandelion is scattered.
38. What is the part of the artichoke which bears the fruit?
39. What is the organ called the embryo?
40. What are the parts of the embryo in flowering plants?
41. Describe the embryo of the common pea.
42. Mention two kinds of embryos in flowering plants. Give an example of each.
43. Describe the position and the appearance of the embryo of the coco-nut.
44. In what part of the grain of oats does the embryo plant lie?
45. What is meant by germination?
46. What are the requisites for germination?
47. Describe the various stages observed in the malting of barley as illustrating germination.

48. What changes take place in the cotyledons?
49. Describe the germination of a monocotyledon.
50. Describe the germination of a dicotyledon.
51. Describe the germination of an acotyledon.
52. What is the nature of the stem in dicotyledonous plants?
53. What is the nature of the stem in monocotyledonous plants?
54. What is the nature of the stem in acotyledonous plants?

CHAPTER III.

THE ORGANS OF NUTRITION AND REPRODUCTION IN FLOWERLESS PLANTS.

We have already alluded to the nutritive organs of these plants in so far as regards their acrogenous stems (pp. 28–30) and their acotyledonous embryo (p. 107). Some of them are composed entirely of cells, such as

Fig. 188.

b Fig. 189. *a*

seaweeds, mushrooms, toadstools, moulds, and lichens; others have cells and vessels, more especially ladder-like vessels (fig. 7, p. 12). Some have leaves, as mosses; others are leafless, as mushrooms. The leaves

Fig. 188.—Portion of the frond of the male Shield-fern, showing two clusters of spore-cases, *s s*, covered with a kidney-shaped involucre or indusium attached by the cleft.

Fig. 189.—Lady-fern. *a*, Entire plant much reduced in size, with root and frond bearing fructification; *b*, portion of the frond or leaf magnified to show the fructification.

of some of these plants bear organs of fructification, as is the case with ferns, and they receive the name of fronds (fig. 189).

In flowerless plants there are no distinct floral organs, such as calyx, corolla, stamens, and pistil. Certain cellular bodies, however, are found in them, by the union of which reproductive germs equivalent to seeds or to embryo plants are formed.

Fig. 190.

Fig. 191.

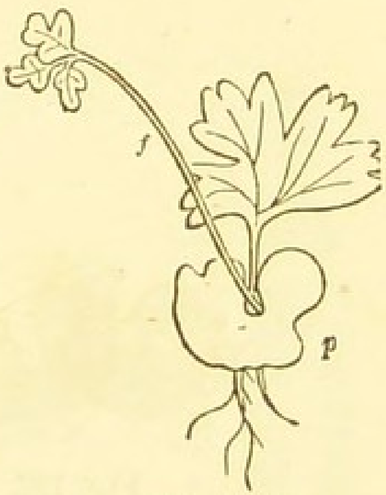


Fig. 192.

In **Ferns** there occur little clusters of minute sacs containing what appears to be brown dust, but which in reality consists of microscopic cellules or germs called

Fig. 190.—Frond of the Royal-fern, bearing pinnæ, *f*. At the extremity of the frond the pinnæ are altered, so as to bear fructification, consisting of sporangia arranged in a spike-like manner, *s*, on a number of short axes.

Fig. 191.—Mature sporangium of the Male-fern. It is supported on a stalk, *p*, some of the cells of which form an elastic ring or annulus, *a*, round the spore-case. The spore-case opens at the side to discharge the spores, *s*.

Fig. 192.—Young plant of a Fern, showing the commencement of the frond, *f*, arising from a fertilized cell; the early frond (prothallus), *p*, being still attached.

spores. These, when scattered in favourable situations, have the power of germinating or sprouting, and thus give rise to new plants. The clusters of sacs or spore-cases are rounded, or linear, or crescent-shaped, and they appear either on the back of the fronds or leaves of ferns, as in the common male shield-fern (fig. 188), and in the lady-fern (fig. 189), or in spike-like processes, as in the royal-fern (fig. 190). The little cases or sacs are frequently surrounded by elastic rings (fig. 191), which open them, and thus allow the spores to be scattered. When the spore germinates it sends out a cellular expansion, as seen in fig. 192 *p*, and from this arises the proper frond. On this frond-like process (prothallus), *p*,

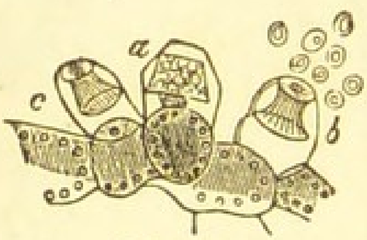


Fig. 193.

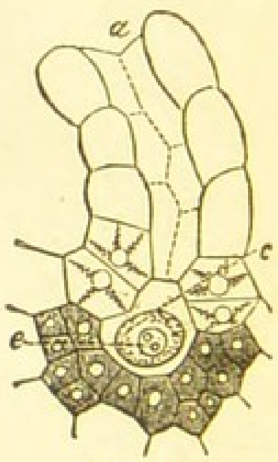


Fig. 194.

are developed certain very minute cellular bodies, which are supposed to be equivalent to the stamens and pistils of the flowering plants. In figs. 193 and 194 these organs are seen; the first showing cellular bodies, *a*, containing moving filaments, *b*, and representing stamens, the second showing a cellular body equivalent to the pistil, with an embryonic cell, *e*.

Fig. 193.—Antheridia (*i.e.*, anther-like bodies) from the prothallus of the common brake. *a*, An unopened antheridium; *b*, antheridium bursting at the apex, and discharging free cellules, each containing a moving filament; *c*, antheridium after the discharge of the cellules.

Fig. 194.—Archegonium (*i.e.*, pistil-like body) of the forked spleen-wort. *a*, Canal leading to the large cell, *c*, at the base of the archegonium; *e*, embryonic cell, whence the proper frond proceed after fertilization.

In **Mosses** the reproductive organs are only seen in the young state of the plant. When the moss is fully developed the germs or spores are contained in urn-like cases, *u* (figs. 195, 196, and 197), covered by a sort of veil, *c*, which falls off and displays a lid, *o*. When this lid is separated, as seen in fig. 197, *o*, there is displayed a series of processes, *p*, called teeth, which are hygrometric, rising up when dry and folding down when

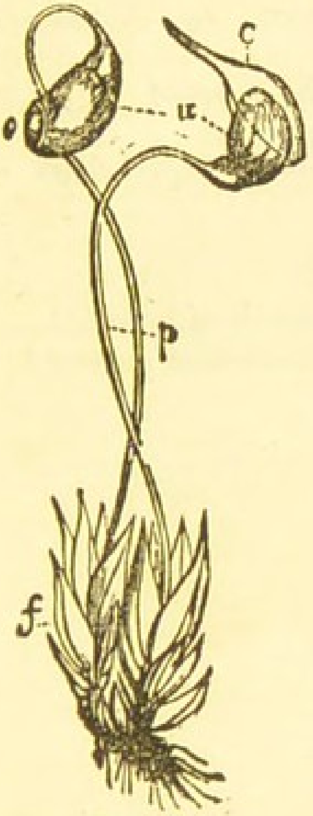


Fig. 195.

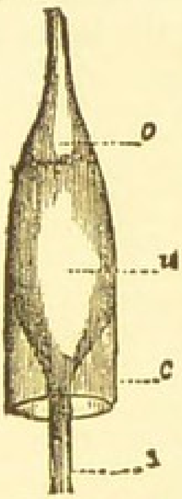


Fig. 196.

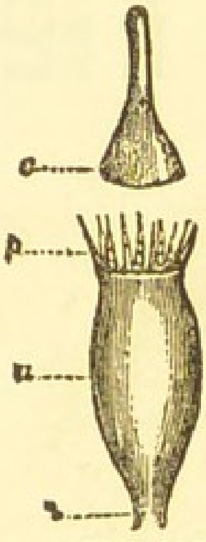


Fig. 197.

moist. These teeth are either four in number or some multiple of four, as 8, 16, 64, 256, etc. They surround the top of the case which contains the spores in its interior.

Fig. 195.—A Moss slightly magnified. Leaves, *f*, connected with the stalk, *p*; *u*, urn-like spore-case, with its veil, *c*, and lid, *o*.

Fig. 196.—Urn-like case of a Moss magnified; *s* stalk, *c* veil, under which, and seen through it, are *u*, the urn-like spore-case, and *o*, the lid.

Fig. 197.—Urn-like case, *u*, of the same Moss, with the veil removed, and the lid, *o*, taken off to show the row of teeth, *p*; *s*, the stalk bearing the case.

QUESTIONS.

1. What is meant by flowerless plants, and what other names are given to them?
2. Describe the ordinary fructification of ferns.
3. What is meant by spores?
4. What function do spores perform?
5. In what organ are spores contained?
6. In the common male shield-fern where are spore-cases found?
7. How do spore-eases burst and scatter the spores?
8. How do spores germinate?
9. What kind of organs are found in ferns equivalent to stamens and pistils?
10. Describe the fructification of a moss.
11. What is meant by the teeth of mosses?
12. What numbers have been noted in the teeth of mosses?
13. What is meant by the lid in the fructification of mosses?

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