the wild flowers, which, by entering the female flowers, caused them to set and ripen. The process was called palmification. Theophrastus, who succeeded Aristotle in his school in the 114th Olympiad, frequently mentions the sexes of plants, but he does not appear to have determined the organs of reproduction. Pliny, who flourished under Vespasian, speaks particularly of a male and female Palm, but his statements were not founded on any real knowledge of the organs. From Theophrastus down to Cæsalpinus, who died at Rome in 1603, there does not appear to have been any attention paid to the reproductive organs of plants. Cæsalpinus had his attention directed to the subject, and he speaks of a halitus or emanation from the male plants causing fertility in the female.

Grew seems to have been the first to describe, in a paper on the *Anatomy of Plants*, read before the Royal Society in November 1676, the functions of the stamens and pistils. Up to this period all was vague conjecture. Grew speaks of the *attire*, or the stamens, as being the male parts, and refers to conversations with Sir Thomas Millington, Savilian professor at Oxford, to whom the credit of the sexual theory seems really to belong. Grew says that, "when the attire or apices break or open, the globules or dust falls down on the seedcase or uterus, and touches it with a prolific virtue." Ray adopted Grew's views, and states various arguments to prove their correctness in the preface to his work on European plants, published in 1694. In 1694 Camerarius, professor of botany and medicine at Tübingen, published a letter on the sexes of plants, in which he refers to the stamens and pistils as the organs of reproduction, and states the difficulties he had encountered in determining the organs of Cryptogamic plants. In 1703 Samuel Morland, in a paper read before the Royal Society, stated that the farina (pollen) is a congeries of seminal plants, one of which must be conveyed into every ovum or seed before it can become prolific. In this remarkable statement he seems to anticipate in part the discoveries afterwards made as to pollen tubes, and more particularly the peculiar views promulgated by Schleiden. In 1711 Geoffroy, in a memoir presented to the Royal Academy at Paris, supported the views of Grew and others as to the sexes of plants. He states that the germ is never to be seen in the seed till the apices (anthers) shed their dust; and that if the stamina be cut out before the apices open, the seed will either not ripen, or be barren if it ripens. He mentions two experiments made by him to prove this—one by cutting off the staminal flowers in Maize, and the other by rearing the female plant of Mercurialis apart from the male. In these instances most of the flowers were abortive, but a few were fertile, which he attributes to the dust of the apices having been wafted by the wind from other plants.

Linnæus was the next botanical author who took up the subject, and by his sexual system he may be said to have opened a new era in the history of botany. He first published his views in 1736, and he thus writes—"Antheras et stigmata constituere sexum plantarum, a palmicolis, Millingtono, Grewio, Rayo, Camerario, Godofredo, Morlando, Vaillantio, Blairio, Jussievio, Bradleyo, Royeno, Logano, &c., detectum, descriptum, et pro infallibili assumptum; nec ullum, apertis oculis considerantem cujuscunque plantæ flores, latere potest." He divided plants into sexual and asexual, the former being Phanerogamous or flowering, and the latter Cryptogamous or flowerless. In the latter division of plants he could not detect stamens and pistils, and he did not investigate the mode in which their germs were produced. He was no physiologist, and did not promulgate any views as to the embryogenic process. His followers were chiefly engaged in the arrangement and classification of plants, and while descriptive botany made great advances the physiological department of the science was neglected. His views were not, however, adopted at once by all, for we find Alston stating arguments against them in his *Dissertation on the Sexes of Plants.* Alston's observations were founded on what occurred in certain unisexual plants, such as Mercurialis, Spinach, Hemp, Hop, and Bryony. The conclusions at which he arrives are those of Pontedera, that the pollen is not in all flowering plants necessary for impregnation, for that fertile seeds can be produced without its influence. He supports parthenogenesis in some plants. Soon after the promulgation of Linnæus's method of classification, the attention of botanists was directed to the study of Cryptogamic plants, and the valuable work of Hedwig on the reproductive organs of Mosses made its appearance in 1782. He was one of the first to point out the existence of certain cellular bodies in these plants which appeared to perform the functions of reproductive organs, and to them the name of antheridia and pistillidia were given. This opened up a new field of research, and led the way in the study of Cryptogamic reproduction, which has since been much advanced by the labours of numerous botanical inquirers. The interesting observations of Morland, already quoted, seem to have been neglected, and no one attempted to follow in the path which he had pointed out. Botanists were for a long time content to know that the scattering of the pollen from the anther, and its application to the stigma, were necessary for the production of perfect seed, but the stages of the process of fertilization remained unexplored. The matter seemed involved in mystery, and no one attempted to raise the veil which hung over the subject of embryogeny. The general view was, that the embryo originated in the ovule, which was in some obscure manner fertilized by the pollen.

In 1815 Treviranus roused the attention of botanists to the development of the embryo, but although he made valuable researches, he did not add much in the way of new information. In 1823 Amici discovered the existence of pollen tubes, and he was followed by Brongniart and Brown. The latter traced the tubes as far as the nucleus of the ovule. These important discoveries mark a new epoch in embryology, and may be said to be the foundation of the views now entertained by physiologists, which have been materially aided by the subsequent elucidation of the process of cytogenesis, or cell-development, by Schleiden, Schwann, Mohl, and others. The whole subject has been investigated recently with great assiduity and zeal by physiologists, as regards both Cryptogamous and Phanerogamous plants. The formation of germinal vesicles in the ovule, and the development of the embryo in flowering plants, have been fully considered by Griffith, Schleiden, Mirbel, Spach, Meyen, Schacht, Mohl, Unger, Naudin, Radlkofer, and others; the embryogenic process in Coniferous plants and in the higher Cryptogams by Hofmeister, Henfrey, Suminski, Mettenius, Strasburger, Eichler, Baillon, Cohn, Pringsheim, Millardet; and that of the lower Cryptogams by Thuret, Bornet, Decaisne, and Tulasne. The observations of Darwin as to the fertilization of Orchids, Primula, Linum, and Lythrum, and the part which insects take in this function, have opened up a new era in Physiological Botany. He has been followed by Hermann Müller. Darwin's experiments in reference to the movements of climbing and twining plants, and of leaves in insectivorous plants, have opened up a wide field of inquiry which he has cultivated with eminent success and with most important results. Among other authors who have contributed to the advance of Vegetable Physiology may be named Hoffmann, Sachs, Van Tieghem, Prillieux, Dehérain, and Famintzen. We have thus been enabled to come to certain general conclusions on this obscure subject, and

future observers have been directed in the proper path of investigation.

In the Physiological department of botany the most important researches have been made by French and German botanists. The laboratories in connection with schools in Germany offer facilities for study which do not exist to the same extent in Britain. Physiological researches demand not only a Botanic Garden with its appendages, but apparatus of various kinds, means of prosecuting histological and chemical investigations, physical experiments, and observations by the spectroscope. Our schools require then not only lecture-rooms, but laboratories well fitted up with all needful appliances, and salaried assistants to aid the teachers in their demonstrations and the pupils in their practical work.

The department of Geographical Botany has made rapid advance by means of the various scientific expeditions which have been sent to all quarters of the globe; and the question of the mode in which the floras of islands and of continents have been formed has given rise to important speculations by such eminent botanical travellers as Darwin and Hooker. The latter has published a valuable paper on insular floras. Under this department the connection between climate and vegetation has been carefully studied both by botanists and by meteorologists. Among the contributors to this department of botany the following authors may be noticed—Humboldt, Schouw, Meyen, Berghaus, Martius, Harvey, Hooker.

The subject of Palæontological Botany has been much advanced of late by the researches of botanists and geologists. The use of the microscope in the examination of tissues has aided much in the determination of fossil plants. The more accurate study of Organography has also been the means of correcting errors in diagnosis. The nature of the climate at different epochs of the earth's history has also been determined from the character of the flora. The works of Brongniart, Goeppert, and Schimper have advanced this department of science. Among others who have contributed valuable papers on the subject may be noticed Heer, who has made observations on the Miocene flora, especially in Arctic regions; Saporta, who has examined the Tertiary flora; Dawson and Lesquereux, who have reported on the Canadian and American fossil plants; and Williamson, who has made a careful examination of many of the coal fossils, and whose excellent drawings of structure have opened a new light on the character of many of the genera. Delineations of fossils by Witham, Lindley and Hutton, and Carruthers, have tended much to advance our knowledge of the fossil flora of Britain.

Botany may be divided into the following departments:—1. *Structural* Botany, having reference to the anatomical structure of the various parts of plants, including Vegetable Histology, or the microscopic examination of tissues; 2. *Morphological* Botany, the study of the form of plants and their organs—(these two departments are often included under the general term of Organography); 3. *Physiological* Botany, by some termed Organology, the study of the life of the entire plant and its organs, or the consideration of the functions of the living plant; 4. *Systematic* Botany, the arrangement and classification of plants; 5. *Geographical* Botany, the consideration of the mode in which plants are distributed over the different regions of the globe; 6. *Palæontological* Botany, the study of the forms and structures of the plants found in a fossil state in the various strata of which the earth is composed.

In the present article we shall confine our attention to the Structure and Morphology of Plants. The limits and classification of the Vegetable Kingdom have been partly considered under BIOLOGY (vol. iii. pp. 690–696). The Classification of Plants will be taken up *in extenso* under the heading VEGETABLE KINGDOM, and the Distribution of Plants in space and time will be treated of in separate articles.

STRUCTURAL ELEMENTS OF PLANTS.

The elementary structure which is the foundation of all vegetable tissue is the *cell.* In the young succulent bud of a growing stem each cell consists of an outer firm, elastic membrane of cellulose constituting a *cell-wall;* within this, a gelatinous soft mass of *protoplasm,* of which there may be a portion distinctly marked off as a *nucleus;* and, enclosed by the protoplasm, a cell-cavity containing a more or less watery fluid, the *cell-sap* (fig. 1). Such may be taken as the structure of a typical vegetable cell, which is thus a closed vesicle or sac with fluid or semi-fluid contents. Of these elements of the cell the protoplasm is that which is essential for its growth and development. In it are contained all the substances requisite for the formation of the cell-wall and the cell-sap; and the nucleus is merely a differentiated portion of it. From it then all the other parts of the cell are formed, and it is essential to the growth of the cell. Hence it has received the appellation of *primordial cell;* and, indeed, amongst many Algæ it exists for some time as a separate cell without any cell-wall or other part. This must be borne in mind when defining the cell as a sac or vesicle. The growth of the cell is usually, at first, uniform throughout, and it has therefore a more or less rounded form; but, according to the function which it is destined eventually to perform, one or other, or it may be all, of the parts of the cell become modified or specially developed. The cell-wall may be greatly thickened; or it may grow more in one direction than another, so as to be elongated and form protuberances; or perforations may occur; or several similar cells arranged in a longitudinal series may, by obliteration of the interposed septa, unite to form a long tube which is then called a *vessel.* The protoplasm in the process of growth may be completely absorbed; and when this occurs growth ceases and the cell-walls form merely a framework. It may, however, remain a long time, assuming various shapes and often uniting with colouring matters. The cell-sap also may disappear or may remain, containing in solution, or as definite forms in its mass, various assimilative substances, as fat granules, oil globules, starch, mineral crystals, &c.

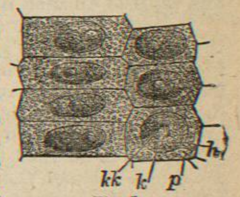

Fig. 1.

Young cells from root of *Fritillaria imperialis.* *h*, cell-wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleolus. (*Sachs.*

In some plants, as amongst Algæ (Protococcus), one cell alone performs all the functions necessary for the existence of the plant. We have thus in this cell an epitome of vegetable life, and this is the most perfect form of cell. As we pass to the higher forms of plants, where many cells are united, we find a physiological specialization taking place, by which certain cells are set apart for assimilation, some being embryonal, some supporting, and others protective, &c. Amongst such plants as Ferns and ordinary Flowering Plants a further differentiation takes place, and some of these cells unite to form true vessels. We thus have a means of arranging all plants in two groups, viz., those whose tissues consist entirely of cells, *cellular plants* (including Fungi, Algæ, Mosses, &c.); and those in which vessels are present, *vascular plants* (including Ferns, Lycopods, and ordinary Flowering Plants).

1. *Cells and Vessels—Cellular and Vascular Tissues.*

Cells united together constitute *cellular tissue* (fig. 2

It exists in all plants and abounds in fleshy roots, stems, leaves, and in succulent fruits. It constitutes the pith and outer bark of trees, and is very abundant in the centre of the stem of the Aralia (Fatsia) papyrifera, whence Chinese rice-paper is derived by cutting it into thin sheets. By cultivation the Turnip, Carrot, Cabbage, and other esculent vegetables acquire much cellular tissue, and become tender and succulent. The cells of the tissue vary much in size. In a cubic inch of a leaf of the Carnation there are said to be upwards of three millions of cells. They are frequently seen $\frac{1}{1000}$th, $\frac{1}{500}$th, and $\frac{1}{300}$th of an inch in diameter. In some of the Cucumber tribe, and in the pith of aquatic plants, cells $\frac{1}{50}$th and $\frac{1}{30}$th of an inch in diameter occur.

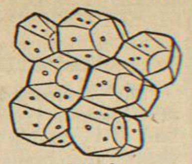
Fig. 2.
Hexagonal complete cellular tissue from the pith of the Elder.

In young cells the cell-wall is a thin membrane consisting of *cellulose*, with some water and a certain amount of incombustible material. It is permeable by water, is slightly extensible and elastic, and is colourless. It dissolves in sulphuric acid, and upon addition of iodine and sulphuric acid assumes a deep blue colour. By intussusception of nutrient material, *i.e.*, the interposition of new molecules between those pre-existing, the cell-wall increases both in surface-extent and in thickness. The resulting cell-wall is not, however, uniform in its structure, but is composed of lamellæ of different refractive power, in which the cellulose is combined alternately with much and with little water. These alternating dense and watery layers,—of which one set is concentric with the cell-wall, whilst two other series are vertical or oblique to the surface of the cell-wall, and cut the concentric ones throughout the whole thickness of the wall,—under a high power of the microscope present a series of mutually intersecting lines, and constitute respectively what are termed the *stratification* and *striation* of the cell-wall.

Independently of these changes in the structure of the cell-wall, consequent on its increase in surface-extent and thickness, which will be presently noticed, there are other changes of a chemical nature which take place during the growth of the cell, and which so affect its wall as to break it into distinct "shells," which differ both chemically and physically from the original cell-wall. Thus, in the epidermis or outer cellular covering of plants, the outermost portion of the outer wall of the cells becomes converted into an elastic substance, quite impervious to water, which acts as a protective covering. This substance is known as cork or cuticular matter. Another alteration is the conversion of the layers of the cell-wall into woody matter, by a process of *lignification*, or formation of wood. Or, again, layers of the cell-wall may be converted into mucilaginous substance, *i.e.*, absorbing water, and becoming gelatinous, as in the cells of pith of Astragalus Tragacantha,—which furnishes gum tragacanth,—and the outer cells of the seed of the Common Flax. Lastly, mineral matters may be deposited in the cell-wall, such as lime, silica, &c., so abundantly in some instances as to constitute, after burning, a perfect skeleton of the cell-wall. In all these cases, however, of alteration of layers of the cell-wall, an innermost layer, giving all the reactions of pure cellulose, may be observed. If growth in surface-extent proceeded uniformly over the whole of a cell-wall the resulting structure would be a more or less rounded vesicle; but at different points portions grow more rapidly than at others, and thus cells, originally oval or spherical, may become cylindrical, conical, &c. The changes consequent on unequal growth in thickness are, however, much more important, giving rise to altered appearances both on the outside and inside of the cell-wall. The external thickenings are most usually projections in the form of spines, knobs, &c., as in some pollen-grains, and in cilia connected with the reproductive cells of many Algæ (fig. 3), or club-shaped hygrometric filaments as in Equisetum (figs. 4, 5); whilst the internal ones are more usually ridges—annular, spiral, or reticulate (figs. 11 and 12)—which may proceed so far as almost to obliterate the cavity of the cell-wall.

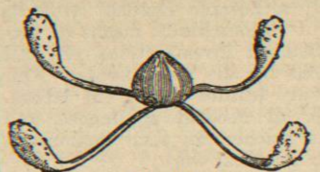
Fig. 3.

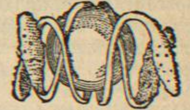
Fig. 4.

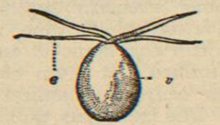

Fig. 5.

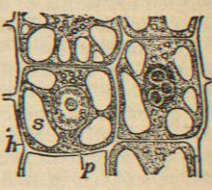

Fig. 6.

Figs. 3 and 4.—Spore or reproductive cell of Equisetum, Horsetail, with two clavate hygrometric filaments. In fig. 3 the filaments are expanded in a dry state; in 4 they are curled round the spore on the application of moisture.
Fig. 5.—Cell *v*, with vibratile filaments or cilia *c*, from Chætophora.
Fig. 6.—Older cells than those represented in fig. 1. *h*, cell-wall; *p*, protoplasm with nucleus and nucleolus; *s*, vacuoles in the protoplasm filled with fluid cell-sap. (*Sachs.*)

The *protoplasm*, which lines the interior of the cell-wall, and which is the essential living portion of the cell, consists of albuminous substance mixed with water and some incombustible materials, and it also contains some organic compounds. It is a homogeneous, soft, gelatinous substance. As we usually find it in cells it has a granular and turbid appearance. This arises from an admixture of formative matters, to which the name *metaplasm* has been applied. It is coagulated by heat, and is soluble in a dilute solution of caustic potash; iodine solution colours it yellow or brown, whilst strong sulphuric acid at first colours it rose-red, subsequently dissolving it. Usually, at points in the interior, drops of fluid become differentiated as *vacuoli* (fig. 6), which may subsequently coalesce, and thus the protoplasm may become a sac containing cell-sap; and if growth of the cell-wall continues the protoplasm eventually forms a mere lining of the cell-wall constituting the *primordial utricle* of Von Mohl. The protoplasm in some cells exhibits phenomena of movement within the cell-wall of a definite character. Thus in the internodal cells of Characeæ (fig. 7) a movement of protoplasm round the longest diameter of the cell is seen, and in the hairs of Tradescantia (Virginian Spiderwort) a circulation of protoplasm occurs. These constitute the phenomena of *rotation* and *circulation*.

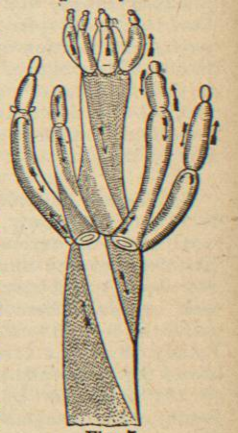
Fig. 7.
A small portion of a Chara magnified to show the intracellular circulation. The arrows mark the direction of the course of the protoplasm in the cells. The clear spaces are parts where there is no movement.

The nucleus (fig. 1, *k*) is present in the cells of all the higher plants. It is a small rounded differentiated portion of the protoplasm, and frequently contains vacuoles, which are termed *nucleoli* (fig. 1, *kk*). It may be in the centre of the cell or close to the sides, but it may change its position. Portions of the protoplasm are also differentiated as grains or granules, to which colouring matters are attached; but these will be noticed hereafter. The protoplasm in old cells may disappear, and then all growth ceases, and the cells consist of a mere framework; or it may remain, and then growth of the cell continues. And it is by a re-arrangement of the molecules of this protoplasm that the formation of new cells begins,—the nucleus entering also into the process.

By the term cell-sap is meant the fluid contained in the vacuoli. It consists in great part of water, in which are dissolved various salts, derived from without, and compounds formed by assimilation in the plant itself. Amongst the latter we may mention inulin, a substance closely allied to starch and sugar, found in Composite plants.

The term *parenchyma* (areolar, utricular, or vesicular tissue) is a general name for any form of cellular tissue, in which thin-walled cells of a diameter nearly equal in every direction are united to one another by broad surfaces (fig. 2). If the cells are pointed at both ends and have a length greatly exceeding their breadth, there is formed *prosenchyma* (fig. 8). Both tissues may be *complete* (figs. 2 and 8) or *incomplete* (figs. 9 and 10), *i.e.*, the component cells may touch each other on every side and leave no intercellular spaces, or intercellular spaces may exist between the cells. According to the amount of surface-growth and thickening of the cell-wall various forms of parenchymatous and prosenchymatous tissue result. Thus, in the Rush and Bean we have a stellate parenchyma, with large intercellular spaces (fig. 10), in the Elder pith a complete angular parenchyma (fig 2), and in the succulent stem of the Cactus a spherical incomplete parenchyma (fig. 9). Those forms of tissue in which the individual cells have been altered by thickening of the cell-wall are the most important; and the alterations in the cell-wall consequent on growth in thickness may be such as to produce obliteration of the septum between superposed cells, and their cavities, freely communicating, then give rise to a tube or vessel, a combination of which constitutes the *vascular tissue* of authors. Whilst this is the nature of a true vessel, considerable confusion has arisen from the term being applied to any cell-like structure in which the longitudinal diameter exceeds the transverse; and thus the difference between a cell and a vessel became one of length only. The term vessel ought to be restricted to such as are formed by coalescence of cells.

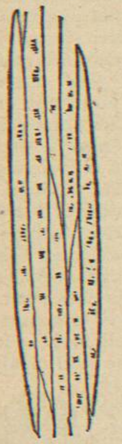
Fig. 8.


Fig. 9.

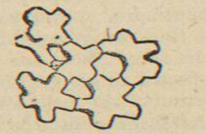
Fig. 10.

Fig. 8.—Prosenchymatous cells. Fig. 9.—Incomplete parenchyma.
Fig. 10.—Stellate or star-like cellular tissue of the Bean, with intercellular spaces or lacunæ.

Under the term *pleurenchyma* (fig. 8) is included tissue composed of such elongated prosenchymatous, flexible, thickened cells, as are found in the bast or phloëm layers of ordinary trees. They also occur in the wood portion. Their walls are thickened regularly, and they constitute when united what is commonly known as the woody or bast fibre. The diameter of the woody fibres varies from $\frac{1}{2000}$th to $\frac{1}{230}$th of an inch. The materials used for ropes and cordage, linen, certain Indian muslins, mummy-cloths, and mats consist of the woody fibre of plants from which the more delicate tissues have been removed by maceration in water. Flax or lint is thus procured from the bark of Linum usitatissimum, hemp from Cannabis sativa, New Zealand flax from Phormium tenax, Pita flax from Agave americana, Sun-hemp from Hibiscus cannabinus, and bass or bast from the common Lime or Linden-tree. Fibres are also procured for manufacture from the Pine-apple plant (Ananassa sativa), from Yucca gloriosa, from Böhmeria nivea, which yields the Indian Rheea fibre, from most of the plants belonging to the Mallow and Nettle tribes, and from some Leguminous plants, such as Crotalaria juncea, which supplies a kind of Bengal hemp. If the maceration of the fibre is carried to a great extent, a pulp is formed from which paper is manufactured. Pleurenchyma does not occur in cellular plants, such as Lichens, Sea-weeds, and Mushrooms. The tissues of these plants speedily disappear under the action of water, and hence, perhaps, the reason of their rarity in a fossil state. In the very young state woody cells are delicate, and it is only in proportion as they attain maturity that their walls acquire a thick consistence. In the sap-wood of ordinary trees the woody cells are thickened in their walls, but are pervious; while in the heart-wood they are rendered solid by the thickening matter, which is often variously coloured.

If the thickening of the cell-wall takes place so that a network, ring, or spiral of thickening matter is formed, then the cells are *reticulated*, *annular* (fig. 11), or *spiral* (fig. 12), as in the leaves of Sphagnum, hairs of Cactaceæ, and seed-coat of Casuarina. In these cells the spiral thickening frequently becomes loosened from the cell-wall as a spiral fibre, and can be unrolled. Such forms occur in the outer covering of the seed of Collomia linearis and of the fruit of Salvia Verbenaca. In these, when placed in water, the spirals rupture the softened membrane of the cells, and spread outwards. The spongy elastic character of the outer cellular covering of the roots of tropical Orchids and Araceæ, of the sepals of Illecebrum verticillatum, of the pericarp of Cachrys Morisoni and C. odontalgica, and of the ribs of the fruit of Æthusa Cynapium, is due to the presence of spiral cells. In the reproductive cells of Hepaticæ spiral fibres called *elaters* are found in connection with the spores. Reticulated or netted cells, produced by fibres forming a sort of mesh or network, occur in the wing of the seed of Swietenia, in the pericarp of Picridium tingitanum and P. vulgare, in the seed-coat of Cucurbita Pepo, in the parenchyma of the leaf of Sanseviera guineensis, and in isolated cells of the pith of Rubus odoratus and of Erythrina Corallodendron.

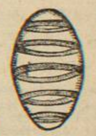
Fig. 11.


Fig. 12.

Fig. 11.—Annular cell from the Mistleto.
Fig. 12.—Spiral cell from an Orchid.

If spiral, annular, or reticulated cells are arranged in a longitudinal series, and the septum between adjoining cells gives way, then we have a spiral, annular, or reticulated vessel (figs. 13, 15, 16) formed, and to this tissue authors have given the name *trachenchyma*, on account of its resemblance to the tracheæ or air-tubes of animals. These vessels vary from $\frac{1}{3000}$th to $\frac{1}{300}$th of an inch in diameter. The spiral thickened portion of the wall of the vessel may become loosened from the membrane of the wall and form a spiral fibre in the interior. These fibres are elastic, usually rounded and simple; but sometimes two or more are combined so as to form a flat band. These flat ribands, consisting of fibres which vary in number from two to twenty-five, or more, are met with abundantly in the stems of Bananas and Plantains, and in the shoots of Asparagus. The spiral in such cases is called compound, and the vessels *pleiotracheæ*. The spiral fibres have such tenacity that when the vessels are ruptured they can be pulled out. This capability of being unrolled characterizes true spiral vessels (fig. 13). When the spiral is not loosened from the cell-wall and cannot therefore be unrolled, it is said to be *closed*. On breaking the young shoots or leaf-stalks of the Geranium, Strawberry, and Rose, or the leaves of the Hyacinth, Amaryllis, and Banana, and pulling the parts gently asunder, the fibres can be easily seen in the form of a fine cobweb. When the aerial stems of the Banana and Plantain are cut across, the spiral fibres may be pulled out in large quantity so as to be used for tinder. Generally, the coils or volutions of the fibre are said to be left-handed, that is, turning to the left of a person supposed to be in the axis. In the garden Lettuce vessels are met with, some having the fibre turning to the left, others to the right. In the Scarlet Bean the coils of the fibres are left-handed, while the plant itself turns to the right in twining. Spiral vessels are abundant in young plants and shoots, while in the hard stems of trees and shrubs they chiefly surround the pith. Spiral vessels occasionally exhibit a branched appearance. This may arise from the union of separate vessels, or it may depend on a regular division of the fibres, as is seen in the Mistleto, House-leek, and Gourd (fig. 14). *Annular* vessels are those in which the thickening (or, if it be loosened from the wall of the vessel, the fibre) is in the form of rings (fig. 15). These rings in Mammillaria quadrispina, and in some other plants of the Cactus tribe, are very thick, and leave only a small canal in the centre of the vessel. Annular vessels are from $\frac{1}{800}$th to $\frac{1}{400}$th of an inch in diameter. In *reticulated* vessels (fig. 16) the thickenings take the form of a network. All vessels of this type lose very early their protoplasmic contents, and serve to convey air.

Fig. 13.

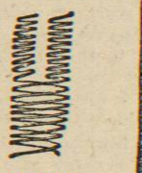

Fig. 14

Fig. 15.

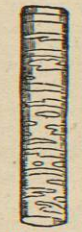

Fig. 16.

Fig. 13.—Spiral vessels of the Melon, showing the elastic fibres uncoiled, and the vessels overlapping at their pointed extremities *a*.
Fig. 14.—Branching fibre, from spiral vessels of Gourd (*Cucurbita Pepo*).
Fig. 15.—An annular vessel taken from the Melon plant.
Fig. 16.—Reticulated vessel taken from the Melon plant.

In the process of thickening of the cell-wall, if large spaces of the cell-wall remain thin, and the thickening mass growing in a circular manner projects into the interior of the cell and gradually arches over the thin portion of cell-wall, a dome-shaped cavity is enclosed betwixt the thin cell-wall and the thickening mass. The growing thickening mass gradually contracts the opening into this cavity, but never completely closes it. On front view this presents the appearance of two concentric circles, an outer marking the edge of the original thin portion of the cell-wall, and an inner indicating the under edge of the gradually contracting ring of thickening matter (fig. 17). When this process takes place on opposite sides of the partition wall between two cells, there are then two similar cavities separated by the thin partition wall of the cells, each communicating freely by a small circular aperture with the cell in which it has been formed (figs. 17 and 18). In process of growth the partition wall is absorbed, and then a lenticular cavity is formed, connected by a circular aperture on each side with adjacent cells (fig. 19). When viewed by transmitted light these present the appearance seen in fig. 17 *t′*; such structures are termed *bordered pits*, and a collection of such cells constitutes the *disk-bearing or punctated tissue* of authors. It is well seen in Firs and other cone-bearing plants. It has been called *glandular* tissue. In the case of some fossil woods, pieces of silica, like double convex lenses, have been found in the cavities. When a vertical radial section is made of the stem of Fir, bordered pits, arranged in two rows, with individual pits on the same level, are seen. In Araucaria double and triple alternating rows are seen; whilst in the Yew a prominent striation line winding spirally amongst the pits is noticeable. When the thickening begins by the formation of transverse ridges extending right across the wall of the cell, and the inwardly projected ridges gradually arch over the thin membranous portion of the wall, a narrow fissure only is left leading into the cavity enclosed by the thickening masses and the thin portion of the partition wall, on the opposite side of which a similar process has proceeded. By the absorption of the partition wall a single cavity between two cells is thus produced, communicating with both, just as in the last case. Viewed by transmitted light these present an appearance like rungs of a ladder, and hence the name *scalariform* applied to the cells in which they occur (fig. 20). They are specially seen in Ferns, where they give rise to long prismatic vessels.

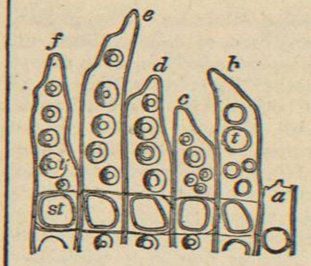

Fig. 17.

Fig. 18.

Fig. 19.

Fig. 17.—Radial longitudinal section of wood of *Pinus sylvestris*. *a*, cambium; *b*, *c*, *d*, *e*, *f*, wood cells; *t*, bordered pits in an early stage of formation, before the thickening ring has arched over the thin portion of cell-wall; *t′*, bordered pit after the thickening mass has arched over the thin cell-wall; *st*, very large pits where in contact with medullary rays.
Fig. 18.—Diagram to show thickening dome on both sides of the partition wall.
Fig. 19.—Partition wall has given way and a single cavity is formed, communicating on both sides with adjacent cells. (*These figures after Sachs.*)

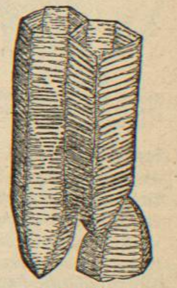

Fig. 20.

Scalariform or ladder-like prismatic vessels of a Tree Fern.

When the thickening takes place over nearly the whole of the cell-wall, thin portions may be left here and there, which appear as pits when viewed by transmitted light,

or as small canals when the cell-wall is very thick. Such cells are termed *porous* or *pitted* or *dotted* cells (fig. 21). In old cells, after the protoplasm has disappeared, the portion of the cell-wall which remained thin is often absorbed, and thus there is a true perforation of the cell-wall. These perforations often occur in groups both upon the cell-wall and upon the septum between superposed cells, and give rise to a remarkable sieve-like structure, in which case they are termed *sieve-cells*. The *latticed cells* of some authors are of a similar nature. When superposed porous or sieve-cells coalesce by complete obliteration of the septum, then a *pitted vessel*, *sieve tube*, or *duct* is formed (fig. 22). These ducts are usually of a larger size than other vessels; they are well seen in the inner phloëm layers and in the wood of trees, and they constitute the large rounded openings which are seen in the transverse section of the stems of the Oak, Poplar, Willow, &c. They also abound in the Bamboo (fig. 23), and in other plants of rapid growth. The names of *bothrenchyma* and *taphrenchyma* have been given to a tissue composed of such cells. Not unfrequently contractions are visible on the outside of the vessel (fig. 22), indicating its formation by coalescence of superposed cells. To vessels exhibiting contractions of this kind, whether spiral or pitted, the terms *moniliform* and *vermiform* have been applied; and the tissue composed of these moniliform vessels has been denominated *phleboidal*. In the ducts of many plants a remarkable appearance is produced by the protrusion, through the perforations into the cavity of the vessel, of portions of the adjoining cells, or, before its absorption, of the portion of partition-wall closing the pit. These portions appear as cells filling the interior of the vessel, and are described under the name of *tylosis* (fig. 24). It is well seen in the Walnut, Chestnut, Oak, &c.

Fig. 21.

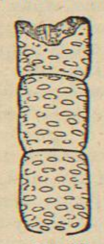

Fig. 22.

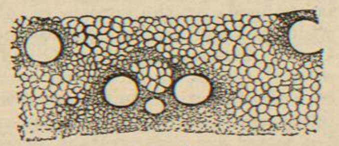

Fig. 23.

Fig. 21.—Porous or pitted cell from the Mistleto.
Fig. 22.—Moniliform dotted or pitted vessel from the Melon.
Fig. 23.—Section of a Bamboo, showing an angular network of cells, and the round apertures of pitted vessels.

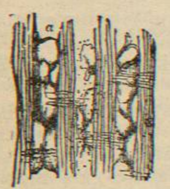

Fig. 24

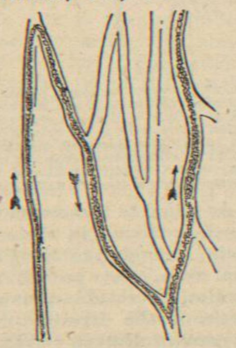

Fig. 25.

Fig. 24.—Longitudinal section of the stem of a species of Walnut (*Juglans cinerea*), showing tylosis in pitted vessels, *a*.
Fig. 25.—Branching and anastomosing laticiferous vessels. The arrows make the direction of the current.

Laticiferous vessels (fig 25) consist of long branching tubes or passages, having a diameter of about $\frac{1}{1400}$th of an inch, forming, by their union, an anastomosis or network, like the veins of animals. They are the *milk* vessels and the *proper* vessels of old authors. They receive their name from containing an emulsion called *latex*, of a granular nature, often milky or coloured. They are seen in the India-rubber and Gutta-percha plants, the Mudar plant, the Cow-tree, Spurges, Dandelion, Lettuce, Chicory, and Celandine, frequently containing a large quantity of caoutchouc. Usually these vessels are thin-walled, but sometimes slightly thickened. They are found most abundantly in the phloëm layers—rarely in the xylem or wood layers (Papayaceæ). They are the result of the coalescence of anastomosing or rectilinear rows of cells, and sometimes they seem to have resulted from the conversion of other vessels. In some Araceæ they seem to represent spiral vessels. In Asclepiadaceæ they are evidently bast-fibres. Some consider them as merely intercellular canals. The milky sap of Euphorbia phosphorea is said to be luminous. The latex exhibits movements which have given origin to the name *cinenchyma* applied to laticiferous tissue by some authors. Those movements, classed under the name *cyclosis*, must not be confounded with the motion of protoplasm in cells which is designated rotation.

We have seen that the cellular tissue is sometimes incomplete, that is, the cells do not touch on every side (fig. 9). The intervening spaces are called *intercellular spaces*, and these may be either circumscribed cavities called *lacunæ*, or they may extend for some length through the tissue as *intercellular canals;* but these two structures pass into one another. In the earliest stage of development the tissue is always complete, and these spaces are formed subsequently by a splitting of the partition or common wall of the cells, and they may subsequently be increased in size by an absorption of the investing cells. These lacunæ and canals may contain air, especially in aquatic plants, to give them buoyancy, as in Potamogeton (fig. 26), or they may be receptacles for various secretions, and when they exist as canals they usually aid in conducting sap. The intercellular canals are exceedingly well seen in coniferous plants, where they constitute resin passages, forming a continuous system throughout the plant, and arranged at intervals in concentric circles in the xylem or wood portion of the stem.

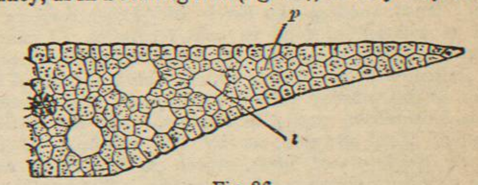

Fig. 26.

Vertical section of the leaf of Potamogeton or Pondweed, showing air cavities or lacunæ *l*, and parenchymatous cells *p*, with granules.

Chlorophyll is the green colouring-matter of plants. It occurs in the cells of the superficial parts of plants united with small portions of the protoplasm (*chlorophyll bodies*), which are combined into grains of various forms. Starch-grains are usually abundant in the chlorophyll bodies. Chlorophyll is soluble in alcohol and ether. It consists of four substances, two yellow and two green, which possess distinct optical properties. It gives a black band in the red of the spectrum. Physiologically it is very important. It is developed under the action of light, and undergoes changes according to its state of oxygenation. Hence the varied tints of leaves in autumn. Numerous colouring matters occur in plants, especially in flowers, and all such when not green are included under the general term *chromule*. Starchy and oily matters and albuminoids occur very abundantly in the cells of plants, where they are stored