for the purposes of nutrition. Starch, composed chemically of carbon and the elements of water (hydrogen and oxygen), its formula being $C_6H_{10}O_5$, occurs in the form of fine grains, more or less oval or rounded, which vary in diameter from the $\frac{1}{4000}$th to the $\frac{1}{240}$th of an inch. Each grain contains starch in two forms,—one, receiving the name *granulose*, is easily soluble, and gives a deep blue colour on the addition of iodine; the other form, *starch cellulose*, is less soluble, and gives a yellow or brown colour with iodine; but the former is most abundant in the grain. The individual grains either lie distinct from each other in the cells, as in the Potato, Wheat, and Pea, or they are aggregated so as to form compound grains, as in West Indian Arrowroot, obtained from Maranta arundinacea, and Portland Sago, procured from Arum maculatum. Grains of starch present a very characteristic concentrically striated appearance (fig. 27). This is the result of their mode of formation. The point round which the striæ are arranged is called the *hilum*. Starch is accumulated in the internal, and often in the subterranean parts of plants. It occurs abundantly in fleshy roots, and in stems, as well as in seeds and fruits, and is easily separated by washing. The ordinary cultivated grains yield starch in considerable quantity; so also do the Potato, Arrowroot, and Cassava plants, the Sago-palms, and Banana fruit. That procured from the Arrowroot plant consists of dull white grains, while that from the Potato, and from various species of Canna supplying tous-les-mois, is in the form of large shining particles. Sago and Tapioca are granulated forms of starch, the former being procured from the cells of various species of Sagus and Metroxylon, the latter from the Cassava plant. The existence of starch in the bark and young wood of trees, such as the Birch and Pine, renders them useful as articles of food in cold countries. Lichenin is a form of starch existing in the cells of Iceland moss and other lichens; while inulin, which occurs dissolved in the cell-sap, is the starchy matter supplied by the roots of the Dahlia, Dandelion, and Elecampane. By the action of prolonged heat, as well as by the addition of dilute sulphuric acid, or of malt, starch is converted into a soluble gummy substance called dextrin. The same change occurs during germination or the sprouting of the seed. Oily matters occur as drops in the interior of cells, usually associated with starchy substances or with albuminoids. These latter exist as small granules or large rounded masses with definite chemical and optical properties, and are termed *aleurone grains*. They are frequently associated with a crystalline arrangement of portions of the protoplasm of the cell known as *crystalloids*. Sugar occurs abundantly in the sap of plants. When pure and in a solid state this substance is crystalline and soluble in water; but it also occurs in an uncrystallized form. There are two marked varieties of it. Cane-sugar, $C_{12}H_{22}O_{11}$, procured from the Sugar-cane, Sugar-maple, Beet, Carrot, &c.; and grape-sugar, occurring in numerous fruits, as Grapes, Gooseberries, Currants, Peaches, and Apricots. The formula for grape-sugar is $C_6H_{12}O_6$. During the sprouting of the seed, starch is converted into grape-sugar, and a similar change is induced by the action of malt, or of any ferment. A sweet substance (not a true sugar), called Mannite, is procured from the Manna-ash (Ornus europæa) as well as from various sea-weeds, from species of Eucalyptus, and from the Dandelion. Gum or mucilage is another substance found in vegetable tissues. When pure it is clear, soluble in water and also in dilute acids, but not soluble in alcohol or ether. It is one of the forms through which vegetable matter passes in being applied to the purposes of plant life. It exists largely in the vegetable juices. From the bark of many trees it is procured in the form of an exudation. Two well-marked kinds of gum are met with,—arabin, soluble in cold water, constituting the chief ingredient of gum-arabic, procured from various species of Acacia; and cerasin, insoluble in cold water, but readily soluble in boiling water, constituting the gummy secretion obtained from the Cherry and Plum. A substance called bassorin, or vegetable jelly, is found in Tragacanth, the roots of some Orchids, as well as in Carrageen (Chondrus crispus), and other sea-weeds. It is allied to gum, but differs in swelling up and becoming gelatinous when mixed with water. Another gum-like substance called pectin exists in the juice of the Apple, Pear, and other pulpy fruits. It is changed by the action of alkalies into pectic acid, which is found in many fruits and such succulent roots as Carrot, Turnip, Beet, &c. Oils, Fats, and Resins occur in cells of plants, or in special canals or glands as products of assimilation. The oils are either fixed or volatile,—the former being divided into drying, fatty, and solid, while the latter are distinguished according as they consist of carbon and hydrogen alone, or of these elements combined with oxygen or with sulphur. Resinous matter occurs in the form either of fluid balsams, or of the various kinds of solid resin and pitch. In the rind of the Orange and Lemon glands of oil occur (fig. 28). Turpentine canals are met with in the wood of Pines; and Vittæ, or oil-canals, in the fruit of Umbelliferous plants, such as the Coriander. In the fleshy covering of the fruit of the Olive there are numerous oil-cells. The fruit of the Guinea-palm yields a solid oil, called palm-oil. The dotted appearance of the leaves of the Orange, Myrtle, Eucalyptus, and St John's Wort, depends on the presence of numerous cells or cavities containing essential oil.

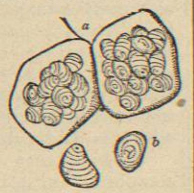

Fig. 27.

a, Starch cells of the Pea, showing grains of starch in the interior. *b*, Separate starch grains, with striæ and hilum.

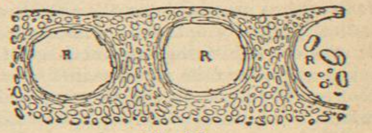

Fig. 28.

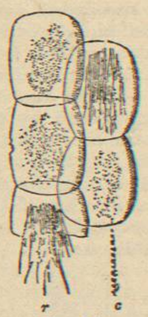

Fig. 29.

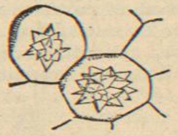
Fig. 30.

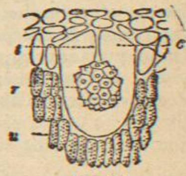

Fig. 31.

FIG. 28.—Vertical section of part of the rind of the Orange, showing glands containing volatile oil, R, R, R, surrounded by cells.
FIG. 29.—Cells of Rumex *c*, containing raphides *r*. The cells are called Raphidian. The raphides are acicular or needle-like crystals forming bundles.
FIG. 30.—Cells of Beet-root, containing conglomerate crystals.
FIG. 31.—Cellular tissue from leaf of *Urostigma (Ficus) elasticum*. *c*, a large cell *r*, cystolith, an agglomeration of crystals situated at the extremity of an inward prolongation of the cell-wall, *t*; *u*, cells filled with chlorophyll granules.

As allied to these secretions, we may notice caoutchouc, which is found in the milky juice of plants, especially those belonging to the Fig, Spurge, and Dogbane orders. The trees most prolific in this substance are Siphonia elastica, Urceola élastica, and Urostigma elasticum. Gutta-percha is the concrete milky juice of the Taban plant (Isonandra Gutta). Wax is also found in the tissues of plants, and it frequently occurs as a secretion on the stems, as in the Wax Palm, and on the surface of fruits, as in the bloom or glaucous secretion of the Plum and the Candleberry Myrtle. Crystals of lime salts occur in the interior of cells, and also in the cell-walls of plants. They

consist of lime in combination with carbonic or oxalic acids, and are in many plants very abundant. In Monocotyledons they usually assume the form of needle-like crystals, and are termed *raphides*; they consist of oxalate of lime (fig. 29). They are remarkably well seen in the Banana. The Squill bulb and the bulb of the Onion exhibit raphidian cells, which are easily separated during the decay of the plants. The crystals are also arranged in a conglomerate form (fig. 30), as may be seen in the root of Turkey Rhubarb, to which they impart grittiness; and in Old-Man-Cactus they constitute 60 to 80 per cent. of the dried tissue. In a single cell of the Poke (Phytolacca decandra) twenty to thirty crystals may be seen. In the epidermal cells of species of Ficus, and other allied plants, prolongations inward of the cell-wall occur, at the extremity of which small crystals of carbonate of lime are deposited (fig. 31); to these the name *cystoliths* has been applied. Siliceous matter occurs in the walls of cells, as in Grasses and Horsetails, and especially in Diatomaceæ.

2. *Integumentary System.*

A more or less marked division of the tissues into an outer layer bounding an inner mass is visible in all plants. Amongst the lower cellular plants this division is not very distinct; the circumferential cells are perhaps only a little smaller and more compacted than those near the centre. The higher cellular plants, however, exhibit great diversity. In them the cells of the circumference may be arranged in layers so as to constitute a true epidermis, the component cells having a definite relation to one another and to the exterior in the respective families. In all vascular plants an epidermis is found. In many cases, however, it is difficult to recognize it, as in the stems of submerged plants and in most roots. It usually consists of a single thin layer of cells closely compacted, and leaving no interspaces except at definite points (*stomata*), where openings lead into intercellular cavities. The cells composing this layer have their outer wall much thickened, the inner wall remaining thin, and they contain no starch or granular matter, and usually are colourless. In many aquatic plants, however, and in Ferns, chlorophyll is present. The apparent colour of the epidermis depends on that of the parenchymatous cells below, from which it can be separated as a colourless layer. Sometimes the cell-sap of the epidermal cells has a red tinge. The outer lamella of the outermost cell-wall of the epidermal cells usually becomes cuticular or corky, and thus is formed an external separable layer or *cuticle* upon the surface of the *epidermis proper*. This layer has different chemical properties from the epidermis, being insoluble in sulphuric acid. Upon this cuticle wax is frequently deposited in various forms, serving as a protective from moisture; of this nature is the bloom of the Plum. The cuticle in aquatic plants is very thin; in aerial plants it is much thicker. The single layer of cells forming the epidermis is not unfrequently strengthened by the addition to the inside of other layers of cells. In the leaves of Begonia, Ficus, and the outer covering (*velamen*) of the aerial roots of Orchids, this constitutes the *hypoderma*, the cells being of various forms. It is well seen also in vascular Cryptogams, many Bromeliaceæ, Ilex, &c. On those parts of the plant which live long and have vigorous growth in thickness the efficacy of the epidermis as a protective covering is increased by a large formation of cork. Each epidermal cell divides into an outer and an inner cell. The former at once becomes a cork cell, losing all its succulent matter; the latter remains capable of division. When a layer of these merismatic cells occurs we have a *cork cambium* or *phellogen*. If several layers of cork cells be formed a *cork tissue* or *periderm* is the result, which supersedes the epidermis, and which from variations in the several layers may be stratified. Not unfrequently the phellogen cells, in addition to giving off cork cells outwardly, give rise on the inner face to cells containing chlorophyll; and if a layer of such is formed it is termed a *phelloderm*. In such cases the phellogen lies between the phelloderm and the periderm. If phellogen lamellæ are formed deeper in the tissues of the plant, the internal layers of tissue become dry and constitute the bark. Periderm is thus replaced by bark. One important character of the epidermis is the presence of *stomata* or breathing-pores. These exist abundantly upon the stems and leaves of plants; they also occur on the parts of the flowers; but they are absent from all root structures, though present on underground axial structures. Each consists of a central pore bounded by two or more cells (guard-cells), which contain chlorophyll, starch, and matters distinct from the surrounding epidermal cells. The pore has various forms, and opens into an intercellular cavity (fig. 32). It may be round (Primrose), oval (Liliaceæ), quadrangular (Yucca). The arrangement of the stomata on the plant varies much. They may be in lines as in Equisetum, or they may be scattered irregularly as in Balsam (fig. 33), or in definite clusters as in Crassula and Saxifraga (fig. 34). In Equisetum the stomata, which are about $\frac{1}{250}$th of an inch in their greatest diameter, consist of four guard-cells; two

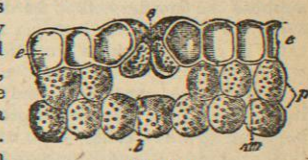

Fig. 32.

Vertical section of epidermis, from the lower surface of the leaf of Madder, showing the intimate union of the epidermal cells *e*, *e*, the loose subjacent parenchyma *p*, with intercellular canals *m*, and lacuna *l*; *s*, stoma.

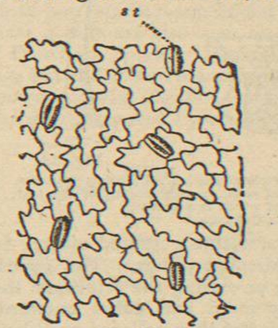

Fig. 33.

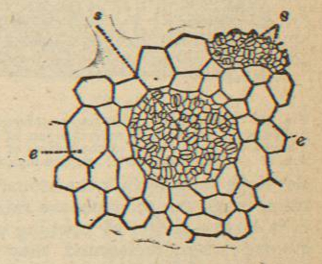

Fig. 34.

FIG. 33.—Epidermis of the garden Balsam (*Balsamina hortensis*), showing stomata *st*, of an elliptical form.
FIG. 34.—Epidermis of leaf of *Saxifraga sarmentosa*, showing clusters of stomata *s*, *s*, surrounded by large epidermal cells *e*, *e*. The cells among which the stomata occur are very small.

of which are arched and thick at their outer convex margin,

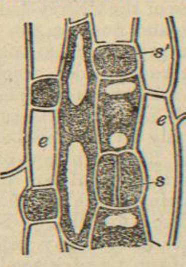

Fig. 35.

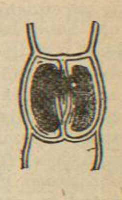
Fig. 36.

FIG. 35.—Formation of stomata from leaf of Hyacinth, seen from the surface. *e*, epidermis cells; *s'*, mother-cell of stomatic guard-cells; *s*, bipartition of mother-cell into two guard-cells. (*Sachs.*)
FIG. 36.—Splitting of partition wall between guard-cells to form the stoma (*Sachs.*)

becoming thin at their inner concave edge, where two other smaller cells overlie them, with their upper walls raised as ridges running at right angles to the stoma. This gives the stoma a fringed appearance, hence called pectinate. The mode of formation of a stoma is an interesting process, resulting from the division of a single epidermal cell. Preparatory to the complete formation of the mother-cell of the stomatic guard-cells, divisions may take place in the epidermal cells by which numerous or few cells are formed surrounding this mother-cell. In the mother-cell a partition wall is developed (fig. 35, *s*). A thickening of the partition wall occurs, and eventually in the central portion a fissure makes its appearance, which gradually increases in size (fig. 36). It does not, however, pass throughout the whole extent of the partition wall. An opening or stoma is thus formed, bounded on each side by a single guard-cell, leading into an intercellular space in the parenchyma beneath. If we suppose the mother-cell to be divided by numerous vertical septa we should have a stoma surrounded by many guard-cells, as occurs in some Hepaticæ; and in this family, after the formation of the fissure a series of horizontal septa appear in the guard-cell, and thus the stomatic opening becomes a canal. In Ceratopteris thalictroides the stoma is bounded by three cells,—two of which, in their open condition, are crescentic and concave inwardly, while the third surrounds them, except for a small space at the end of the long axis of the stoma, and has on this account been called *peristomatic*. In Urostigma elasticum four cells form the stoma. Subsequent changes in the surrounding epidermal cells may cause alterations in their relations to the stomata. Thus, in the Oleander (fig. 37) the epidermis

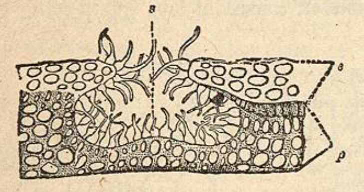

Fig. 37.

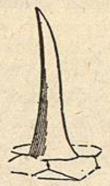
Fig. 38.

FIG. 37.—Vertical section of lower epidermis of the leaf of *Nerium Oleander*. *e*, epidermis composed of several layers of cells, *p*, parenchyma of the leaf; *s*, cavity filled with hairs, at the bottom of which is a stoma.
FIG. 38.—Unicellular hair of the Common Cabbage.

develops so as to sink the stoma within a ciliated cavity; in other cases the stomata are raised on pillars. The guard-cells have a power of opening or closing the orifice of the stoma; when moistened they swell and curve outward, and leave a free opening; when dry they collapse and their edges are straightened, and they close the orifice. Stomata are most abundant on the under surface of leaves. Their number varies from 200 to 160,000 or more in a square inch of surface. In the leaves of the White Lily there are 60,000 in a square inch on the under surface, and about 3000 on the upper; on the leaves of the Cherry-Laurel there are 90,000 on the lower surface, and none on the upper.

Upon the epidermis and as outgrowths from it are found certain appendages. These are hairs, scales, prickles, &c., and all have been embraced under the general name *trichome*. Hairs (*pili* or *villi*) are productions each of an epidermal cell, having typically an elongated or conical form, and covered by the cuticle. They are erect or oblique, or they lie parallel to the surface, and are appressed. Sometimes they are formed of a single cell, which is simple and undivided (fig. 38), or forked (fig. 39), or branched; at other times they are composed of many cells, either placed end to end, as in moniliform or necklace-like hairs (fig. 40), or united together laterally, and gradually forming a cone, as in compound or branched hairs. When the branches of a hair proceed from a common centre, it is stellate or radiated (fig. 41, *a*, *b*), as in hairs of the Mallow tribe, in those of Deutzia scabra, and those on the stem of the Rice-paper plant (Fatsia papyrifera). When stellate hairs are flattened out, so as to form a sort of membranous expansion (fig. 44), a *scale* or *scurf* is produced. In Bromeliaceæ the scurfiness of the leaves is a marked character. To such expansions of the epidermis the name *lepis* is applied, and the surface is said to be *lepidote*. These scales have sometimes a beautiful silvery appearance, as in Elæagnus and Sea-buckthorn (fig. 44). Surrounding the base of the leaves of Ferns a brown chaffy substance occurs, consisting of elongated cells, to which the name of *ramentaceous hairs*, or *ramenta*, has been given. In Palms also a similar substance but of a fibrous texture occurs, called *reticulum* or *mattulla*. *Setæ* are bristles, or stiff hairs, and the surfaces on which they occur are said to be *setose* or *setaceous*. Some hairs, as those of Drosera


Fig. 39.

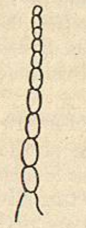
Fig. 40.

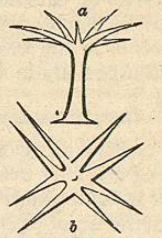

Fig. 41.


Fig. 42.

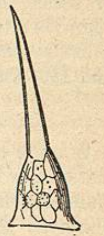
Fig. 43.

FIG 39.—Forked or bifurcated unicellular hair of Draba or Whitlow-grass.
FIG 40.—Moniliform or necklace-like hair of Virginian Spiderwort (*Tradescantia virginica*).
FIG 41.—Unicellular hair *a*, of Alyssum, dividing into rays at the apex. The stellate or star-like arrangement is represented in the lower figure *b*.
FIG 42.—Glandular, multicellular or many-celled hair of Frogsmouth (*Antirrhinum majus*). It is a partitioned capitate hair.
FIG. 43.—Sting (stimulus) of Nettle (*Urtica dioica*); its base is formed by numerous cells containing irritating fluid; from these arises a simple unicellular conical hair, which serves as a duct for conveying the fluid.

(Sundew), have one or more spiral fibres in their interior. When the cells of hairs are hardened by thickening of the cell-wall, as in the Rose and Bramble, they are called Prickles (*aculei*). By some these are not considered as hairs, but are termed *emergencies*, inasmuch as they arise from a collection of cells, not from one epidermal cell. Various names have been given to the different forms of hairs. They are *clavate*, or *club-shaped*, gradually expanding from the base to their apex; *capitate* (fig. 42), having a distinct rounded head; *rough* or *scabrous*, with slight projections on their surface; *hooked* or *uncinate*, with a hook at their apex pointing downwards and to one side; *barbed* or *glochidiate*, with two or more hooks around the apex; *shield-like* or *peltate*, when attached by their middle, and projecting horizontally on either side, as in Malpighia urens (fig. 45), and in many Cruciferous plants; *cilia*, when surrounding the margin of leaves. On the pod of the Cowitch (Mucuna pruriens) hairs are produced with projections on their surface, which cause irritation of the skin. In Venus's Fly-trap (Dionæa muscipula) stiff hairs exist on the blades of the leaf (fig. 46), which, when touched, induce their closure.

Hairs occur on various parts of plants,—on the stem, leaves, flowers, seed-vessels, and seeds, and even in the interior of vessels. In the interior of the spathe of some Palms numerous ovate cells, analogous with hairs, occur in clusters, and can, when the spathe is dried, be shaken out in the form of powder. Cotton consists of the hairs surrounding the seeds of Gossypium herbaceum and other species of the genus. These when fresh are elongated tubular cells; when dried their walls collapse and they appear twisted. Hairs are occasionally developed to a great extent on plants exposed to elevated temperatures, as well as on those growing at high altitudes. When they occur on the organs of reproduction they are connected with fertilization, as the hairs on the style of Goldfussia, and the retractile hairs on the style of Campanula.

Different organs of plants are transformed into hairs,—as may be seen in the flowering stalks of the Wig-tree (Rhus Cotinus), and in the calyx of Compositæ.

Names are given to the surfaces of plants according to the presence or absence of hairs, as well as the nature of the hairs which cover them. The following are the more important terms;—*Glabrous*, smooth, having no hairs; *hairy* or *pilose*, furnished with hairs; *pubescent*, covered with soft, short, downy hairs; *villous*, having long, weak, often oblique hairs; *sericeous*, covered with long, closely appressed hairs, having a silky lustre; *hispid*, covered with long harsh or stiff hairs not appressed, *hirsute*, having long tolerably distinct hairs, not harsh nor appressed; *velvety* or *velutinous*, with a dense covering of short down, like velvet; *tomentose*, covered with crisp, rather rigid, entangled hairs like cotton, which form a sort of felt (*tomentum*); *woolly*, with long curled and matted hairs like wool; *bearded* or *stupose*, when hairs occur in small tufts. The hairs which are most frequently met with in plants are called *lymphatic*, from their not being connected with any peculiar secretion. Those, on the other hand, which have secreting cells at their base (fig. 43) or apex, are denominated *glandular*, and are not to be distinguished from glands. On young roots cellular projections occur, which may be called *radical* hairs. Young leaves and buds are frequently covered with protecting hairs. On the parts of the flower, as in the Iris, coloured hairs occur which have been called *corolline*.

In connection with the epidermal appendages we may notice glands, although they may occur in any tissue. A gland consists of a single cell or a collection of cells secreting substances different from those contained in the surrounding cells. In the former case the gland is simple, in the latter it is compound. In compound glands it frequently happens that the walls of the inner cells are absorbed, and thus the gland has only a single cavity, as in the glands of the Orange rind (fig. 28); these are termed *vesicular*. The secretion of the glands may be stored in their interior, as in Orange rind, and in the leaves of Laurus Camphora, or it may be exuded as in Lychnis viscaria, and in the nectaries of Fritillaria imperialis (fig. 50). Hairs serve as ducts through which the secretion of glands is discharged. Such hairs are seen in the Nettle (fig. 43), in Loasa or Chili Nettle, and in Malpighia (fig. 45), and are

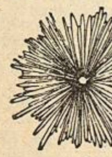
Fig. 44

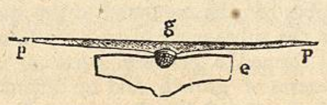

Fig. 45.

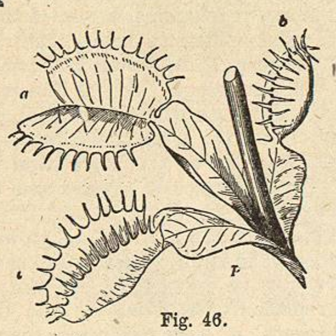

Fig. 46.

FIG. 44.—Radiating hair or scale from Elæagnus (*Oleaster*).
FIG. 45.—Peltate hair *pp* of *Malpighia urens* rising from *e*, epidermis, *g*, gland.
FIG. 46.—Irritable leaves of Venus's Fly-trap (*Dionæa*)

commonly called stings (*stimuli*). In the Nettle they are formed of a single conical cell, dilated at its base, and closed at first at the apex by a small globular disk placed obliquely. This disk breaks off on the slightest touch, when the sharp extremity of the hair enters the skin, and pours into the wound the irritating fluid which has been pressed out from the elastic epidermal cells at the base. When a nettle is grasped with violence, the sting is crushed, and hence no injury is done to the skin. The glandular enlarged apex of hairs sometimes exudes a viscid secretion, as in the Chinese Primrose and in the Sundew. The hairs of the latter plant, by this secretion, detain insects which happen to alight on them. The hairs gradually close on the insects, electrical phenomena taking place during the movement, and then the secretion from the glands becoming acid, an action takes place upon the organic matter analogous to that of the pepsin of the gastric juice, by which it is rendered soluble, and is eventually absorbed by the plant. A similar property is possessed by the secretion from the glands upon the surface of the leaf of Venus's Fly-trap (Dionæa muscipula, fig. 46). The acid in both instances belongs to the formic acid series. Glands may be either internal or external, and they may be situated at the extremity of a hair (when they are *stalked*), or they may be immersed in the substance of the plant (*sessile*). In the Dittany (Dictamnus albus, fig. 47) a form of gland is seen intermediate between the sessile and stalked form. The glands in this plant secrete a green oily matter, so also do the stalked glands in the Rose. In the Ice-plant the glands appear as elevations of the epidermis, containing a transparent fluid like ice, which is said to have an alkaline reaction; in the Chick-pea similar superficial cells contain an acid fluid. Clear glands are also seen on the under surface of the leaf of Passiflora lunata. Resinous glands are seen in the Hop (fig. 48) and Hemp plants. At the base of the petals of the Crown-imperial (fig. 50), cavities occur containing a honey-like fluid, secreted by what are called *nectariferous* glands.

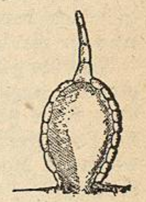
Fig. 47.
Gland of Dittany cut vertically.

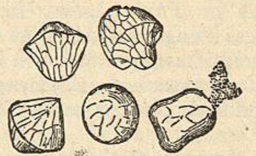
Fig. 48.


Fig. 49.

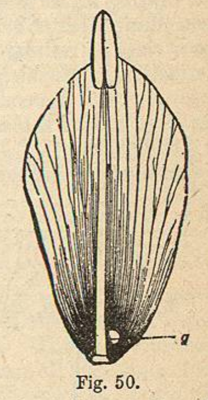

Fig. 50.

FIG. 48.—Superficial glands of the Hop, containing a resinous secretion called Lupulin.
FIG. 49.—Cluster of ovate-oblong glands from the base of the stipule of the Ipecacuan plant (*Cephaelis Ipecacuanha*).
FIG. 50.—One of the petals of *Fritillaria imperialis*, Crown Imperial, showing a pit or depression *g* at the base containing a honey-like secretion. This gland is sometimes called a nectary.

Cavities containing saccharine matter, surrounded by small thin-walled cells, are met with in the leaves of Acacia longifolia, also in Viburnum Tinus, and Clerodendron fragrans. The cavities communicate with the surface of the leaves by means of canals. Peculiar sessile glands secreting a gummy substance are found at the inner side of the base of the petioles of Cinchona and Ipecacuan plants (fig. 49). On the buds of various trees peculiar glandular hairs termed *colleters* exist, secreting a gummy mucilaginous matter, the *blastocolla*, which covers the bud. These, however, disappear on the bursting of the bud. They seem to have a protective function. The secretions of glands are very various, oily, waxy, resinous, gummy, saccharine, acid, &c.

ORGANS OF PLANTS.

Having now considered the elementary structures and tissues found in the Vegetable Kingdom, we proceed to view them in combination to form the plant. The simplest plant is found amongst Algæ, where, as in the Red-snow plant (Protococcus nivalis, fig. 51) the whole organism consists of a single isolated cell. Other Algæ and all Fungi and Musci are composed of a number of cells united in various ways; whilst in Ferns and their allies and all flowering plants vessels are formed in addition to the cells. The plants in which the tissues are entirely cellular are termed *cellular* plants; those in which vessels are also found are *vascular* plants.

Fig. 51.

Cells of the Red-snow plant (*Protococcus nivalis*), in different stages of growth and development. *a*, cell in the young state; *b*, cell fully formed, with cellules in its interior ready to be discharged, and to form independent plants; *c*, cell after its contents have been discharged.

That the portions of a plant may be properly maintained two functions have to be performed, namely, *nutrition*, on the proper performance of which the life of the individual plant depends, and *reproduction*, by which the perpetuation of the type is provided for. In such a simple form as the Red-snow plant (fig. 51) those functions are performed by the single cell. In the plants composed of numerous cells a differentiation takes place by which special cells are set apart for particular functions, and thus certain organs are formed in the plant. In the higher plants those organs become more complicated from the introduction of the vascular element.

The nutritive organs of plants are generally known as the *root*, the *stem*, and the *leaves*. In all vascular plants and the higher cellular plants an axis or stem having roots and bearing leaves is distinguishable, and such plants have been designated *Cormophytes* or *Phyllophytes*. In the lower class of cellular plants, as Fungi and Algæ, no such distinction is possible, and there is merely a flattened leafy expansion with dependent filiform processes; this structure has been termed a *thallus*, and such plants are *Thallogens* or *Thallophytes*.

Amongst the higher plants the reproductive organs are,

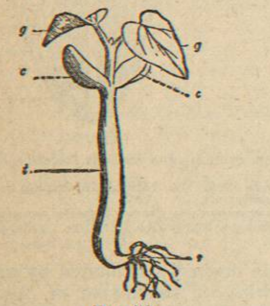

Fig. 52.

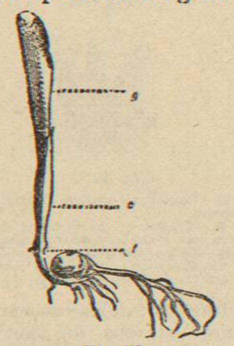

Fig. 53.

FIG. 52.—Haricot or French Bean, a Dicotyledonous plant, germinating. *r*, the roots coming off from the radicular end of the axis; *t*, the hypocotyledonary portion of the axis bearing the cotyledons *c*, *c*; the young stem and leaves, *g*, *g*.
FIG. 53.—Grain of Maize or Indian Corn, a Monocotyledonous plant, germinating. Roots come off from lower end of *t*, the axis; *c*. the single cotyledon; *g*, the young stalk and leaves.

in ordinary language, comprehended under the term flower; and, as they are conspicuous, such plants have been denominated *Flowering*, *Phanerogamous*, or *Phænogamous*. Amongst all cellular plants and in some vascular plants, as Ferns and Equisetum, there are no flowers, and the reproductive organs are inconspicuous, hence they have been termed *Flowerless* or *Cryptogamous*. In all cases the young plant, or embryo, is completely cellular. But as growth proceeds, that differentiation takes place which distinguishes the several classes of plants one from the other. In Phanerogams the first leaves produced upon the embryo plant are termed primary, seed-lobes, or *cotyledons*. In some cases these are two in number, and are opposite one another. Plants in which this occurs are *Dicotyledonous* (fig. 52), as our ordinary forest trees. In other plants the lobes alternate and only one cotyledon is formed; such are *Monocotyledonous* (fig. 53), as Grasses, Lilies. In Cryptogams, on the other hand, no such seed-lobes or cotyledons are produced, and they are *Acotyledonous* (fig. 54).

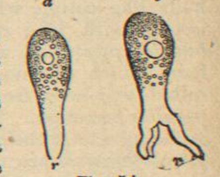

Fig. 54.

Germinating spores of a cellular plant (*Prolifera rivularis*). *a*, spore giving out a conical root-like process *r*, while the other extremity, containing a nucleus and granules, forms a cellular frond; *b*, the same spore, with the root-like process *r*, dividing. No cotyledons are produced.

In all plants the original cell tissue which gives origin to its parts is of a uniform nature, and is termed the *primary tissue*. When all the cells of this tissue are capable of multiplication and division the tissue is a *meristem* or *generating tissue*. If the cells are not so capable, then it is a *permanent tissue*. The primary tissue at the growing point of any shoot or root is essentially a meristem, and it has been designated the *primary meristem* to distinguish it from the *secondary meristem*, which is applied to a tissue in the older parts of a stem or root which remains or becomes capable of division. The growing point of the apex has been termed the *punctum vegetationis*, and it not unfrequently forms a conical projection, and is then the *vegetative cone*. By growth at this punctum vegetationis the shoot or root increases in length, and the mode of addition is in many cases of a definite character. Two chief types of growth are recognized. In one of these a single large cell is always present at the apex, termed the *apical cell*, which may be regarded as the mother-cell, whence by bipartition in a definite manner the whole meristem below it has arisen, as is well seen in vascular Cryptogams and cellular plants. The other type is seen in Phanerogams, and here no such apical cell is visible, but a number of cells are found at the apex by whose multiplication the subsequent tissues are formed. But in whatever way formed, a primary meristem is the result of all the processes of growth, and by differentiation of its cells the various parts of the shoot or root are formed. The outer layer of the primary meristem, which extends completely over the punctum vegetationis, is termed the *dermatogen*; it is the primordial epidermis, being continuous with the epidermis of the shoot and afterwards becoming epidermis. Underneath the dermatogen several layers of cells are distinguished, continuous with the cortical portion of the shoot or root; this is the primordial cortex, and constitutes the *periblem*. Enclosed by this is a central cellular mass, out of which the fibro-vascular bundles and the structures of the central part of the shoot or root are formed; this has been termed the *plerome*. If the growing axis be a young root there is in addition developed, usually from the dermatogen, a mass of cells at the extremity, constituting a *root-cap*, or protective covering, to the delicate merismatic cells beneath; no such structure is formed in a stem. Thus a stem is structurally distinct from a root in having no root-cap.

In the plerome the fibro-vascular bundles are formed. Certain cells become elongated and prosenchymatous and united in bundles leaving no intercellular spaces

this mass is termed the *procambium* of the fibro-vascular bundle. As growth proceeds changes take place in the cells by thickening, and, their contents disappearing, various kinds of cells and vessels are formed. In this way the whole mass of the procambium may be converted into permanent tissue, and then growth ceases; or an inner portion of the bundle remains merismatic, which is called the *cambium*, and then growth proceeds, the shoot or root increasing in thickness by the cambium forming new cells on both sides. In the former case the bundle is *closed*; as in Cryptogams and Monocotyledons and some Dicotyledons; in the latter it is *open*, as in most Dicotyledons and Conifers. In every fibro-vascular bundle a separation into two groups of structures may be distinguished—the wood or xylem layers, and the bast or phloëm layers. As long as the bundle is open and cambium present, these layers are separated by the cambium (fig. 55). Their

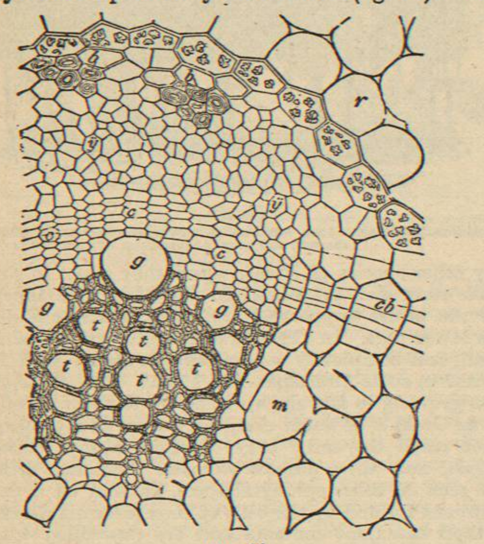

Fig. 55.

Transverse section of an open fibro-vascular bundle. *c*, cambium; *cb*, continuation of cambium between the fibro-vascular bundles; *g*, large pitted vessels; *t* smaller pitted vessels and spiral vessels intermixed with wood-cells; *y*, inner phloëm layers; *b*, bast fibres; *m* is the parenchyma of the pith; *r* is the cortical parenchyma. Immediately external to the bark lies the bundle sheath of cells filled with starch. (*Sachs.*)

relative position as regards the axis of the stem or root

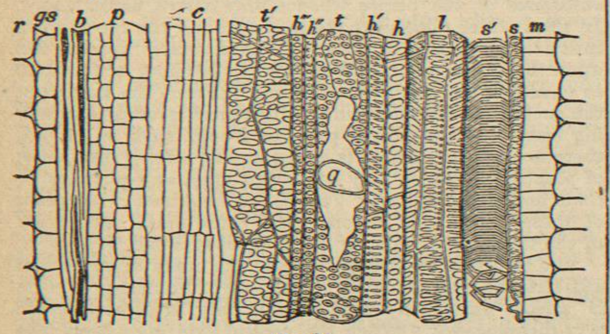

Fig. 56.

Longitudinal section of an open fibro-vascular bundle. *c*, cambium; *s*, *s*, spiral vessels with fibres which can be unrolled; *l*, scalariform reticulated vessel; *h*, *h′*, *h″*, *h‴*, wood-cells; *t*, bordered pitted vessel; *t′*, young pitted vessel; *p*, inner phloëm layer; *b*, bast layer; *gs*, bundle-sheath; *r*, cortical parenchyma; *m*, pith parenchyma. The elements are developed from *s* to *t′* in the xylem portion. (*Sachs.*)

varies. In some cases the phloëm is nearer the circumference, in other instances the xylem is peripheral, and in rare cases amongst Dicotyledons there are phloëm layers both on the outer and inner sides of the fibro-vascular bundles. In vascular Gryptogams the phloëm layers always surround the xylem portion of the bundle.

In the xylem or wood portion of a fibro-vascular bundle the cells all tend to thicken their walls, and, consequently, numerous kinds of cells and vessels are found, which are usually arranged in a definite manner. On the side furthest removed from the phloëm we find spiral vessels interspersed with wood-cells (figs. 55 and 56), outside are reticulated and scalariform vessels, and then interspersed with wood cells are large pitted vessels. In the phloëm or bast layers the cells have not such a tendency to thicken, but usually remain thin-walled, forming ordinary parenchymatous cells, or becoming perforated and forming sieve cells. In certain layers, however, the cell-walls are thickened so as to become flexible, constituting the bast fibres. Around every fibro-vascular bundle a single layer of cells of the fundamental cellular tissue of the stem is marked off from its surroundings, the cells get filled with starch-grains, and this constitutes what has been termed the *bundle sheath* or starch-bearing layer (fig. 57). In fig. 57 is seen a transverse section of the closed fibro-vascular bundle from the Maize, and it will be observed that it is essentially the same as that of the open bundle (fig. 55), only that all the cambium cells have passed into permanent tissue.

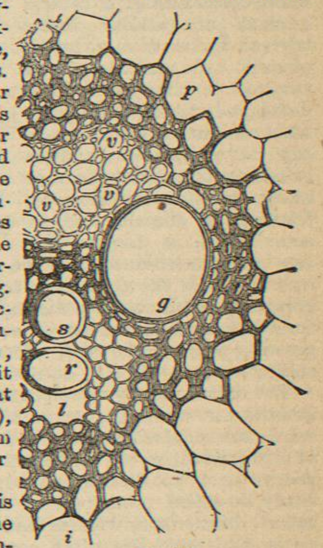

Fig. 57

Transverse section of a closed fibro-vascular bundle. *r*, annular vessel; *s*, spiral vessel; *l*, inter-cellular canal; *g*, pitted vessel, *v*,*v*, cambiform tissue which has become permanent. Between *v* and *s* are reticulated vessels. *p*, surrounding parenchyma. Outer cells *a* of the bundle are parenchymatous, *i* marks the inner side of the bundle. (*Sachs.*)

In all plants a provision is made for branching of the various organs, and two principal forms of it may be recognized. In one of these the generating axis elongates at the apex, producing in succession lateral structures. To this form the term *monopodium* has been applied. In the second form there is a cessation of growth at the apex in the direction of previous elongation of the axis, and a continuance in two diverging directions. This is *dichotomous* branching. In their rudimentary state all branchings may be easily referred to one or other of those types; but in the mature system it is frequently difficult to recognize the type, owing to irregular development of the successive branching. Thus in a dichotomous branching only one of the secondary axes may develop strongly, the weaker branch appearing as a small lateral shoot from its base; and an apparent primary shoot is thus produced which in reality consists of the bases of single branches of consecutive forkings. Such an axis is termed a *pseudaxis* or *sympodium*. And, again, in monopodial branchings the primary axis may continue to develop more strongly than its lateral axes, which in their turn develop similarly, and a *racemose* form arises; or the primary axis may be arrested in growth, and the secondary axes develop more strongly and overlap it, when a *cymose* branching results. More will be said on this subject when considering the inflorescence of Phanerogams, in which the various forms of branching are well seen.