a prosenchymatous manner. Subsequently by cell-division a complicated structure is developed in this investing mass. No fibro-vascular bundles are found in Characeæ.

In Mosses and many Hepaticæ we find no fibro-vascular system, but a slender leafy cellular stem. In it there is sometimes a differentiation into an inner and a peripheral mass of tissue. In the former the cells have usually thin walls, and are not coloured, though in some cases a thickening of the walls of the central cells is observed, and a sort of rudimentary bundle is formed. The circumferential cells have usually thickened walls, and are not unfrequently coloured.

In Ferns we have a familiar example of an Acotyledonous stem. Ordinary ferns of Britain seldom attain any height, but usually creep along the ground, forming rhizomes. But in the Tree-ferns of warm climates the caudex frequently attains a great height. A transverse section of the stem of a fern (fig. 89) exhibits an irregular circle of fibro-vascular bundles, composed of masses *f*, *v*, of various forms and sizes, situated near the circumference,—the centre *m* being formed of cellular tissue, frequently with solitary fibro-vascular bundles scattered through it, and often becoming hollow. On the outside of the vascular circle cells exist, *p*, covered by an epidermal layer or cellular integument *e*, often of hard and dense consistence, and marked with the scars of the fronds.

The vascular system is of greater density than the rest of the tissue, and is distinguished by the dark colour of the outer portion (fig. 89, *f*), which surrounds the paler

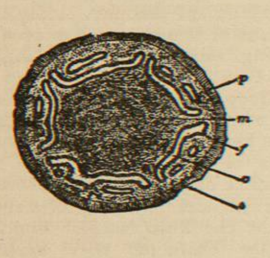

Fig. 89.

Fig. 90.

FIG. 89.—Transverse section of the stem of a Tree-fern (*Cyathea*). Cellular tissue in the centre, *m*; that of the circumference, *p*; vascular bundles, *f*, *v*, consisting of dark-coloured woody fibres *f*, and paler vessels, chiefly scalariform and dotted, *v*; the outer cortical portion formed by the bases of the leaves, *e*.
FIG. 90.—Fibro-vascular network from stem of *Aspidium Filix-mas*. (*Sachs*.)

vessels in the centre. In a very young stem only a single fibro-vascular bundle is found in the axis of the stem, surrounded by a mass of cellular tissue; but as growth proceeds a network of anastomosing bundles is formed in place of the central bundle, constituting a wide meshed hollow cylinder (fig. 90), and separating the fundamental cellular tissue of the stem into an outer cortical and an inner medullary portion. In addition, however, scattered through the pith, other bundles occur, as in Pteris aquilina, where two large cauline bundles are found; and in Tree-ferns numerous small bundles are found which pass out through the meshes of the cylinder into the leaves. The primary bundles are ribbon-shaped and broad, and curve outwards at their margins, from which the bundles for the leaves pass off—a leaf arising always from an opening of the network. The xylem portion of the fibro-vascular bundles is characterized by the great abundance of scalariform vessels, spiral vessels also being present, and intermixed with them thin-walled prosenchymatous cells, containing in winter a large amount of starch. This constitutes the inner, lighter-coloured portion of the bundles. The phloëm portion, which completely surrounds the bundle, has also starch-cells, and, in addition, sieve-tubes and elongated bast-like thick-walled fibres are found at the periphery of the bundle. The whole bundle is usually enclosed by a distinct sheath of elongated cells; these cells are frequently much thickened and of a dark brown colour, hence the appearance presented on transverse section of a dark layer enclosing a lighter-coloured part. The central cellular portion of the stem frequently becomes ruptured and absorbed in old stems, which are thus hollow. The bases of the leaves remain long attached, but ultimately fall off, leaving marked scars (fig. 91, *c*), which are at first

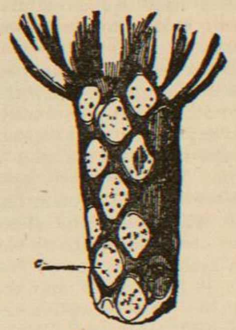

Fig. 91.

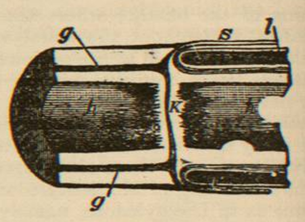

Fig. 92.

FIG. 91.—Rhizome of Male Fern, *Lastrea* (*Aspidium*) *Filix-mas*, showing the scars (cicatrices) of the leaves (fronds), with the markings of the vascular bundles, *c*.
FIG. 92.—Longitudinal section of rhizome of Equisetum, showing septum, *k*, between cavities *h*, *h*; *g*, *g*, fibro-vascular bundles; *l*, vallecular canal; *s* leaf-sheath. (*Sachs*.)

close together, but often separate afterwards by interstitial growth. On these scars or *cicatrices* the markings of the vessels are easily seen, arranged in the same manner as those of the stem. From all points of the woody cylinder stem-roots may be given off, and frequently they are formed so abundantly as completely to invest the stem and conceal it.

In Equisetaceæ or Horsetails we have another example of an Acotyledonous stem. The true stem in those plants is a rhizome underground, from which aerial shoots are sent up annually. Every aerial stem consists of a series of joints (internodes), which are usually hollow and closed at their base by a thin septum (fig. 92). Each internode passes up into a leaf-sheath embracing the next internode, and this sheath is usually split into teeth at its upper margin. In transverse section a circle of fibro-vascular bundles is seen (fig. 93) marking off an inner medullary from an outer cortical portion, and separated one from the other by a mass of parenchyma. These bundles are all common bundles. From each tooth of the leaf-sheath the bundle may be traced, passing vertically down into the internodes

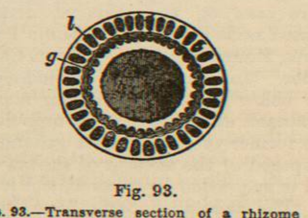

Fig. 93.

Fig. 94.

FIG. 93.—Transverse section of a rhizome of Equisetum. *g*, fibro-vascular bundle; *l*, vallecular canal; *h*, central cavity. (*Sachs*.)
FIG. 94.—To show union of the fibro-vascular bundle of an upper with a lower internode; *i*, *i*, internode; *k*, node. *Sachs*.)

as far as the node beneath, and at the lower end dividing into two, uniting by each branch with a bundle of the next lowest internode (fig. 94). In transverse section the bundle

resembles much that of a Monocotyledon. One peculiarity, however, must be noticed. The spiral, annular, and reticulated vessels at the inner side of the bundle soon disappear, and an air-canal is formed in the bundle. This canal must be distinguished from the *vallecular* canals found in the cortex, with which they alternate. Round the bundles a single layer of usually thickened and coloured cells forms a sheath, and this may either run continuously round the stem, and thus shut off completely the medullary from the cortical portion of the stem, or may invest separately each bundle, in which case the medullary and cortical portions of the stem are continuous. In some cases a layer of thickened cells is found within the vascular bundles. The cortical portion is divisible into two layers, an inner layer of parenchymatous cells with air canals, the *vallecular* canals, and an outer layer of thickened cells immediately underlying the epidermis. The structure of the rhizome resembles that of the aerial stem, differing only in the fact that the thickened cells of the outer cortical layer are dark coloured, and that the central canal of the internodes is often absent. In Calamites, a fossil plant which flourished abundantly during the Carboniferous Period, we have a plant which in all particulars is closely allied to Equisetum of the present day. But whilst the young stem of Calamites presented a zone of vascular bundles separating it into a medullary and cortical portion (just as in an Equisetum), new vessels were added to the exterior of the pre-existing bundles as the plant grew, so that a series of woody wedges were formed, increasing in growth to an enormous extent.

In Lycopodiaceæ, or Club Mosses, the stem presents differences from that in Ferns and Equisetaceæ. In most members of the family there is an axial cylinder formed of either one or more fibro-vascular bundles. In some cases (Selaginella) the fibro-vascular bundles remain separate and do not form a cylinder. They are surrounded by a mass of prosenchymatous cellular tissue, the cells of which may be thin-walled, leaving no intercellular spaces, or the cell-walls may be much thickened. Immediately surrounding the central axial bundle in Selaginella are large air lacunæ, which are wanting in Lycopodium. The fibro-vascular bundles consist of tissues very similar to what occurs in Ferns, and the bundles are all cauline. In the leaves, bundles arise which pass into the stem and coalesce with the cauline bundles. In Isoetes we find a most anomalous structure. Here there are no internodes in the stem; consequently, it is much shortened. The central axial fibro-vascular bundle is very poorly developed, and round it a meristem is formed, which, by adding new parenchyma outside, increases the diameter of the stem. Thus we have here a thickening ring, but it differs from that structure in Dicotyledons, inasmuch as it is not formed by a union of cambium cells of the fibro-vascular bundles. It resembles more the thickening ring formed in Dracæna, Yucca, and other Monocotyledons.

In Rhizocarpeæ the structure of the stem is very simple, consisting of an axial fibro-vascular bundle surrounded by parenchyma full of air-cavities.

In plants with Acotyledonous stems the mode of branching is various. In Lycopodiaceæ we have an example of a dichotomous branching, and the same is also seen in Ferns. In the Equisetaceæ a mode of branching occurs seen nowhere else in the Vegetable Kingdom. The branches arise from deeply-seated lateral buds, which, upon developing, break through the superincumbent tissue; these have been termed *endogenous* buds. In Characeæ the branching is of the normal monopodial type.

Amongst Thallogens, as a rule, there is no evident distinction between stem and leaf. The vegetative organs consist of a number of cells separate or combined into a more or less flattened expansion termed the thallus. In this group are included all the Algæ, Fungi, and Lichens, and many Hepaticæ. The vegetative structures vary much in each of these groups. In many Hepaticæ, as Marchantia, the vegetative structure is of a thalloid nature, and appears as a flattened, broad, dichotomously-branched plate, composed of several layers of cells. The upper and lower layers consist of colourless cells, and form a sort of epidermis. The upper epidermal layer has stomata, while the lower gives off root-like filaments, which attach it to the stratum on which it grows. The stomata are, by repeated division of the guard-cells, converted into canals. The central layer of cells contains green matter, and between the cellules there are large intercellular spaces, which communicate with the stomata on the upper surface. In what are usually termed the foliose Hepaticæ, such as Jungermanniæ, a distinct stem is visible bearing leaves. All are cellular, no differentiation occurring beyond a compacting of the peripheral layers of cells. The mode of branching is usually dichotomous.

In Fungi the vegetative organs consist of a mass of cellular filaments, anastomosing and branching in various ways, constituting the *mycelium* or *spawn* (fig. 95, *m*), from which diversely-shaped portions of cellular tissue are developed, forming *receptacles* for the support of the reproductive organs. The mycelium creeps along in or upon the stratum whence it is nourished, sending up here and there a receptacle. The structural elements which form these are colourless cellular filaments, or *hyphæ*, divided usually by many transverse septa. These sometimes combine to form a dense mass of parenchyma. In some cases the hyphæ of the mycelium are densely interwoven, and form masses of definite shape, the outer layer of which (pseudo-parenchymatous) forms a hard shell or skin; such a mass is termed a *sclerotium*. The reproductive receptacle formed from the mycelium is also composed of hyphæ. When there is only a single hypha the reproductive bodies are borne on the ends of its branches; but more usually the branches of the hyphæ bearing the reproductive bodies unite to form a flattened expansion, the *hymenium*. As they contain no chlorophyll, Fungi take up assimilated matter from other organisms, and therefore are frequently parasites.

Fig. 95

A species of Mould-fungus (*Botrytis*), consisting of a mycelium *m*, bearing a septate cellular stalk *s*, which branches at the apex, each division bearing a rounded spore *c*.

In Algæ the simplest forms present nothing but a cell-wall, containing a coloured protoplasmic substance, as in some Nostocaceæ. In some cases firmness is attained by deposition of silica as in Diatoms, or by lime carbonate as in Acetabularia. Lignification never occurs. More usually, however, the cells are combined into a tissue, but the forms which this may assume and the modes of combination are more various than in any other class of plants,—linear masses, strings, globes, laminæ, &c., being formed. There may be in some cases a slight differentiation into distinct organs. Thus, in some of the higher forms, as Fucaceæ, a distinct stem is formed, from which flattened thalli resembling leaf structures arise, and at the base root-like structures (*rhizoids*) are formed. These parts, however, have none of the internal structures which characterize higher plants, but consist entirely of cellular tissue. At most there is a condensation of cellular tissue at the periphery, forming an epidermis, and a similar condensation in the axis. The mode of branching amongst Algæ is either monopodial or dichotomous.

In Lichens the thallus (fig. 96) consists of a *hyphal* element of anastomosing and interlacing filaments, amongst which are distributed rounded unicellular coloured bodies, the *gonidia* (fig. 97, *g*). These gonidia are either arranged in one layer in the thallus, which is then said to be *heteromerous* (the hypha layer being divided into a cortical and deeper part), or they are scattered equally throughout its substance and are *homœomerous*. The gonidia are separable, and may form independent plants. When they are being detached, the separation begins at the centre of the thallus, so that the middle of the Lichen becomes pulverulent, while its circumference may remain foliaceous or crustaceous. By the continuation of this process it sometimes happens that the whole Lichen becomes a mass of greenish or yellowish powder. The thallus may be crustaceous, in the form of an incrustation upon rocks, trees, &c., with which it becomes closely connected, as in Graphis; or it may be foliaceous, forming a flattened expansion easily detachable from the substratum to which it is connected by small root-like bodies or *rhizines*, as in Peltigera; or the lichen may be what is termed fruticose, *i.e.*, composed of a much-branched thallus rising from a single point of attachment, as in Usnea. Recent observations upon Lichens tend to show that they are in reality composed of two distinct organisms,—one, a Fungus, being the hyphal part, and the other, an Alga, the gonidial portion, and that the Fungus is parasitic upon the gonidia.

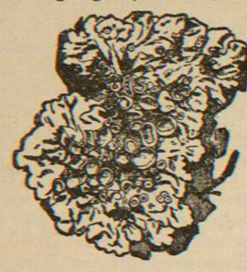

Fig. 96.

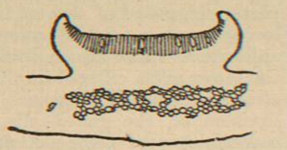

Fig. 97

FIG. 96.—A Lichen (*Parmelia*), with its cellular expansion (thallus), and its rounded apothecia, or spots of fructification.
FIG. 97.—Vertical section of an apothecium and thallus of a Lichen. Rounded free cells *g*, of a green colour, and called gonidia, are seen in the centre of the thallus. The apothecium *a* consists of thecæ and paraphyses. Its upper surface is often coloured and covered by a perithecium.

3. *Leaves and their Modifications.*

In popular language all the green expanded organs borne upon an axis are designated leaves. Investigation, however, has shown that many other parts of a plant which externally appear very different from ordinary leaves are, in their essential particulars, very similar to them, and are in fact their morphological equivalents. Thus the scales on the bulb of the Onion, the various parts of the flower, &c., are all leaves. Assuming, then, that the structure ordinarily termed a leaf is the typical form, these latter are designated changed or *metamorphosed* leaves; and all structures morphologically equivalent with the leaf are included under the general term *phyllome* (leaf-structure). Leaves are produced as lateral outgrowths of the stem. This character, common to all leaves, distinguishes them from other organs. In the higher plants we can easily recognize the distinction between stem and leaf. Amongst the lower plants, however, it is found that a demarcation into stem and leaf is impossible, but that there is a structure which partakes of the characters of both,—such is a *thallome*. The leaves always arise from the outer portion of the primary meristem of the plant, and the tissues of the leaf are continuous with those of the stem. Every leaf originates as a simple cellular papilla, which consists of a development from the cortical layers covered by epidermis; and as growth proceeds, the fibro-vascular bundles of the stem are continued outwards, and finally expand and terminate in the leaf. The increase in length of the leaf by growth at the apex is usually of a limited nature. In some Ferns, however, there seems to be a provision for indefinite terminal growth, while in others this growth is periodically interrupted. It not unfrequently happens, especially amongst Monocotyledons, that after growth at the apex has ceased, it is continued at the base of the leaf, and in this way the length may be much increased. Amongst Dicotyledons this is very rare. In all cases the dimensions of the leaf are enlarged by interstitial growth of its parts.

The simplest leaf is found in some Mosses, where it consists of a single layer of cells. Usually it consists of several layers, and amongst vascular plants is distinguishable into an epidermis and a central parenchyma with fibro-vascular bundles distributed through it.

The *epidermis* (fig. 98, *es*, *ei*), composed of cells more or less compressed, has usually a different structure and aspect on the two surfaces of the leaf. It is chiefly on the epidermis of the lower surface (fig. 98, *ei*) that stomata, *st*, are produced, occupying spaces between the veins, and it is there also that hairs, *p*, usually occur. The lower epidermis is often of a dull or pale-green colour, soft, and easily detached. The upper epidermis is frequently smooth and shining, and sometimes becomes very hard and dense. Many tropical plants present on the upper surface of their leaves several layers of compressed epidermal cells. These appear to be essential for the preservation of moisture in the leaf. In leaves which float upon the surface of water, as those of the Water-lily, the upper epidermis alone possesses stomata.

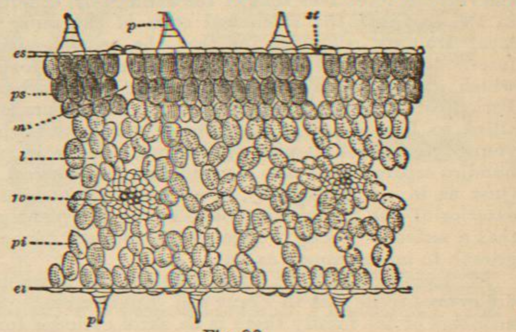

Fig. 98.

Section of a Melon-leaf, perpendicular to the surface *es*, upper epidermis; *ei*, lower epidermis; *p*, hairs; *st*, stomata; *ps*, upper layers of parenchymatous cells; *pi*, lower layers of parenchymatous cells; *m*, meatus, or canals connected with stomata; they are sometimes called hypostomatic spaces; *l*, lacunæ, or cavities between the loose cells in the cavernous lower parenchyma; *fv*, bundles of fibro-vascular tissue, consisting of woody, dotted, spiral, and other vessels.

The *parenchyma* of the leaf is the cellular tissue surrounding the vessels, and enclosed within the epidermis (fig. 98, *ps*, *pi*). It has sometimes received the names of *diachyma*, *mesophyllum*, and *diploë*. It is formed of two distinct series of cells, each containing chlorophyll or green-coloured granules, but differing in form and arrangement. Below the epidermis of the upper side of the leaf there are one or two layers of oblong blunt cells, placed perpendicularly to the surface (fig. 98, *ps*), and applied so closely to each other as to leave only small intercellular spaces (fig. 98, *m*), except where stomata happen to be present. On the under side of the leaf the cells are irregular, often branched, and are arranged more or less horizontally (fig. 98, *pi*), leaving cavities between them, *l*, which often communicate with stomata. On this account the tissue has received the name of *cavernous*. In leaves having a very firm texture, as those of Coniferæ and Cycadaceæ, the cells of the parenchyma immediately beneath the epidermis are very much thickened and

elongated in a direction parallel to the surface of the leaf, so as to be fibre-like. These constitute a hypodermal layer, beneath which the chlorophyll cells of the parenchyma are densely packed together, and are elongated in a direction vertical to the surface of the leaf; this has been termed *palisade* tissue. The form and arrangement of the cells, however, depend much on the nature of the plant, and its exposure to light and air. Sometimes the arrangement of the cells on both sides of the leaf is similar, as occurs in leaves which have their edges presented to the sky. In very succulent plants the cells form a compact mass, and those in the centre are often colourless. In some cases the cellular tissue is deficient at certain points, giving rise to distinct holes in the leaf, as in Monstera Adansonii: such a leaf has been called *pertuse*. In Victoria regia perforations in the leaf seem to be subservient to the purposes of nutrition, by permitting the gases collected beneath the large expanded leaf to escape, and thus allowing its under surface to be brought into immediate contact with the water. The fibro-vascular system in the leaf constitutes the *venation*. The fibro-vascular bundles from the stem bend out into the leaf, and are there arranged in a definite manner. They usually form two layers, which may be separated by maceration. In *skeleton leaves*, or leaves in which the parenchyma is removed, these layers are well seen. In some leaves, as in the Barberry, the vessels forming the veins are hardened, producing spines without any parenchyma. The hardening of the extremities of the vascular tissue is the cause of the spiny margin of many leaves, such as the Holly, of the sharp-pointed leaves of Madder, and of mucronate leaves, or those having a blunt end with a hard projection in the centre.

Submerged leaves, or leaves which are developed under water, differ in structure from aerial leaves. They have usually no fibro-vascular system, but consist of a congeries of cells, which sometimes become elongated and compressed so as to resemble veins. They have a layer of compact cells on their surface, but no true epidermis, and no stomata. Their internal structure consists of cells, disposed irregularly, and sometimes leaving spaces which are filled with air for the purpose of floating the leaf. When exposed to the air these leaves easily part with their moisture, and become shrivelled and dry. In some instances there is only a network of filamentous-like cells formed, the spaces between which are not filled with parenchyma, giving a peculiar skeleton appearance to the leaf, as in Ouvirandra fenestralis (Lattice plant). Such a leaf has been called *fenestrate*. A leaf, whether aerial or submerged, generally consists of a flat expanded portion (fig. 99, *l*), called the *blade*, *limb*, or *lamina*, of a narrower portion called the *petiole* or *stalk* (fig. 99, *p*), and sometimes of a portion at the base of the petiole, which forms a *sheath* or *vagina* (fig. 99, *g*), or is developed in the form of leaflets, called *stipules* (fig. 123, *s*). The sheathing portion is sometimes incorporated with the stem, and is then called *tigellary*. These portions are not always present. The sheathing or stipulary portion is frequently wanting, and occasionally only one of the other two is developed. When a leaf has a distinct stalk it is called *petiolate*; when it has none, it is *sessile*, and if in this case it embraces the stem it is said to be *amplexicaul*. The part of the leaf next the petiole or the axis is the *base*, while the opposite extremity is the *apex*. The surfaces of the leaf are called the *paginæ*, and its edges or margins form the *circumscription* of the leaf. The leaf is usually flattened and expanded horizontally, *i.e.*, at right angles to the longitudinal axis of the shoot, so that the upper pagina is directed towards the heavens, and the lower pagina towards the earth. In some cases leaves, as in Iris, or leaf-like petioles, as in Australian Acacias and Eucalypti, have their plane of expansion parallel to the axis of the shoot; or the leaf may have a cylindrical or polyhedral form, as in Mesembryanthemum. In other instances, as in Alströmeria, the leaf becomes twisted in its course, so that what is superior at one part becomes inferior at another. The upper angle formed between the leaf and the stem is called its *axil*, and everything arising at that point is called *axillary*. It is there that leaf-buds are usually developed. The leaf is sometimes articulated with the stem, and, when it falls off, a *scar* or *cicatricula* remains; at other times it is continuous with it, and then decays, while still attached to the axis. In their early state all leaves are continuous with the stem, and it is only in their after growth that articulations are formed. When leaves fall off annually they are called *deciduous*; when they remain for two or more years they are *persistent*, and the plant is called *evergreen*. The laminar portion of a leaf is occasionally articulated with the petiole, as in the Orange, and a joint at times exists between the vaginal or stipulary portion and the petiole.

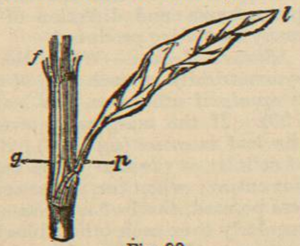

Fig. 99.
Leaf of Polygonum, with part of stem.

The arrangement of the fibro-vascular system in the lamina constitutes the *venation* or *nervation*. In an ordinary leaf, as that of the Elm, there is observed a large central vein running from the base to the apex of the leaf, this is the *midrib* (fig. 100); it gives off veins laterally (*primary veins*), which either end in a curvature within the margin (*curve-veined*), as in Lilac and Belladonna, or go directly to the edge of the leaf (*feather-veined*), as in Elm (fig. 100) and Chestnut. If they are curved, then external veins and marginal veinlets are interspersed through the parenchyma external to the curvature. There are also other veins of less extent (*costal veins*) given off by the midrib, and these give origin to small *veinlets*. A leaf with only a single midrib is said to be *unicostate* (fig. 100). In some cases, as Sycamore and Cinnamon, in place of there being only a single midrib there are several large veins (ribs) of nearly equal size, which diverge from the point where the blade joins the petiole or stem, giving off lateral veins. The leaf in this case is *multicostate* (fig. 101). When there are three prominent ribs, as in Cinnamon and Cassia the leaf is *tricostate*; when five, *quinquecostate*. When the midrib gives off two ribs a little above the base, the leaf becomes *triplicostate*; when it gives off five, *quintuplicostate*.

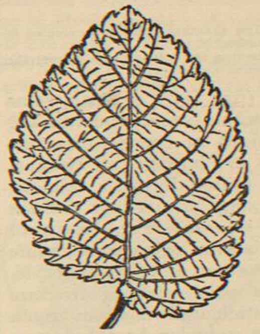

Fig. 100

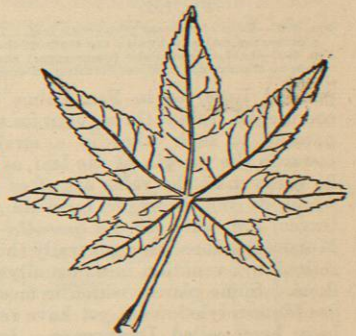

Fig. 101.

FIG. 100.—Leaf of *Ulmus effusa*. Reticulated venation; primary veins going to the margin, which is serrated. Leaf unequal at the base.
FIG. 101.—Multicostate divergent leaf of Castor-oil plant (*Ricinus communis*). It is palmately-cleft, and exhibits seven lobes at the margin. The petiole is inserted a little above the base, and hence the leaf is called peltate or shield-like.

in a leaf having many ribs they may converge towards the apex, as in Cinnamon, or they may diverge, as in Sycamore and the Castor-oil plant (fig. 101). Thus the primary veins give off secondary veins, and these in their turn give off tertiary veins, and so on until a complete network of vessels is produced, and those veins usually project on the under surface of the leaf. To a distribution of veins such as this the name of *reticulated* or *netted* venation has been applied. In the leaves of some plants there exists a midrib with large veins running nearly parallel to it from the base to the apex of the lamina, as in Grasses (fig. 102); or with veins diverging from the base of the lamina in more or less

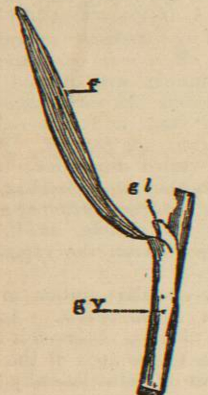

Fig. 102.

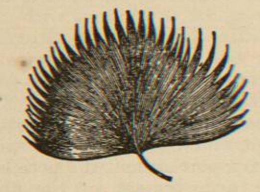

Fig. 103.

FIG. 102.—Stem of a Grass (*Poa*) with leaf. The sheathing petiole *gv* ending in a process *gl*, called a ligule; the blade of the leaf, *f*.
FIG. 103.—Leaf of Fan Palm (*Chamærops*), showing the veins running from the base to the margin, and not forming an angular net-work.

parallel lines, as in Fan Palms (fig. 103), or with veins coming off from it throughout its whole course, and running parallel to each other in a straight or curved direction towards the margin of the leaf, as in Plantain and Banana. In these cases the veins are often united by cross veinlets, which do not, however, form an angular network. Such leaves are said to be *parallel-veined*. The leaves of Monocotyledons have generally this kind of venation, while reticulated venation most usually occurs amongst Dicotyledons. Some plants, which in most points of their structure are Monocotyledonous, yet have reticulated venation. Such have been called Dictyogens. In vascular Acotyledonous plants there is frequently a tendency to fork exhibited by the fibro-vascular bundles in the leaf; and when this is the case we have *fork-veined* leaves. This is well seen in many Ferns. The distribution of the system of vessels in the leaf is usually easily traced, but in the case of succulent plants, as Hoya, Agave, Stonecrop, and Mesembryanthemum, the veins are obscure, and the leaves are said to be *hidden-veined*. In the cellular leaves of Mosses a median vein of several layers of cells is often visible, but as there are no fibro-vascular bundles present this is considered a false venation, and they are styled *veinless* (*Avenia*).

TABULAR ARRANGEMENT OF VENATION.

A.—Reticulated Venation.
 I. *Unicostate*. A single rib or costa in the middle (midrib).
  1. Primary veins coming off at different points of the midrib.
   a. Veins ending in curvatures within the margin, and forming what have been called *true netted* leaves (Lilac).
   b. Veins going directly to the margin and forming *feather-veined* leaves (Oak and Chestnut).
  2. Primary veins coming off along with the midrib from the base of the leaf.
 II. *Multicostate*. More than one rib. Authors usually give to these leaves the general name of *costate* or *ribbed*.
  1. *Convergent*. Ribs converging, running from base to apex in a curved manner, as in Cinnamon and Melastoma. There is occasionally an obscure rib running close to the edge of the leaf, and called intra-marginal, as in the Myrtle.
  2. *Divergent*. Ribs diverging or proceeding in a radiating manner, as in Sycamore, Vine, Geranium, Castor-oil plant.
B.—Parallel Venation.—The term parallel is not strictly applicable, for the veins often proceed in a radiating manner, but it is difficult to find a comprehensive term. This venation may be characterised as *not reticulated*.
 I. Veins proceeding transversely from midrib to margin, usually with convexity towards the midrib, as in Musa and Canna.
 II. Veins proceeding longitudinally from base to apex.
  1. Veins more or less convergent, as in Iris, Lilies, Grasses.
  2. Veins more or less divergent, as in Fan Palms.
C.—Furcate Venation. Veins dividing in a forked manner, as in the case of many Ferns.

In all plants, except Thallophytes, leaves are present at some period of their existence. In Cuscuta (Dodder), however, we have an exception. The forms assumed by leaves vary much, not only in different plants but in the same plant. It is only amongst the lower classes of plants,—Mosses, Characeæ, &c.,—that all the leaves on a plant are similar. As we pass up the scale of vegetable life we find them becoming more and more variable. The structures in ordinary language designated as leaves are considered so *par excellence*, and they are frequently spoken of as *foliage leaves*. In relation to their production on the stem we may observe that when they are small they are always produced in great number, and as they increase in size their number and rapidity of growth diminish correspondingly. The cellular process from the axis which develops into a leaf is simple and undivided; it rarely remains so, but in progress of growth becomes segmented in various ways, either longitudinally or laterally, or in both ways. By longitudinal segmentation we have a leaf formed consisting of vagina, petiole, and lamina; or one or other of these may be absent, and thus stalked, sessile, sheathing, &c., leaves are produced. Lateral segmentation affects the lamina, producing indentations, lobings, or fissuring of its margins. In this way two marked forms of leaf are produced—(1.) *Simple* form, in which the segmentation, however deeply it extends into the lamina, does not separate portions of the lamina which become articulated with the midrib or petiole; and (2.) *Compound* form, where portions of the lamina are separated as detached *leaflets* (*foliola*), which become articulated with the midrib or petiole. In simple leaves, then, there is never more than one articulation, which is at the point of their insertion on the stem. In compound leaves there are one or more articulations beyond the point of insertion on the stem. In both simple and compound leaves, according to the amount of segmentation and the mode of development of the parenchyma and direction of the fibro-vascular bundles, many forms are produced.

Simple Leaves.—When the parenchyma is developed symmetrically on each side of the midrib or stalk, the leaf is *equal;* if otherwise, the leaf is *unequal* or *oblique* (fig. 100). If the margins are even and present no divisions, the leaf is *entire* (fig. 104); if there are slight projections of cellular or vascular tissue beyond the margin the leaf is not entire; when the projections are irregular and more or less pointed, the leaf is *dentate* or toothed; when they lie regularly over each other, like the teeth of a saw, the leaf is *serrate* (fig. 100); when they are rounded the leaf is *crenate*. If the divisions extend more deeply into the lamina than the margin, the leaf receives different names according to the nature of the segments; thus, when the divisions extend about half-way down (fig. 105), it is *cleft* (*fissus*), and its lines of separation are called *fissures;* when

the divisions extend nearly to the base or to the midrib the leaf is *partite*, and its lines of separation are called *partitions*.

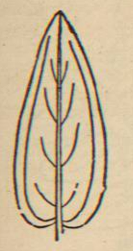

Fig. 104.

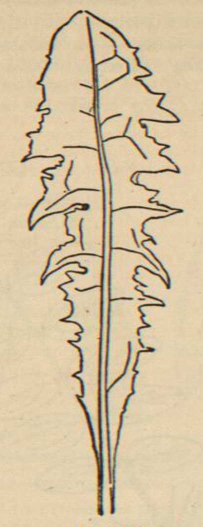

Fig. 105.

Fig. 106.

FIG. 104.—Ovate acute leaf of *Coriara myrtifolia*, one of the adulterations of senna. Besides the midrib there are two intra-marginal ribs which converge to the apex. The leaf is therefore tricostate.
FIG. 105.—Runcinate leaf of Dandelion (*Leontodon Taraxacum*). It is a pinnatifid leaf, with the divisions pointing towards the petiole.
FIG. 106.—Pinnatifid leaf of *Valeriana dioica*.

If these divisions take place in a simple *feather-veined* leaf it becomes either *pinnatifid* (fig. 106), when the segments extend to about the middle and are broad; or *pectinate*, when they are narrow; or *pinnatipartite*, when the divisions extend nearly to the midrib. These primary divisions may be again subdivided in a similar manner, and thus a *feather-veined* leaf will become *bipinnatifid* or *bipinnatipartite;* and still further subdivisions give origin to *tripinnatifid* and *laciniated* leaves. If the divisions of a pinnatifid leaf are more or less triangular, and point downwards towards the base, the extremity of the leaf being undivided and triangular, the leaf is *runcinate* (fig. 105), as in the Dandelion. When the apex consists of a large rounded lobe, and the divisions, which are also more or less rounded, become gradually smaller towards the base, as in Barbarea, the leaf is called *lyrate*, from its resemblance to an ancient lyre. When there is a concavity on each side of a leaf, so as to make it resemble a violin, as in Rumex pulcher, it is called *panduriform*. The same kinds of divisions taking place in a simple leaf with *radiating* venation, give origin to *lobed*, *cleft*, and *partite* forms. When the divisions extend about half-way through the leaves, they may be *three-lobed*, *five-lobed*, *seven-lobed*, *many-lobed*, or *trifid*, *quinquefid*, *septemfid*, *multifid*, according to the number of the divisions. The name *palmate*, or *palmatifid* (fig. 101), is the general term applied to leaves with radiating venation, in which there are several lobes united by a broad expansion of parenchyma, like the palm of the hand, as in the Castor oil plant, Rheum palmatum, and Papaw. The divisions of leaves with radiating venation may extend to near the base of the leaf, and the names *bipartite*, *tripartite*, *quinquepartite* (fig. 107), *septempartite*, *digitipartite* (Plate II. fig. 1), are given according as the partitions are two, three, five, seven, or more. In Drosera dichotoma bipartite and tripartite leaves are seen. The term *dissected* is applied to leaves with radiating venation, having numerous narrow divisions, as in Geranium dissectum. When in a radiating leaf there are three primary partitions, and the two lateral lobes are again cleft, as in Helleborus

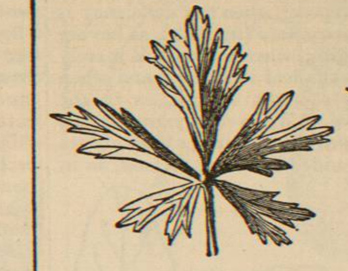

Fig. 107.

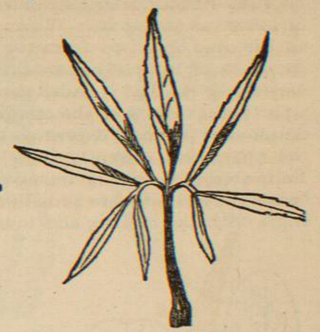

Fig. 108.

FIG. 107.—Five-partite leaf of Aconite. Such a leaf is sometimes called palmipartite, palmately-partite, or dissected. The venation is radiating, and the segments of the leaf are cuneate, and each of them is cleft and toothed at the apex
FIG. 108.—Pedate leaf of Stinking Hellebore (*Helleborus fœtidus*). The venation is radiating. It is a palmately-partite leaf, in which the lateral lobes are deeply divided. When the leaf hangs down it resembles the foot of a bird, and hence the name.

(fig. 108), the leaf is called *pedate* or *pedatifid*, from a fancied resemblance to the claw of a bird. In all the instances already alluded to the leaves have been considered as flat expansions, in which the ribs or veins spread out on the same plane with the stalk. In some cases, however, the veins spread at right angles to the stalk. If they do so equally on all sides, and are united by parenchyma, so that the stalk occupies the centre, the leaf becomes *orbicular*, as in Hydrocotyle; if unequally, so that the stalk is not in the centre, the leaf is *peltate*, as in Indian Cress (fig. 109). The edges or margins of orbicular and peltate leaves are often variously divided.

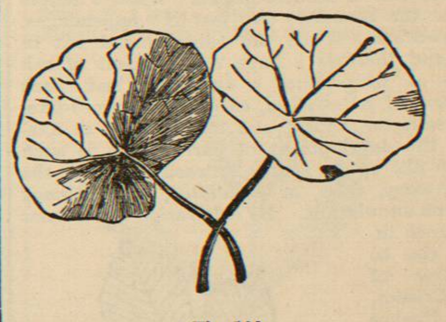

Fig. 109.

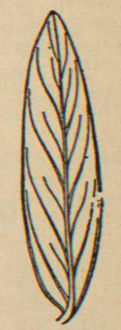

Fig. 110.

FIG. 109.—Peltate leaves of Indian Cress (*Tropæolum majus*).
FIG. 110.—Lanceolate leaf of a species of Senna.

Without attempting to notice all the forms of leaves, the following are enumerated as the most important. When the veins do not spread out, but run from the base to the apex with a narrow strip of parenchyma, the leaf is *linear* or *acicular*, as in Pines and Firs. These trees are hence called in Germany *Nadel-hölzer*, or needle trees. When the veins diverge, those in the middle being longest, and the leaf tapering at each end (fig. 110), it becomes *lanceolate*. If the middle veins exceed the others slightly, and the ends are convex, the leaf is either *rounded*, *elliptical*, *oval*, or *oblong* (fig. 111). If the veins at the base are longest, and the leaf narrows to the top, it is *ovate* or egg-shaped (fig. 104), as in Chickweed; if the apex is broadest, the leaf is *obovate*, or inversely egg-shaped (fig. 112). Leaves are *cuneate* or wedge-shaped, in Saxifraga; *spathulate*, or spatula-like, having a broad rounded apex, and tapering