is formed on the outside; and in this way the stem increases in thickness. This growth in thickness, however, ceases periodically, and is renewed with each new period of vegetation, and thus the wood is formed in concentric layers, sharply marked off from succeeding layers, each being an *annual ring* of wood, and the same is seen in the cortex (fig. 74). The rings of wood are thus formed successively outside those pre-existing, while in the cortex the new layers are produced inside those already formed.

The inner vessels of the primary fibro-vascular bundles immediately surround the pith and often project into it, and form what is termed the *medullary sheath*, which consists of spiral vessels, and through this sheath the primary medullary rays pass. These medullary rays extend from the pith to the cortex, but as new zones of wood and cortex are produced, new rays are formed in them, which increase by additions from the cambium layer. The secondary cortex, formed from the cambium ring, constitutes what is commonly known as the inner bark or *endophlœum;* the primary cortex, which forms the outer bark, consists of two layers of cells, which have been respectively termed the *mesophlœum* and the *epiphlœum.* Outside all is the epidermis. This, however, does not remain as thin-walled cells, but is usually converted into *periderm*, and this may in turn be completely supplanted by the bark. Thus, if a transverse and a longitudinal section of a Dicotyledonous stem be made, the following structures will be seen as represented in fig. 74. In the centre is the cellular pith *a*, *a*,

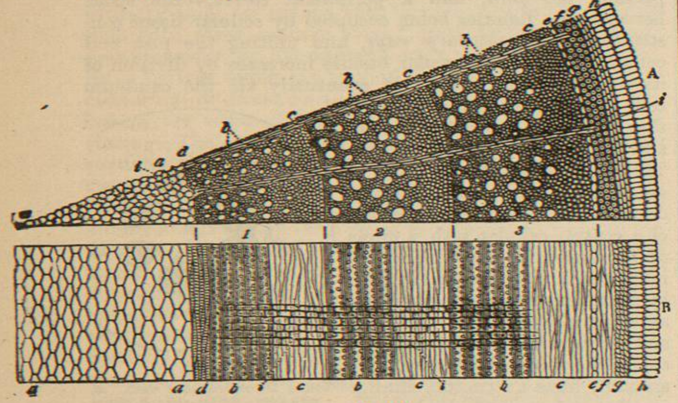

Fig. 74.

Diagram of the structure of an Exogenous or Dicotyledonous stem of three years' growth, A being a transverse section, and B a vertical section. The figures 1, 2, 3, mark the years of growth, and the letters refer to the same parts in both figures. *a*, *a*, medulla or pith, consisting of hexagonal parenchyma; *b*, *b*, *b*, pitted or dotted vessels, and *c*, *c*, *c*, wood-cells, of successive annual layers; *d*, spiral vessels of the medullary sheath; *e*, layer of cambium cells between wood and bark; *f*, inner bast layer of bark (Liber, Endophlœum); *g*, cellular envelope, forming middle layer of bark (Mesophlœum); *h*, outer corky layer of bark (Epiphlœum); *i*, *i*, medullary ray which, in the transverse section, is seen running continuously from the pith to the bark. (*After Carpenter.*)

immediately surrounding it comes the medullary sheath *d*, then the secondary layers of wood *b*, *c*, of successive years' growth, outside this the cambium ring *e*, separating the wood-layers from the cortical layers. Of these last, the inner, *f*, is the bast layer or endophlœum, *g* is the middle cellular layer or mesophlœum, and *d* is the outer epiphlœum. The latter two constitute the outer bark. Connecting the mesophlœum with the pith is seen a medullary ray *i*. Outside all are the epidermal tissues.

Let us now examine the different parts of an Exogenous stem proceeding from the centre to the circumference:—

The *Pith*, or the central part of a Dicotyledonous stem, is composed of cellular tissue. In the young stem it is succulent, the cells being full of fluid and frequently of a greenish hue; but in process of time it becomes pale-coloured, dry, and full of air. These changes take place first in the central cells. Sometimes the pith is broken up into cavities, which have a regular arrangement, as in the Walnut, Jessamine, and Cecropia peltata; it is then called *discoid* or *disciform*. At other times, by the rapid growth of the outer part of the stem, the pith is ruptured irregularly, and forms large cavities, as in the fistular stem of Umbelliferous plants. In some cases fibro-vascular bundles are found in the pith, as in Elder, Pitcher-plant, and Ferula, and occasionally its cells are marked by pores indicating a thickening of the cell-wall. The extent of pith varies in different plants and in different parts of the same plant. In Ebony it is small, while in the Elder it is large. In Æschynomene aspera (Shola plant, the Rice-paper plant of India), the interior of the stem is almost entirely composed of cellular tissue or pith; from this a kind of paper is made, and light hats. The same kind of tissue occurs in the Papyrus of the Nile. Large pith is also seen in Fatsia (Aralia) papyrifera (Tung-tsaou or Chinese rice-paper plant), and in Scævola Taccada of the Malay archipelago. When the woody circle of the first year is completed, the pith usually remains stationary as regards its size, retaining more or less its dimensions, even in old trunks, and never becoming obliterated.

The *Medullary Sheath* is the fibro-vascular layer immediately surrounding the pith. It is the inner layer of the fibro-vascular bundle of the first year (fig. 74, *d*), and consists chiefly of true spiral vessels, with annular and reticulated vessels, intermixed with long woody fibres, which continue to exercise their functions during the life of the plant, and which extend into the leaves. Between the vessels of the sheath the medullary rays from the pith pass.

The *Wood*.—The layers of wood (fig. 74, *b*, *c*) are formed outside the medullary sheath in concentric rings in the manner already described. On account of this mode of formation of wood-layers successively outside pre-existing layers the stem increases indefinitely. There are no annular or spiral vessels present; these have been replaced by pitted and punctated vessels along with wood-cells. The stems have been called *exogenous* and also *indefinite*, and Dicotyledonous plants have sometimes received the name of *Cyclogens*, in consequence of exhibiting concentric circles in their stems. On a transverse section each zone or circle is usually seen to be separated from that next to it by a well-marked line of demarcation. This line, as in the Oak and in the Ash, is indicated by holes which are the openings of large pitted vessels,—the remainder of the tissue in the circle being formed by pleurenchymatous tubes with thickened walls and of smaller calibre. In some trees, as the Lime, Hornbeam, and Maple, the line is by no means so well marked, as the openings are smaller and more generally diffused; but there is usually a deficiency of pitted vessels towards the outer part of the circle. In cone-bearing plants, as the Fir, in which the woody layers consist entirely of punctated tissue, without any large pitted vessels, the line of separation is marked by the tissue becoming dense and often coloured. In some kinds of wood, as Sumach, the zones are separated by a marked development of cellular tissue. The separation between the zones is owing to the interruption in the growth of the tree during autumn and winter, and hence it is well defined in trees of temperate and cold climates. But even in tropical trees, the lines, although often inconspicuous, are still visible,—the dry season, during which many of them lose their leaves, being their season of repose.

The woody layers vary in their texture at different periods. At first all the tissues are pervious and full of fluid; but by degrees they become thickened, and the channels of the vessels get filled up and obliterated. The first-formed layers are those which soonest become thus

altered. In old trees there is a marked division between the central *heart-wood* or *duramen*, and the external *sap-wood* or *alburnum*,—the former being hard and dense, and often coloured, with its tubes dry and thickened, while the latter is less dense, is of a pale colour, and has its tubes permeable by fluids. The difference of colour between these two kinds of woods is often very marked. In the Ebony tree the duramen or perfect-wood is black, and is the part used for furniture, while the alburnum is pale; in the Beech, the heart-wood is light-brown; in the Oak, deep-brown; in Judas tree, yellow; in Guaiacum, greenish. The alteration in colour is frequent in tropical trees. In trees of temperate climates, called *white-wood*, as the Willow and Poplar, no change in colour takes place; this is also the case in the Chestnut and Bombax. The relative proportion of alburnum and duramen varies in different trees. The heart-wood is more useful than the sap-wood, and is less liable to decay.

From the mode in which the woody layers are formed, it is obvious that each vascular zone is moulded upon that which precedes it; and as, in ordinary cases, each woody circle is completed in the course of one year, it follows that, by counting the concentric circles, the age of a tree may be ascertained. Thus fig. 75 represents an oak eight years old, having eight woody layers *b*. This computation can only be made in trees having marked separations between the circles. There are, however, many sources of mistake. In some instances, by interruption to growth, several circles may be formed in one year, and thus lead to an erroneous estimate. Care must be taken to have a complete section from the bark to the pith, for the circles sometimes vary in diameter at different parts of their course, and a great error might occur from taking only a few rings, or circles, and then estimating for the whole diameter of the tree. When by the action of severe frost, or other causes, injury has been done to the tender cells from which the young wood is developed, while, at the same time, the tree continues to live, so as to form perfect woody layers in subsequent years, the date of the injury may be ascertained by counting the number of layers which intervene between the imperfectly formed circle and the bark. Inscriptions made in the wood become covered, and may be detected in after years when a tree is cut down; so also wires or nails driven into the wood. As the same development of woody layers takes place in the branches as in the stem of an exogenous tree, the time when a branch was first given off may be computed by counting the circles on the stem and branch respectively. If there are fifty circles, for instance, in the trunk, thirty in one branch and ten in another, then the tree must have been twenty years old when it produced the first, and forty when it formed the other.

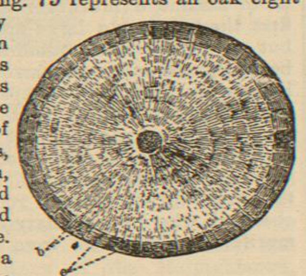

Fig. 75.

Horizontal section of the stem of an oak eight years old. *b*, wood, showing concentric circles or zones, separated by points which correspond to the opening of the large pitted vessels; *e*, bark, showing also eight concentric circles, thinner and less distinct. The wood and bark are traversed by medullary rays, some of which are the primary rays extending from the bark to the pith, while others (the secondary rays) reach only a certain way inwards.

In exogenous stems the pith is not always in the centre. The layers of wood on one side of a tree may be larger than those on the other, in consequence of their fuller exposure to light and air, or the nature of the nourishment conveyed, and thus the pith may become *excentric*. Zones vary in size in different kinds of trees, and at different periods of a plant's life. Soft wooded trees have usually broad zones, and old trees form smaller zones than young ones. There are certain periods of a plant's life when it seems to grow most vigorously, and to form the largest zones. This is said to occur in the Oak between twenty and thirty years of age.

Cambium.—External to the layers of wood, and between them and the bark, there is a layer of thin-walled cells in which the protoplasm and cell-sap remain, and consequently they are capable of division and growth. To this layer the name of *cambium* has been given. This cambium layer marks the separation between the wood and the bark, and may be regarded as constituting the active formative tissue of Dicotyledonous stems. It constitutes the *thickening zone*, by means of which the stem is enlarged,—the cambium cells situated most internally being subservient to the purposes of the wood formation, while the external ones give origin to the new bark. When these cells are carrying on the process of growth with activity, during the flow of the sap in spring, the bark can be easily separated from the wood.

The *Bark* or *Cortical System* lies external to the wood, and, like it, consists of several layers. In the early state it is entirely cellular, and is in every respect similar to the pith; but as the fibro-vascular bundles are developed, the bark and pith are separated, and the former gradually becomes altered by the formation of secondary deposits. We find in the cortex, as in the wood portion of the stem, fibro-vascular along with cellular tissue. But the position and relative proportion of these two systems is reversed. In the bark the cellular system is external, and is much developed, while the fibro-vascular is internal, and occupies comparatively a small space. The cellular portion of the bark consists of an external layer, or *epiphlœum*, and the cellular envelope, or *mesophlœum*, while the vascular system forms the internal portion called *liber*, or *endophlœum*.

The *endophlœum*, liber, or inner bark, is formed from the secondary cortex of the young stem. It consists mainly of thick or thin walled woody fibres, commonly known as bast-fibres, mixed with elongated cellular tissue and frequently with laticiferous vessels. It is separated from the wood by the cambium layer. The pleurenchymatous tubes are thickened so as to be flexible, but are not lignified, and are thus very tenacious. The endophlœum of the Lime-tree and of Antiaris saccidora (the Sack tree of Coorg) is used to form mats, cordage, and bags; and the toughness of the fibres of the inner bark of flax, hemp, and of many of the Nettle and Mallow tribes, render them fit for various manufacturing purposes. The endophlœum is sometimes, from its uses, called the *bast-layer*. Occasionally it is continuous and uninterrupted, as in the Vine and Horse-chestnut; at other times, as in the Oak, Ash, and Lime, the fibres are separated during the progress of growth, and form a sort of network, in the interstices of which the medullary rays are seen. The fibres of the Lace-bark tree (Lagetta lintearia) are similar. In fig. 76 is represented the bark of Daphne Laureola,—*f* indicating the woody fibres of liber, and *r* the medullary rays. The endophlœum increases by layers on its inside, which are thin, and may be separated like the leaves of a book. The outer layer of bast-fibres betwixt the endophlœum and the outer bark has been termed the *cortical sheath*, corresponding to the medullary sheath on the inside of the stem.

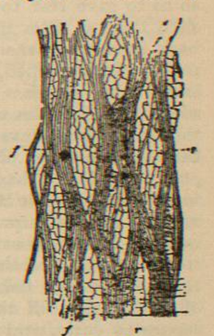

Fig. 76.

Network formed by liber of *Daphne Laureola*. *f*, *f*, fibrous bundles; *r*, *r*, medullary rays.

The outer bark is formed from the primary cortex; it is always cellular, and is divided into two layers, the epiphlœum with the mesophlœum underneath. The cellular envelope, or *mesophlœum*, lies immediately on the outside of the liber. It consists of polyhedral, often prismatical cells, elongated vertically to the surface, usually having chlorophyll, or green colouring matter, in their interior, but sometimes being colourless, and containing raphides. They are distinguished from those of the epiphlœum by their form and direction, by their thicker walls, their green colour, and the intercellular spaces which occur among them. This covering is usually less developed than the outer suberous layer, but sometimes, as in the Larch and common Fir, it becomes very thick, and separates like the epiphlœum. In the cellular envelope laticiferous vessels occur. The *epiphlœum* is the outer covering of the bark, consisting of cells which usually assume a cubical or flattened tabular form. The cells have no chlorophyll in their interior, are placed close together, and are elongated in a horizontal direction; and thus they are distinguished from the cells of mesophlœum. In the progress of growth they become often of a brown colour. This covering may be composed of a single layer of tabular cells; but in some trees it consists of numerous layers, forming the substance called *cork*, which is well seen in Quercus Suber, the Cork-oak; hence the name *suberous*, or *corky layer*, which is given to it. The form of its cells varies in some instances, being cubical at one part, and more compressed or tabular at another, thus giving rise to the appearance of separate layers. On the exterior of the epiphlœum is situated the epidermis, which has already been described. It is formed of a layer of cells, which in woody stems serve only a temporary purpose, becoming ultimately transformed in various ways.

The bark, in its increase, follows an order exactly the reverse of that which occurs in the woody layers. The layers of liber owe their increase to the cambium cells, which, by their constant reproduction, mark the separation between the xylem and phloëm portions of the stem. These layers are often so compressed and united together as to be counted with difficulty, while at other times they are separated by rings of cellular tissue, and thus remain conspicuous. As the additions are made to the woody layers on the outside, and to the bark on the inside, there is a constant distension going on, by which the bark becomes compressed, its layers of liber are condensed, the fibres are often separated (fig. 76) so as to form meshes, its epidermis is thrown off, and the epiphlœum is either detached along with it, or, when thick, is ruptured in various ways, so as to give rise to the rugged appearance presented by such trees as Elm and Cork-oak. In some instances the bark is very distensible, and its outer cellular covering is not much developed, so that the surface remains smooth, as in the Beech. The outer suberous layer sometimes separates with the epidermis, in thin plates or scales; in the Birch these have a white and silvery aspect. There is thus a continual destruction and separation of different portions of the bark. The cellular envelope and liber may remain while the epiphlœum separates, or they also may be gradually pushed off—the parts which were at first internal becoming external. In the case of some Australian trees both the cellular and fibrous portions are detached in the form of thin flakes, and occasionally each annual layer of liber pushes off that which preceded it. The epidermis separates early, and no renewal of it takes place. It is, however, replaced by the cork layer, which then covers the outer part of the stem. To this covering the name *periderm* is given.

From the mode in which the outer layers of bark separate, it follows that inscriptions made on them, and not extending to the wood, gradually fall off and disappear. A nail driven into these layers ultimately falls out. In consequence of the continued distension of an exogenous stem, it is found that woody twining plants cause injury, by interrupting the passage of the fluids. Thus a spiral groove may be formed on the surface of the stem by the compression exercised by a twining plant, such as Bush-rope (Bauhinia, fig. 77) or Honeysuckle. From what has been stated relative to the changes which take place in the bark, it will be understood that it is often difficult to count its annual layers, so as to estimate the age of the tree by means of them. This may, however, be done in some cases, as shown at fig. 75, where there are eight layers of bark *e*, and eight woody layers *b*.

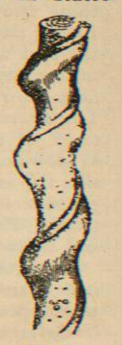

Fig. 77.

Stem of an Exogenous tree, surrounded by a woody climber called Bush-rope.

Medullary Rays or Plates.—While the bark and pith become gradually separated by the intervention of vascular bundles, the connection between them is kept up by means of processes called *medullary rays* (figs. 78 and 79). These form the *silver grain* in wood, so conspicuous in the maple; they communicate with the pith and the cellular envelope of the bark, and they consist of cellular tissue, which becomes compressed and flattened so as to assume a muriform appearance. At first they occupy a large space (fig. 72, *st*); but as the vascular bundles increase they become more and more narrow, forming thin laminæ or plates, which separate the woody bundles. On making a transverse or horizontal section of a woody stem, the medullary rays present the aspect of narrow lines running from the centre to the circumference (fig. 74); and on making a vertical section of a similar stem through one of the rays, the appearance represented in fig. 78 will be observed, where a medullary ray *mr*, composed of flattened muriform cells, passes from the pith *p* to the cellular envelope *ce*, crossing the tracheæ of the medullary sheath *t*, the ligneous tissue *l*, the pitted vessels of the wood *b*, and the fibres of the liber *cf*. The laminæ do not by any means preserve an uninterrupted course from the apex to the base of the tree. They are broken up by the intervention of woody fibres, as seen in a vertical section of a woody stem (fig. 79), tangentially to the medullary rays *mr*, *mr*, *mr*, which are separated by interlacing fibres *ll*. The primary medullary rays extend completely from the pith to the bark; but in the secondary wood and secondary cortex new rays are formed which, therefore, extend only through a portion of the stem. These are secondary medullary rays. All may increase by division of the merismatic cells of the cambium. Medullary rays are conspicuous in the Cork-Oak, Hazel, Beech, Ivy, Clematis, Vine. They are not so well marked in the Lime, Chestnut, Birch, Yew.

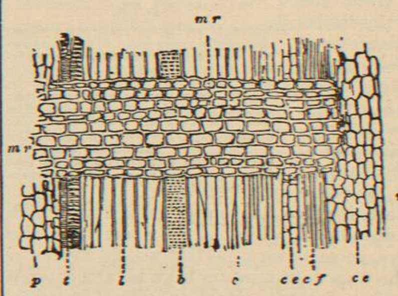

Fig. 78.

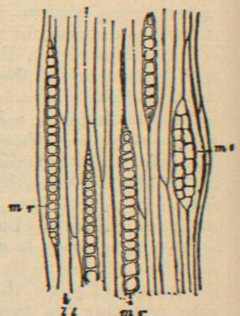

Fig. 79.

Fig. 78.—Vertical section of a young Dicotyledonous stem, parallel to the medullary rays.
Fig. 79.—Vertical section of the same, tangential to the medullary rays.

The medullary rays are in some cases, as in Clematis and Aristolochia, large and broad, while the woody wedges are comparatively small.

The stems of Dicotyledonous plants occasionally present anomalous appearances in the structure and arrangement of their wood, bark, and medullary rays. In place of concentric circles there are sometimes only a few rows of wedge-shaped vascular bundles produced during the life of the plant, additions being made by the annual interposition of bundles of a similar kind, resembling in this respect the formation of woody bundles in the early growth of herbaceous plants. In Piperaceæ, Aristolochiaceæ, and Menispermaceæ, these anomalous stems occur. In Gnetum (fig. 80), the vascular bundles, *b*, *b*, *b*, *b*, *b*, form zones, which are each the produce of several years' growth, and are separated by layers, *l*, *l*, *l*, *l*, *l*, *l*, which may be considered as representing different bast-layers. In some of the Menispermaceæ the separating layers are of a cellular and not of a fibrous nature. Many of the Malpighiaceæ, Sapindaceæ, and Bignoniaceæ of Brazil exhibit stems in which the woody layers are arranged in a very irregular manner. In some of them (fig. 81) there is a central woody mass with from three to ten small secondary ones round it. Each of the masses contains true pith, derived either from the cortical cellular tissue, or from the original medullary centre. Around these separate collections of pith there is a medullary sheath and spiral vessels. No annual rings have been detected in the secondary masses, but medullary rays exist usually in their outer portion. In some anomalous Sapindaceæ, the central and lateral woody masses are enclosed in a common bark, with a continuous layer of liber. Some have supposed that the lateral masses are undeveloped branches united together under the bark.

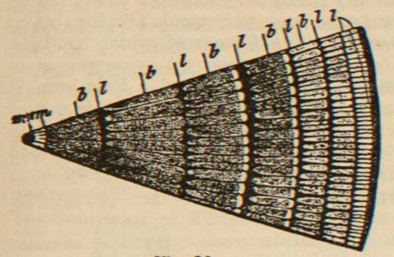

Fig. 80.

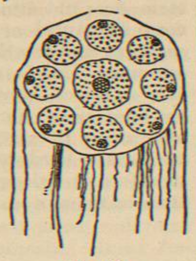

Fig. 81.

Fig. 80.—Horizontal section of stem of Gnetum. *m*, pith; *em*, medullary sheath; *b*, *b*, *b*, *b*, *b*, woody bundles forming seven concentric zones, each of which is the produce of several years; *l*, *l*, *l*, *l*, *l*, *l*, fibres of liber, forming interposed circles equal in number to the woody zones.
Fig. 81.—Peculiar stem of a Malpighiaceous plant of South America. The plant is Dicotyledonous.

In some Bignoniaceæ (fig. 82) the layers of wood are divided in a crucial manner into four wedge-shaped portions by the intervention of plates differing in texture from the ordinary wood of the plant, and probably formed by the introversion, or growing inwards, of the liber. In Aspidosperma excelsum (Paddle-wood) of Guiana, and in Heteropterys anomala, the stem assumes a peculiar lobed and sinuous aspect; and in some woody climbing plants pressure causes the stems to become flattened on the side next the tree on which they are supported, while from being twisted alternately in different directions, they present a remarkable zigzag form, having the woody layers developed only on one side (fig. 83). In Firs the wood is occasionally produced in an oblique in place of a perpendicular manner, thus injuring the timber and causing it to split in an unusual way. The young plants produced from the seed of such twisted-wooded firs are said to inherit the peculiarity of their parents. Occasionally the Dicotyledonous stem becomes swollen at certain places, especially near the root, and thus exhibits a tuberous appearance. This peculiarity is said to be liable to occur in Coniferous plants grown from cuttings. In some of the lower class of plants a cellular stalk is produced, which on a transverse section presents an appearance like that of a Dicotyledonous stem. Thus Lessonia fuscescens, a species of sea-weed, has stems which are often 5 to 10 feet long, and as thick as the human thigh, and which show concentric elliptic cellular rings. Such is also the case with Usnea melaxantha, a tree-like lichen. In these plants, however, the structure is entirely cellular, and quite distinct from that of Dicotyledonous plants.

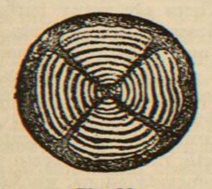

Fig. 82.

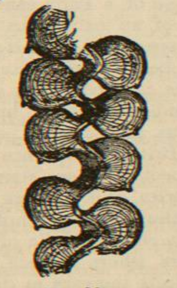

Fig. 83.

Fig. 82.—Horizontal section of the stem of *Bignonia capreolata*, showing the crucial division of the woody layers.
Fig. 83.—Fragment of a stem of a climbing species of Banisteria (*B. scandens*), showing the effects of compression.

In the young stem of a Monocotyledonous plant the fibro-vascular bundles appear scattered in an irregular manner through the fundamental parenchyma, becoming more numerous towards the periphery. There is thus no primary separation in the stem into pith, cortex, and medullary rays, although the central cellular mass may be considered as representing the pith. Thus, if a section be made across a young Monocotyledonous stem, an appearance is observed such as is represented in fig. 84, where the vessels are seen as points scattered through a cellular matrix, the circumference not having any marked cortex, and the whole covered by an epidermis. A similar section of a further advanced stem, as of a Palm (fig. 85), shows numerous bundles of vessels dispersed irregularly in cellular tissue; those near the centre, *m*, being scattered at a distance from each other, while those towards the outside are densely aggregated, forming a darkish zone *b*, and are succeeded at the circumference by a paler circle of less compact vessels *l*, with some compressed cells, covered by an epidermis *e*. The central cellular mass has no medullary sheath. In some cases its cells are ruptured, and disappear during the progress of growth, leaving a hollow cavity; but in general it remains permanent, and is gradually encroached upon by the development of the vascular system. The peripheral portion differs from *true* bark in not being separable from the rest of the tissue. It has received the name of *false* bark, and consists of the epidermal cells *e*, and what has been called the cortical integument, *l*. This

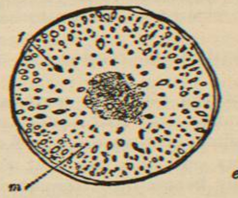

Fig. 84.

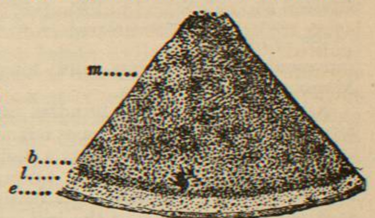

Fig. 85.

Fig. 84.—Transverse section of the stem of a Palm, which is Monocotyledonous *m*, the central loose cellular portion; *f*, the outer fibrous portion, showing numerous vascular bundles. The whole being covered by a false bark or rind.
Fig. 85.—Transverse section of the stem of a Palm, more advanced.

portion of the stem is often very inconspicuous, but sometimes it is much developed, as in Testudinaria Elephantipes, in which it is rugged, and is formed of a substance resembling cork in many respects. The fibro-vascular bundles of the stem very soon become closed, and thus all growth in them ceases, the cambium cells being converted completely into permanent tissue. Fig. 57 represents a transverse section of a closed fibro-vascular bundle from the stem of the maize (Zea Mays). In it the several elements seen in the section of the fibro-vascular bundle from a Dicotyledonous stem may be recognized, but there is no cambium, the cells marked *v*, *v* representing those cambiform cells which have last become permanent tissue. This absence of cambium necessarily curtails the growth of the bundle, and hence the limited diameter characteristic of the stems of Monocotyledons. In fig. 86 a diagram

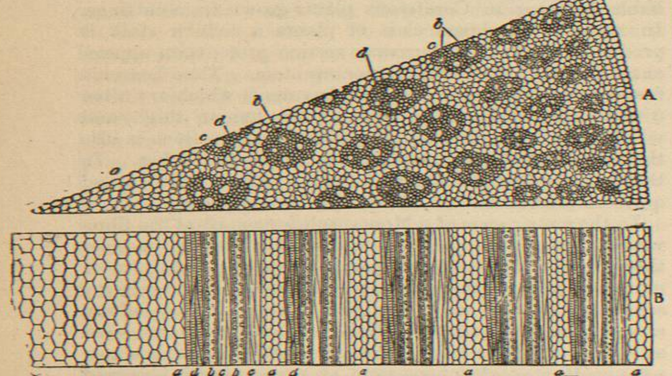

Fig. 86.

Diagram of a Monocotyledonous stem. A, transverse section; B, longitudinal section; *a*, *a*, cellular tissue (Parenchyma); *b*, *b*, dotted vessels (Bothrenchyma); *c*, *c*, woody fibres (Pleurenchyma); *d*, *d*, spiral vessels (Trachenchyma). (*After Carpenter.*)

represents a transverse and longitudinal section of a Monocotyledonous stem.

All the fibro-vascular bundles of the stem are *common* bundles, that is, they pass out into the leaf, and in these stems each bundle has a definite arrangement. At the point where the bundle curves out into the leaf it has its greatest thickness, gradually becoming attenuated as it passes upwards into the leaf and downwards into the stem. In some instances, however, the bundles as they descend increase at different parts of their course, probably by interstitial growth, and give rise to irregular swellings of the stem, as in Ceroxylon Andicola. The distension takes place occasionally at the base of the stem, as in Euterpe montana. This downward prolonged portion does not, however, run a straight course, but first passing inwards towards the centre of the stem, it then gradually arches outwards towards the periphery. This passing inwards at first of the fibro-vascular bundle gave origin to the idea that the first formed fibres were gradually pushed towards the circumference by those which succeeded them, and that the wood portion of these stems was increased by additions to the centre; hence the term endogenous applied to them, meaning internal growth. But, as has been shown, the fibro-vascular bundles really become external at the base, although internal above. On making a vertical section of the endogenous stem, as of a Palm (fig. 87), there is observed an interlacing of fibres, the fibro-vascular bundles are first directed towards the centre, and then curve outwards towards the circumference, so that those last formed ultimately become external. The term endogenous will, therefore, only apply strictly to the fibres at the early part of their course. The true distinction between exogenous and endogenous stems is, that in the former the fibro-vascular bundles remain open, a cambium ring being eventually formed from which the stem increases indefinitely in diameter. In the latter the fibro-vascular bundles soon become closed, and being scattered irregularly through the cellular tissue, and not in a circle, no cambium ring can be formed, and thus growth in a transverse direction is soon arrested, and the stem is of a comparatively uniform diameter throughout. The investing bark of the former permits an unlimited extension of woody growth beneath it; the fibrous cortical layer of the latter, by maintaining an intimate union with the subjacent tissue, prevents unlimited increase in diameter. Hence we find that the stem does not attain the enormous diameter exhibited by some Dicotyledonous trees, such as Sequoia (Wellingtonia) gigantea and the Baobab,—the former of which has been measured 116 feet in circumference. In consequence of this mode of formation, the outer part of a Palm-stem is the hardest and densest, and after acquiring a certain degree of firmness it resists all further distension, and frequently becomes so hard as to withstand the blow of a hatchet, and therefore a woody twining plant does less injury to it than to trees of exogenous growth (fig. 88). The growth

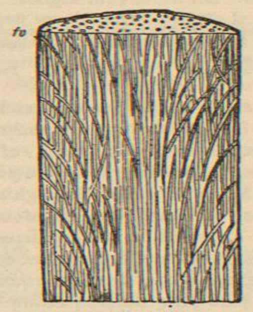

Fig. 87.

Fig. 88.

Fig. 87.—Vertical section of a Palm-stem, showing the vascular bundles, *fv* curving downwards and interlacing.
Fig. 88.—Monocotyledonous stem, surrounded by a twining woody plant, and remaining uninjured.

of endogenous stems may be said to resemble an upward growth of an exogen by the terminal bud only, for there is no cambium layer, and no peripherical increase. The terminal central bud is called a *phyllophor* or *phyllogen*. As growth only proceeds in this manner, no annual rings of wood are formed. From the absence of concentric circles the age of a Palm cannot be estimated in the same way as that of an exogenous tree. The elongation, however, of each species of Palm is pretty regular, and by this some idea may be formed of its age. There are many herbaceous plants in Britain, as Lilies, Grasses, &c., having Monocotyledonous stems, but there are no British Monocotyledonous plants with permanent aerial woody stems. All the British trees are Dicotyledonous. Illustrations of Monocotyledonous stems must be taken from trees of other countries, and of these Palms furnish the best examples.

Although this limited growth in a transverse direction is characteristic of most Monocotyledons, we find instances where a true thickening ring is formed and an indefinite increase in diameter takes place, as in Dracæna, Yucca, &c. This thickening ring, however, originates in a manner different from that in Dicotyledonous plants. A layer of the fundamental cellular tissue parallel to the surface of the stem becomes merismatic, and produces new closed fibro-vascular bundles and new cellular tissue

between them. The new woody tissue so formed thus corresponds to the secondary wood in Dicotyledonous stems, and the new fibro-vascular bundles are all cauline, that is, do not pass out into the leaves. By this means an enormous increase in diameter of the stem may take place. And not unfrequently the primary central portion of the stem gives way, and thus a hollow cylinder formed by this secondary wood remains. This was well seen in the famous Dracæna Draco, or Dragon tree of Orotava, in the Canary Islands, which had a hollow stem capable of holding several men.

The composition of the vascular bundles in different parts of their course varies. Thus, at the upper part, tracing them from the leaves towards the centre, they contain spiral vessels, pitted vessels with some cellular tissue, a few laticiferous vessels, and woody fibres resembling those of liber. As we descend to the older portions of the bundle, where the tissues have become permanent throughout, the spiral vessels disappear, then the pitted vessels, and at the periphery nothing but pleurenchymatous tissue remains, forming a complicated anastomosis or network. Not unfrequently at the nodes of the stem a network of horizontal vessels occurs. They are well seen in many Grasses, where the central portion of the stem has given way, and there they serve to strengthen the stem. The branching of Monocotyledonous stems is originally the same as in Dicotyledons, namely, a monopodial form; frequently however, the axillary buds do not unfold, and the form becomes much varied. In Palms this is well seen, and usually no lateral shoots are formed. In some Palms, however, as the Doum Palm of Egypt (*Hyphæne thebaica*), the lateral shoots are developed in such a way that the stem appears to fork. Other examples of the development of branches are seen in the case of the Screw-pine (*Pandanus*), in Grasses, as the Bamboo, in Asparagus, Cordyline, Dracæna, &c. In some instances the axillary shoots detach themselves from the parent stem and form an independent plant, as in Lilium bulbiferum (fig. 71). The bases of the leaves produced from the stem remain attached to the stem in many Palms, being surrounded by a fibrous substance, the *mattulla or reticulum*.

When the internodes of the caudex of a Palm are not much elongated, the scars of the leaves are seen forming spirals on the stem, as in the Coco-nut and Date. In Xanthorrhœa Hastile the same arrangement is observed. In this plant also a curious internal structure of the stem occurs. On making a vertical section the structure appears to be that of a Dicotyledon. The woody part is formed of vertical loose fibres as in Palms, and there are other fibres, radiating from the centre, and cutting the preceding at right angles. These horizontal fibres resemble the medullary rays, but differ in their structure. They probably serve for the origin of leaves, which are numerous, and are disposed throughout the whole length of the stem. In Palms, such as species of Chamædorea, the internodes are much lengthened, and rings are seen on the stem at distant intervals, showing thickened node-like joints. Some Palm stems, as those of Calamus Rudentum, the common Cane, are very thin and slender. In many Monocotyledonous plants the stem remains below ground, developing shoots which are simple, as in Banana and Plantain, or branched, as in Asparagus. In the former the stem above ground is an herbaceous shoot, composed of the sheaths of the leaves. It dies after fruiting, and is succeeded by other shoots from the subterranean stem. The shoots or buds from such stems occasionally remain in part below ground in the form of bulbs, as in Lilies, Tulips, and Hyacinths; or as corms, as in Colchicum, Crocus, Gladiolus, and Arum. In some instances the aerial stem has the usual Monocotyledonous structure, while in the underground stem the fibro-vascular bundles are arranged in a circle, enclosing a central cellular mass or pith, and thus resembling in structure a Dicotyledonous stem. This structure has been remarked in the Smilax or Sarsaparilla family. Lindley calls these plants *Dictyogens*, from their netted leaves, by which they differ from most Monocotyledons.

Amongst Acotyledonous plants there are some which possess stems consisting entirely of cellular tissue, whilst in others the stems have a well-developed vascular system. Of the former we have examples in Mosses, Hepaticæ, and Characeæ; the latter we find represented in Ferns, Equisetaceæ, and Lycopodiaceæ. The term *Acrogenous* has been used as descriptive of the stems of Acotyledonous plants, as they were supposed to be formed by additions to the summit, and by the elongation of vessels already formed. They are also sometimes called *Acrobrya*. But as in the case of the terms exogenous and endogenous applied to the stems of Dicotyledons and Monocotyledons respectively, recent research has shown that the term acrogenous cannot have the significance formerly attached to it; for in some Acotyledonous plants a true cambium ring is formed by which layers of tissue are successively added, and the stem increases in diameter, and also in many instances the fibro-vascular bundles develop from above downwards. The characters of the stem, however, enable us easily to distinguish it from that in Dicotyledons or Monocotyledons. With merely a slight exception there is no provision for lateral growth of the stem, and all increase in size takes place by an elongation of the terminal growing-point. No cambium ring is as a rule formed; where it does exist, it is not produced in the same way as in Dicotyledons, but rather resembles the formation of the cambium ring in Dracæna amongst Monocotyledons. When a permanent woody stem occurs amongst Acotyledonous plants it resembles in general aspect the stem of a Monocotyledonous plant, having nearly a uniform height, and being usually unbranched and producing a tuft of leaves (fronds) at the summit. Tree-ferns furnish the best example of this kind of stem. In them it is denominated a *stipe*, and it often attains the height of 120 feet. The stem in Acotyledonous plants is distinguished from that in Dicotyledons by the absence of annual rings of wood, of (with only slight exception) a cambium ring, of a separable bark, and by the fact that the fibro-vascular bundles are all closed; in this latter character they agree with Monocotyledons, but are distinguished from them by the arrangement of the vascular bundles.

In Acotyledonous stems growth takes place by division of a single apical cell, situated at the extreme end of the punctum vegetationis. By divisions of this cell two portions of tissue are marked out in the stem,—an inner portion, from which arise the fibro-vascular tissues when they exist, and an outer or cortical portion. The primary fibro-vascular bundles originate from the cellular tissue of the stem in a manner analogous to what occurs in Dicotyledons and Monocotyledons,—a procambial bundle being first formed, which differentiates subsequently into xylem and phloëm layers, but the bundles always become closed. The character of the stem varies very much in the several families of Acotyledonous plants.

In Characeæ the stem consists of a series of joints (internodes), each composed of a single much elongated cell. Interposed between successive internodes are the nodes, each composed of a whorl of small cells, from which the leaves are developed, one leaf from every cell of the node. In the genus Chara a cortex is found completely investing the internodal cell. It is formed by the development, from every cell, of the nodes of an ascending and descending lobe. The ascending lobes of one node and the descending lobes of the next higher node meet in the middle of the intervening internode, and there interlock in