character, it has received the name of *sarcosperm* or *sarcoderm*. The nature of the testa depends upon that of the pericarp. When the pericarp is dehiscent then the seed-covering is of a strong and tough character; but when

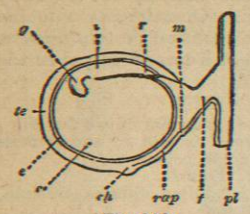

Fig. 308.

Fig. 309.

FIG. 308.—The seed of the Pea (*Pisum*), deprived of one-half of its integument or spermoderm. The outer covering, called either episperm, exosperm, or testa, is marked *te*, the inner, called endopleura, *e*. Within these integuments is the nucleus, consisting of cotyledons or seed-lobes *c* containing nourishing matter, the gemmule or young leaf-bud *g*, the radicle or young root *r*, the tigelle or stalk between root and bud *t*. The seed is attached to the placenta *pl* by a cord or funiculus *f*. The nourishing vessels *rap* enter the nucleus at the chalaza *ch*, and the root of the embryo points to the micropyle or foramen *m*.

FIG. 309.—Seed of Asclepias, with a cluster of hairs arising from the edges of the micropyle, and by some considered as a hairy aril. These hairs are for the purpose of scattering the seed.

the pericarp is indehiscent and encloses the seed for a long period, its outer covering has a proportional softness. The cells of the testa are often coloured, and have projections and appendages of various kinds. Thus in Abrus precatorius and Adenanthera pavonina it is of a bright red colour; in French beans it is beautifully mottled; in the Almond it is veined; in the Tulip and Primrose it is rough; in the Snapdragon it is marked with depressions; in Cotton and Asclepias (fig. 309) it has hairs attached to it; and in Mahogany, Bignonia, and Firs it is expanded in the form of wing-like appendages (fig. 310). In Collomia, Acanthodium, and other seeds, it contains spiral cells, from which, when moistened with water, the fibres uncoil in a beautiful manner; so also in Çobæa scandens and Calempelis scaber. In the testa of the seed of Ulmus campestris the cells are compressed, and their sinuous boundaries are traced out by minute rectangular crystals adhering to their walls; and in such plants as the Flax (Linum) the cells are converted into mucilage. These structural peculiarities of the testa in different plants have relation to the scattering of the seed and its germination upon a suitable nidus. But in some plants the pericarps assume structures which subserve the same purpose; this especially occurs in small pericarps enclosing single seeds, as achenes, caryopsides, &c. Thus in Compositæ (fig. 197) and Valerian, the pappose limb of the calyx forms a parachute to the pericarp; in Labiatæ and some Compositæ spiral cells are formed in the epicarp; and the epicarp is prolonged as a wing in Fraxinus (fig. 281) and Acer (fig. 296).

The endopleura (fig. 308, *e*) is usually a thin and transparent layer of cells underneath the testa, frequently incorporated with it. It represents the outer layer of the cells of the nucleus, constituting the tercine of the ovule, though frequently the embryo-sac is incorporated with it. Sometimes there is an additional covering to the seed, formed after fertilization, to which the name *arillus* has been given (fig. 311). This is seen in the Passion-flower, where the covering arises from the placenta or extremity of the funiculus at the base of the ovule and passes upwards towards the apex, leaving the micropyle uncovered. In the Nutmeg and Spindle-tree this additional coat commences at the side of the exostome, and is formed from above downwards, constituting in the former case a laciniated scarlet covering called *mace*. In such instances it has been called by some an *arillode* (fig. 312). This arillode, after growing downwards, may be reflected upwards so as to cover the foramen. The fleshy scarlet covering formed around the naked seed in the Yew is by some considered of the nature of an aril. On the testa, at various points, there are produced at times cellular bodies, which are not dependent on fertilization, to which the name of *strophioles*, or *caruncules*, has been given, the Plate II fig. 5.
seeds being strophiolate or carunculate. These tumours may occur near the base of the seed, as in Polygala, or at the apex, as in Ricinus, where they are swellings of the exostome; or they may occur in the course of the raphe, as in Blood-root and Asarabacca. The funiculi of the ovules frequently attain a great length in the seed, and in some Magnolias, when the fruit dehisces, they appear as long scarlet cords suspending the seeds outside. The hilum or umbilicus of the seed is usually well marked, as a scar of varying size, in the Calabar bean and in some species of Macuna and Dolichos, extending along a large portion of the edge of the seed; and it frequently exhibits marked colours, being black in the Bean, white in many species of Phaseolus, &c. The *micropyle* (fig. 308, *m*) of the seed, with its exostome and endostome, may be recognizable by the naked eye, as in the Pea and Bean tribe, Iris, &c., or it may be very minute or microscopic. It indicates the true apex of the seed, and is important as marking the point to which the root of the embryo is directed. At the micropyle in the Bean is observed a small process of integument, which, when the young plant sprouts, is pushed up like a lid, and is called *embryotega*. The chalaza (fig. 311, *ch*) is often of a different colour from the rest of the seed. In the Orange (fig. 313) it is of a reddish-brown colour, and is easily recognized at one end of the seed when the integuments are carefully removed. In anatropal seeds the raphe forms a distinct ridge along one side of the seed (fig. 314).

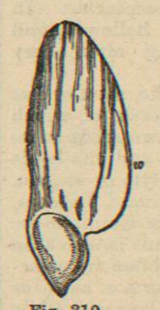

Fig. 310.

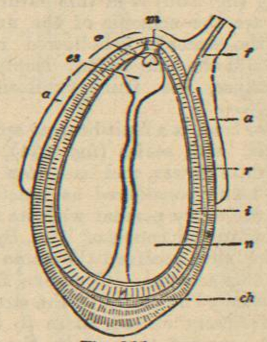

Fig. 311.

Fig. 312.

Fig. 313.

FIG. 310.—Seed of Fir (*Pinus*), with a membranous appendage *w* to the testa, called a wing. The seed is said to be winged.

FIG. 311.—Young anatropal seed of the White Water-lily (*Nymphæa alba*), cut vertically. It is attached to the placenta by the funiculus or umbilical cord *f*, cellular prolongations from which form an aril *a a*. The vessels of the cord are prolonged to the base of the nucleus *n* by means of the raphe *r*, composed of cells and spiral vessels. The base of the nucleus is indicated by the chalaza *ch*, while the apex is at the micropyle *m*. The covering of the seed is marked *t*. *n* is the nucleus or perisperm, surrounded by its covering, and enclosing the embryo-sac *es*, in which the endosperm is formed. The embryo *e*, with its suspensor, is contained in the sac, the radicle pointing to the micropyle *m*.

FIG. 312.—Arillode *a*, or false aril, of the Spindle-tree (*Euonymus*), arising from the micropyle *f*.

FIG. 313.—Anatropal seed of the Orange (*Citrus Aurantium*) opened to show the chalaza *c*, which forms a brown spot at one end.

The position of the seed as regards the pericarp resembles that of the ovule in the ovary, and the same terms are applied—erect, ascending, pendulous, suspended, curved, &c. These terms have no reference to the mode in which the fruit is attached to the axis. Thus the seed may be erect while the fruit itself is pendent, in the ordinary meaning of that term. The part of the seed next the axis or the ventral suture is its *face*, the opposite side being the *back*. Seeds exhibit great varieties of form. They may be flattened laterally (*compressed*), or from above

downwards (*depressed*). They may be round, oval, triangular, polygonal, rolled up like a snail, as in Physostemon, or coiled up like a snake, as in Ophiocaryon paradoxum.

The endosperm formed in the embryo-sac of angiosperms after fertilization, and found previous to it in gymnosperms, consists of cells containing protoplasmic substance and starchy or fatty matter, or both, destined for the nutriment of the embryo. It arises by free-cell division from the protoplasm of the embryo-sac,—and may occupy the whole cavity of the embryo-sac, or may be formed only at certain portions of it, at the apex, as in Rhinanthus, at the base, as in Vaccinium, or in the middle, as in Veronica. As the endosperm increases in size along with the embryo-sac and the embryo, the substance of the original nucleus of the ovule is gradually absorbed, and usually at last disappears except the layer constituting the endopleura, and in some cases this goes also. Sometimes, however, as in Musaceæ, Cannaceæ, Zingiberaceæ, no endosperm is formed; the cells of the original nucleus, becoming filled with food-materials for the embryo, are not absorbed, but remain surrounding the embryo-sac with the embryo, and constitute the *perisperm*. Again, in other plants, as Nymphæaceæ (fig. 311) and Piperaceæ, both endosperm and perisperm are present. It was from observations on cases such as these that old authors, imagining a resemblance betwixt the plant-ovule and the animal ovum, applied the name *albumen* to the outer nutrient mass or perisperm, and designated the endosperm as *vitellus*. The term albumen is very generally used as including all the nutrient matter stored up as a separate mass in the ovule, but it would be advisable to discard the name as implying a definite chemical substance. There is a large class of plants in which although at first after fertilization a mass of endosperm is formed, yet, as the embryo increases in size, the nutrient matter from the endospermic cells passes out from them, and is absorbed by the cells of the embryo plant. In the mature seed, in such cases, there is no separate mass of tissue containing nutrient food-material apart from the embryo itself. Such a seed is said to be *exalbuminous*, as in Compositæ, Cruciferæ, and most Leguminosæ. When either endosperm or perisperm or both are present the seed is said to be *albuminous*.

The albumen varies much in its nature and consistence, and furnishes important characters. It may be *farinaceous* or *mealy*, consisting chiefly of cells filled with starch, as in cereal grains, where it is abundant; *fleshy* or *cartilaginous*, consisting of thicker cells which are still soft, as in the Coco-nut, and which sometimes contain oil, as in the oily albumen of Croton, Ricinus, and Poppy; *horny*, when the cell-walls are slightly thickened and capable of distension, as in Date and Coffee; and they sometimes become greatly thickened, filling up the testa as a hard mass, as in Vegetable Ivory. The albumen may be uniform throughout, or it
Plate XII. fig. 11. may present a mottled appearance, as in the Nutmeg, the seeds of Anonaceæ, and some Palms, where it is called *ruminated*. This mottled appearance is due to a protrusion of a dark lamella of the endopleura between folded protuberances of albumen. The endosperm within the embryo-sac is developed from the protoplasm of that sac, but in many cases as it grows inward the whole protoplasm is not converted into a solid mass, but a cavity is left in the centre which is usually filled with fluid, as in the Coco-nut. In the thickened albumen of this Palm, as well as in that of the Attalea funifera, the Date, and the Doum Palm, the small cavity in the centre and radiating spaces are well seen under the microscope. The albumen is a store of matter laid up for the nourishment of the embryo. The relative size of the embryo and of the endosperm varies much. In Monocotyledons the embryo is usually small, and the endosperm large, and the same is true in the case of Coffee and many other plants amongst Dicotyledons. The opposite is the case in other plants, as in the Labiatæ, Plumbaginaceæ, &c.

In angiosperms after fertilization the embryonal vesicle undergoes changes by which the embryo plant is eventually formed. The portion of the vesicle nearest the apex of the embryo-sac coalesces with it. The lower portion enlarges and lengthens greatly, and divides by transverse partition until a large terminal cell is formed at the extremity of a *suspensor or proembryo* (figs. 316, 317), formed of smaller cells. It is this terminal cell which immediately forms the

Fig. 314.

Fig. 315.

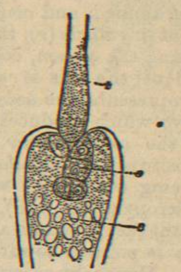

Fig. 316.

Fig. 317.

FIG. 314.—Entire anatropal seed of the Orange (*Citrus Aurantium*), with its rugose or wrinkled testa, and the raphe *r* ramifying in the thickness of the testa on one side.

FIG. 315.—Seed of Wallflower (*Cheiranthus*) cut vertically. The seed is exalbuminous or aperispermic—all the nourishing matter being incorporated with the cotyledons *c*. On removing the integument which is marked by the dark lines, the embryo alone is found in the interior. The radicle *r* is folded on the edges of the cotyledons, which are accumbent. The plant belongs to the division of Cruciferæ, called Pleurorhizeæ.

FIG. 316.—Section of the ovule of *Œnothera*, showing the pollen-tube *t*, with its enlarged extremity applied to the end of the embryo-sac, and introverting it slightly; the germinal vesicle in the sac has been impregnated, and has divided into two parts, the upper part forming a confervoid septate suspensor *s*, and the lower dividing into four parts, which form a globular mass—the rudimentary embryo, surrounded by endospermal cells *e*.

FIG. 317.—A Dicotyledonous embryo, in different stages of development, within the seed. At 1 it appears as a globular cellular mass at the extremity of a cellular cord or suspensor; at 2 it becomes more ovoid; it enlarges still more at 3; and at 4 it presents two distinct portions,—*a*, the radicle attached to the suspensor, and *b*, the two cotyledons.

embryo. By longitudinal growth the terminal cell becomes pushed into the endosperm (when present) of the sac, and becomes completely surrounded by it. In the lower part of the central cell of gymnosperms a cell is produced which divides until a proembryo is formed, which elongates and bursts through the central cell. The divisions in this proembryo take place so that several suspensors are formed, penetrating the endosperm. Usually, each of these elongates and bears a large cell at its extremity, which becomes an embryo; thus polyembryony occurs. The terminal cell of the proembryo in both angiosperms and gymnosperms increases in size, and divides repeatedly, until a cellular axis is formed. This is the rudiment of the embryo. Upon this axial mass, one, two, or more rounded cellular protuberances appear, the indications of the first leaves or cotyledons; and at the point where the embryo joins the proembryo is intercalated a mass of cellular tissue forming the *hypophysis*, from which subsequently the young root or radicle is formed. The axial mass continues to grow, and soon a differentiation is observable into an outer peripheral layer, the *dermatogen* or primordial epidermis, covering over the central mass, which soon is distinguishable into a *plerome* or axial mass, from which the fibro-vascular bundles develop, and a portion between it and the dermatogen,—the *periblem* or primordial cortex. After this has been formed a differentiation takes place in the hypophysis, by which an upper and a lower layer of cells is formed. The upper divides into two layers, the lower of which forms a continuation of the dermatogen of the axial mass, the upper being continuous with the central portion of the axis. The lowermost cells of the hypophysis form the first layer of the root-cap. Lateral roots are frequently given off from the embryo, especially in Monocotyledons, and these arise as cellular processes from the outer or pericambial layer of the plerome in the hypocotyledonary portion of the axis. The primary root of the embryo is, by reason of its formation, always directed to the micropyle. In Monocotyledons and some Dicotyledons the young root rises deep in the tissues of the embryo, which, when it sprouts, form a sheath or coleorhiza around it. The lateral roots have also sheaths.

The embryo then consists of *cotyledons* (figs. 52, 53, 58, *c*), or the first leaves of the plant produced upon a cellular axial mass. To that part of this axis immediately beneath the cotyledons the terms *hypocotyledonary portion, caulicle,* or *tigellus* (*t*) have been applied, and continuous backwards with it is the young root or *radicle* (*r*), the descending axis, their point of union being the *collum*, collar, or neck. The terminal growing bud of the axis is called the *plumule* or *gemmule* (*g*), and represents the ascending axis. That extremity of the embryo which produces the first leaves or cotyledons is called the *cotyledonary* extremity of the embryo, while the opposite is the *radicular* extremity. The radicular extremity being continuous with the suspensor points towards the micropyle (fig. 318), or the summit of the nucleus, an important fact in practical botany; while the cotyledonary extremity is pointed towards the base of the nucleus or the chalaza. Hence, by ascertaining the position of the micropyle and chalaza, the two extremities of the embryo can in general be discovered. In some rare instances, in consequence of a thickening in the coats of the seed, as in Ricinus and some other Euphorbiaceæ, there is an alteration in the micropyle, so that the radicle does not point directly to it. It is in many cases difficult to recognize the parts in an embryo; thus in Cuscuta, the embryo appears as an elongated axis without divisions; and in Caryocar butyrosum, the mass of the embryo is made up by the radicular extremity and tigelle, in a groove of which the cotyledonary extremity lies embedded. In some Monocotyledonous embryos, as in Orchidaceæ, the parts of the embryo of the ripe seed are not differentiated, and only become so after germination. In parasitic plants which form no chlorophyll, as Orobanche, Monotropa, &c., the embryo remains without differentiation, consisting merely of a mass of cells until the ripening of the seed. When the embryo is surrounded by the endosperm on all sides except its radicular extremity it becomes *internal* or *intrarius*; when lying outside the endosperm, and only coming into contact with it at certain points, it is *external* or *extrarius*. When the embryo follows the direction of the axis of the seed, it is *axile* or *axial* (fig. 318), and it may be either *external*, so as to come into contact with the endosperm only by its cotyledonary apex, or *internal*. In the latter case the radicular extremity may, as in some Coniferæ, become incorporated with the endosperm apparently by means of a thickened suspensor. When the embryo is not in the direction of the axis, it becomes *abaxile* or *abaxial*; and in this case it may be either straight or curved, internal or external. In campylotropal seeds the embryo is curved, and in place of being embedded in endosperm, is frequently external to it, following the concavity of the seed (fig. 319), and becoming *peripherical*, with the chalaza situated in the curvature of the embryo, as in Caryophyllaceæ

It has been already stated that the radicle of the embryo is directed to the micropyle, and the cotyledons to the chalaza. In some cases, by the growth of the integuments, the former is turned round so as not to correspond with the apex of the nucleus, and then the embryo has the radicle directed to one side, and is called *excentric*, as is seen in Primulaceæ, Plantaginaceæ, and many Palms, especially the Date. The position of the embryo in different kinds of seeds varies. In an orthotropal seed the embryo is inverted or *antitropal*, the radicle pointing to the apex of the seed, or to the part opposite the hilum. Again, in an anatropal seed the embryo is *erect* or *homotropal* (fig. 318), the radicle being directed to the base of the seed. In some anatropal seeds, as in Castor oil, the exostome is thickened or carunculate, and the endostome does not correspond exactly to it, so that the radicle of the embryo is directed to a point a little removed from the exostome. In curved or campylotropal seeds the embryo is folded so that its radicular and cotyledonary extremities are approximated, and it becomes *amphitropal*. In this instance the seed may be exalbuminous, and the embryo may be folded on itself; or albuminous, the embryo surrounding more or less completely the endosperm, and being peripherical. According to the mode in which the seed is attached to the pericarp, the radicle may be directed upwards or downwards, or laterally, as regards the ovary. In an orthotropal seed attached to the base of the pericarp it is superior, as also in a suspended anatropal seed. In other anatropal seeds the radical is inferior. When the seed is horizontal as regards the pericarp, the radicle is either centrifugal, when it points to the outer wall of the ovary; or centripetal, when it points to the axis or inner wall of the ovary.

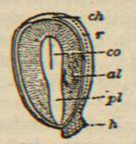

Fig. 318.


Fig. 319.

Fig. 320.

Fig. 321.

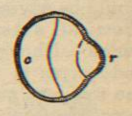

Fig. 322.

FIG. 318.—The seed of the Pansy (*Viola tricolor*) cut vertically. The embryo *pl* is axial, in the midst of fleshy albumen *al*. The seed is anatropal, and the embryo is homotropal; the cotyledons *co* point to the base of the nucleus or chalaza *ch*, while the radicle, or the other extremity of the embryo, points to the foramen, close to the hilum *h*. The hilum or base of the seed, and the chalaza or base of the nucleus are united by means of the raphe *r*.

FIG. 319.—Seed of the Red Campion (*Lychnis*), cut vertically, showing the peripherical embryo, with its two cotyledons and its radicle. The embryo is curved round the albumen, so that its cotyledons and radicle both come near the hilum. The embryo is sometimes called amphitropal.

FIG. 320.—Mature Dicotyledonous embryo of the common Almond, with one of the cotyledons removed; *r*, radicle; *t*, tigelle or caulicule; *c*, one of the cotyledons left; *ie*, cicatrix left at the place where the other cotyledon was attached; *g*, gemmule composed of several small leaves.

FIG. 321.—Transverse section of the seed of the Wallflower (*Cheiranthus*). The radicle *r* is folded on the edges of the cotyledons *c*, which are said to be accumbent.

FIG. 322.—Transverse section of the seed of the Dame's Violet (*Hesperis*) The radicle *r* is folded on the back of the cotyledons *c*, which are said to be incumbent

Plants in which there are two cotyledons produced in the embryo are *Dicotyledonous*. The form of this embryo varies much; and although sometimes resembling in its general aspect that of Monocotyledons, yet it is always distinguished by a division taking place at the cotyledonary extremity (fig. 317), by which two, more or less evident, lobes are formed. The two cotyledons thus formed are opposite to each other (figs. 58 and 320). The cotyledons are not always, however, of the same size. Thus, in a species of Hiræa, one of them is smaller than the other; and in Carapa guianensis there appears to be only one, in consequence of the intimate union which takes place between the two. The union between the cotyledonary leaves may continue after the young plant begins to germinate. Such embryos have been called *pseudo-monocotyledonous*. The texture of the cotyledons varies. They may be thick, as in the Pea (fig. 58), exhibiting only slight traces of venation, with their flat internal surfaces in contact, and their backs more or less convex; or they may be in the form of thin and delicate laminæ,

flattened on both sides, and having distinct venation, as in Ricinus, Jatropha, Euonymus, &c. In the former case they are called *fleshy*, or seminal lobes; in the latter, *foliaceous*, or seminal leaves. The cotyledons usually form the greater part of the mature embryo, and this is remarkably well seen in such exalbuminous seeds as the Bean and Pea.

Cotyledons are usually entire and sessile. But they occasionally become lobed, as in the Walnut and the Lime, where there are five lobes; or petiolate, as in Geranium molle; or auriculate, as in the Ash. Like leaves in the bud, cotyledons may be either applied directly to each other, or may be folded in various ways. In Geranium the cotyledons are twisted and doubled; in Convolvulus they are corrugated; and in the Potato and in Bunias, they are spiral,—the same terms being applied as to the foliage leaves. The radicle and cotyledons may be either straight or curved in various ways. Thus, in some Cruciferous plants, as the Wallflower, the cotyledons are applied by their faces, and the radicle (fig. 321) is folded on their edges, so as to be *lateral*; the cotyledons are here *accumbent*. In others, as the Hesperis, the cotyledons (fig. 322) are applied to each other by their faces, and the radicle, *r*, is folded on their back, so as to be *dorsal*, and the cotyledons are *incumbent*. Again, the cotyledons are *conduplicate* when the radicle is dorsal, and enclosed between their folds. In other divisions the radicle is folded in a spiral manner, and the cotyledons follow the same course.

In many gymnosperms more than two cotyledons are present, and they are arranged in a whorl. This occurs in Coniferæ, especially in the Fir (fig. 323), Spruce, and Larch, in which six, nine, twelve, and even fifteen have been observed. They are linear, and resemble in their form and mode of development the clustered or fasciculated leaves of the Larch. Plants having numerous cotyledons are occasionally denominated *polycotyledonous*. In the gymnospermous genus Welwitschia, there are two cotyledons which last throughout its life (more than a century), and in the course of time they grow to an enormous size, being sometimes six feet long and two or three feet in breadth. They constitute the only leaves of the plant. In species of Streptocarpus the cotyledons are also permanent, and act the part of leaves. One of them is frequently largely developed, while the other is small or abortive.

In those plants in which there is only a single cotyledon (fig. 53) in the embryo, hence called *Monocotyledonous*, the embryo usually has a cylindrical form more or less rounded at the extremities, or elongated and fusiform, often oblique. The axis is usually very short compared with the cotyledon, which in general encloses the plumule by its lower portion, and exhibits on one side a small slit which indicates the union of the edges of the vaginal or sheathing portion of the leaf (fig. 324). In Grasses, by the enlargement of the embryo in a particular direction, the endosperm is pushed on one side, and thus the embryo comes to lie outside at the base of the endosperm. The lamina of the cotyledon is not developed. Upon the side of the embryo next the endosperm and enveloping it is a large shield-shaped body, termed the *scutellum*. This is by some authors considered to be an outgrowth from the hypocotyledonary portion of the axis or expansion of the radicular extremity, enveloping more or less the cotyledon and plumule, in some cases, as in Maize, completely investing it; in other cases, as in Rice, merely sending small prolongations over its anterior face at the apex. By others this scutellum is considered as the true cotyledon, and the sheathing structure covering the plumule is regarded as a ligule or axillary stipule. In several other Monocotyledonous plants, as Ruppia and Zostera, this scutellar structure is well seen, and in these cases its homology, as an expansion of the radicular extremity of the embryo, is clearly discernible; and this is further borne out by such cases as that of Caryocar butyrosum among Dicotyledons, where the radicular swelling occupies most of the embryo (fig. 326). In some Grasses, as Oats and Rice, a projection

Fig. 323.

Fig. 324.


Fig. 325.

Fig. 326.

FIG. 323.—Polycotyledonous embryo of the Pine (*Pinus*) beginning to sprout. The axis *t* shows its radicular portion *r* and cotyledonary portion *c*. The cotyledons *c* are numerous. Within the cotyledons the primordial leaves are seen, constituting the plumule or first bud of the plant.

FIG. 324.—Embryo of a species of Arrow-grass (*Triglochin Barrelieri*), showing a uniform conical mass, with a slit *s* near the lower part. The cotyledon *c* envelops the young bud, which protrudes at the slit during germination. The radicle is developed from the lower part of the axis *r*.

FIG. 325.—Grain of Wheat (*Triticum*) germinating. The embryo lies at one side of the grain *g*. The radicular portion of the embryo gives off rootlets *r r r r r* covered with cellular hairs. The principal root is the central one; the others being developed subsequently in succession. The roots pass through sheaths *c c c*. The ascending axis *t*, sheathed in the cotyledon, rises upwards.

FIG. 326.—Embryo of *Caryocar butyrosum*. *t*, thick tigelle or caulicule, forming nearly the whole mass, becoming narrowed and curved at its extremity, and applied to the groove *s*. In the figure this narrowed portion is slightly separated from the groove; *c*, two rudimentary cotyledons.

of cellular tissue is seen upon the side of the embryo opposite to the scutellum, that is, on the anterior side. This has been termed the *epiblast*. It is very large in Rice. This by some was considered the rudimentary second cotyledon; but this is impossible, as it arises outside, and after the first cotyledon. It is merely an outgrowth of the radicular extremity like the scutellum. The radicular portion of the axis is usually shorter than the cotyledon, and more dense in structure; but in some instances it becomes much larger, giving rise to what has been called a *macropodous* embryo.

5. *Female Organs and Reproduction in Cryptogams.*

The female organs of reproduction, like the male organs, have not been demonstrated in all Cryptogams. In all vascular Cryptogams, and in Mosses and Hepaticæ, certain usually flask-shaped bodies, which have been termed *archegonia* or *pistillidia* (fig. 327), represent the female organs producing cells or spores, which germinate and form new plants (fig. 54). These archegonia have the general structure of a large cell, the *central cell* or *oosphere* (*c*) surrounded by a layer of smaller cells. From the apex of this oosphere leads a canal, which is bounded by four rows of small cells and constitutes the *neck*, and in it is a large cell full of soft mucilaginous matter, which has been formed from the central cell, and is the *canal cell*. Upon the wall of the oosphere, turned towards the neck, a small portion different from the surrounding part is the *receptive spot*. Fertilization is effected by the antherozoids freed from the antheridium, penetrating the neck of the archegonium, and eventually reaching the receptive spot of the central cell or oosphere; they then enter the oosphere and coalesce with it. The fertilized oosphere is termed an *oospore*, and it then may escape from the archegonium, and sooner or later germinates; or it germinates within the archegonial cells. These archegonia are, in vascular Cryptogams, produced upon a cellular expansion formed asexually from a spore, and termed the *prothallus* (fig. 245), which is of varying size and form. Both archegonia and antheridia may be formed on one prothallus, or only one form of organ may be produced, thus indicating a tendency to diclinism.

In Characeæ the female organ has a peculiar structure.

and is termed a *nucule* (fig. 240, *n*). This consists of a large *central cell*, of which the contents at the apex are clear and hyaline, while the lower part contains much starch and fat. Rising from its base and twisting round it are five long tubes (fig. 328), at the extremity of each of which

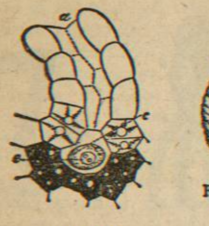

Fig. 327.

Fig. 328.

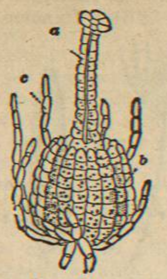

Fig. 329.

FIG. 327.—Archegonium of the Forked Spleenwort (*Asplenium septentrionale*) immediately after fertilization. *a*, canal leading to the large cell (oosphere) *c* at the base of the archegonium; *e*, nucleated embryonic cell, whence the sporangiferous frond proceeds.
FIG. 328.—Nucule of Chara entire, with five cells wound round a large central cell in a spiral manner; *a*, crown or coronula of five smaller cells.
FIG. 329.—Pistillidium of Liverwort (*Marchantia*). It is a cellular body surrounded by an involucre (perigone or calyx) *b*, and septate filaments (paraphyses) *c*, and it is provided with a styloid calyptra *a*.

above the apex of the central cell is a single short cell in Chara, while in Nitella it is divided transversely into two. These five or ten short cells form the *crown*. They unite together so that their apices project as small teeth. Between the crown and the apex of the central cell, which is termed the *apical papilla*, a cavity is included, bounded at the sides by the five enveloping tubes, which at this point form the *neck* of the nucule. The cavity of the neck is constricted in the middle by the projection inwards of the tubes to form a sort of diaphragm, so that the enclosed cavity has a rude hour-glass-like shape, the upper cavity closed above by the crown being connected by a narrow canal with a lower cavity bounded beneath by the apical papilla of the central cell. When fertilization takes place slits are formed betwixt the five tubes of the neck, beneath the crown and above the diaphragm. The antherozoids from the globule enter by them into the upper cavity, pass through the canal into the lower one, and fuse with the apical papilla of the central cell or oosphere. The oospore thus formed becomes detached from the plant, being covered by the thickened inner wall of the tube which invested it. The nucule rises from the base of one of the whorl leaves in Chara, and is therefore above the globule; in Nitella it is produced upon the leafy axis beneath the globule.

In Mosses the archegonia are frequently situated along with the antheridia and paraphyses. They are surrounded by the same whorl of leaves, or *perichætium*, when the moss is said to be hermaphrodite, or they occur separately on the same or on different plants, the moss being then monœcious or diœcious. The term *perigone* is applied to the whorl of leaves around the antheridia. The basal portion of the archegonia which surrounds the oosphere is termed the *epigone*. In Hepaticæ the archegonia (fig. 329) are situated in the substance of the thallus itself, or they may be in various situations, as in Jungermannia (fig. 330); in Marchantia they are produced upon the under surface of a stalked stellate disk (fig. 331).

In many Thallogens no structure analogous to a female organ has been as yet discovered; in some, however, such structures have been met with. Thus amongst Algæ large cells, termed *oogonia*, are found, in which usually one, sometimes many (Fucaceæ), oospheres are produced (fig. 332). The antherozoids from the antheridium fertilize these, penetrating the oogonia at a definite point thinner than the surrounding portion; and oospores are formed. In the Florideæ, a group of Algæ, the organs are different in character. Here the antherozoids are not motile, having no cilia. On discharge from the antheridium, these are washed into a long filiform hollow body, termed the *trichogynium*. This is supported usually upon a cellular stalk—the *trichophore*—at the side of the base of which is a small cellular mass. The antherozoids having entered the trichogynium, fertilization is effected, and results in the formation, from the cellular mass at the base of the

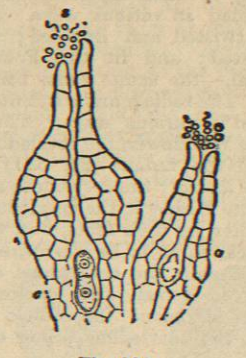

Fig. 330.

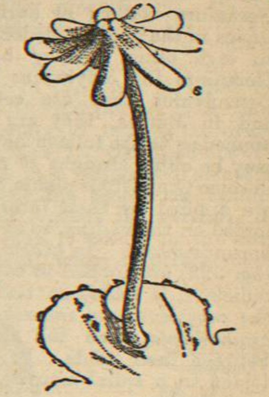

Fig. 331.

FIG. 330.—Archegonia of *Jungermannia bicuspidata*. *a*, archegonium, with a tube leading to a cavity near the base of which is a cell; *b*, archegonium after fertilization, with the cell *c* divided into two nucleated portions. This double nucleated body is the rudiment of the fruit-bearing stalk. At the apex of the canal leading to the cell are seen spermatozoids *s s*.
FIG. 331.—Thallus of Liverwort (*Marchantia polymorpha*), bearing a stalked fruit *s*, which is the product of the impregnated cell of the archegonium. The receptacle at the apex of the stalk bears on its under surface sporangia containing spores and elaters. The spores, when germinating, produce a thallus, on which antheridia and archegonia are formed.

trichophore, of a large cell, the *cystocarp*, in which spores are formed. In the Saprolegnieæ the antheridia actually penetrate into the oogonium and discharge their antherozoids. Amongst Fungi it is rare to find sexual organs. In some thecasporous fungi, as Eurotium, a sexual process has been observed. The female organ, here termed *ascogonium* or *carpogonium*, is of a spiral elongated character, immediately surrounding which are the antheridia

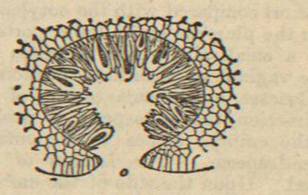

Fig. 332.

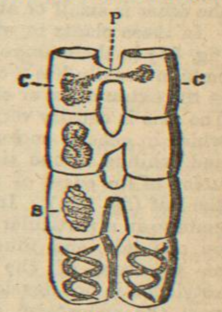

Fig. 333.

FIG. 332.—Transverse section of a conceptacle of a Seaweed (*Fucus vesiculosus*), showing the spores in the coverings, *p*, and paraphyses lining the cavity. The spores escape by an orifice *o*.
FIG. 333.—Two filaments of a Confervaceous Alga (*Zygnema*), conjugating, *i.e.*, uniting together by tubes *p*, which pass between the different cells. The contents of two cells *c c* unite so as to form a germinating spore *s*. In the lower two cells spiral filaments are seen.

few in number, which open into the apex of the female organ, and discharge their antherozoids. The result is the formation of cellular tissue round the ascogonium, forming what is termed a *perithecium*, and within the ascogonium large cells (*asci*) are produced, in which spores

or sporidia are subsequently developed. In Lichens no sexual organs have as yet been clearly demonstrated.

Amongst Fungi and Lichens there are certain bodies to be noted, which may be connected with sexual reproduction, but the function of which is at present unknown. Embedded in the margin of the thallus in Lichens and on various parts of the plant in Fungi, certain hollow urn-shaped bodies are found, which have been termed *spermagones* (conceptacles) (fig. 334). These are usually closed all but a small opening at the apex. From their base rise peg-shaped projections or *sterigmata* (fig. 335), bearing at

Fig. 334.

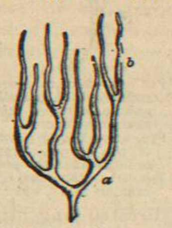

Fig. 335.

FIG. 334.—Two spermagones on thalli of Lichens.
FIG. 335.—Sterigmata *a* and spermatia *b* of *Cladonia fimbriata*.

their summit elongated, sometimes curved, bodies, termed *spermatia*, which, when mature, are discharged through the apex of the spermagone. These are by some considered the analogues of the antherozoids in other Cryptogams. There are also found other conceptacles, to which the name of *pycnidia* or *pycnides* is given. These contain large spores, which have been termed *stylospores* (fig. 336), but their homology is at present unknown.

Conjugation. Another process of reproduction is seen amongst Cryptogams. This is termed *conjugation* (fig. 333). It differs from the process of fertilization just described in that it consists of a union of the contents of two similar cells, whilst fertilization essentially consists in the mutual influence of dissimilar cells. It is well seen in many Algæ, such as Diatoms, Volvocineæ, Conjugatæ, also in some Fungi, such as species of Rhizopus and Zyzygites. It may consist in the coming together of two cells,—either moving spores, as in Pandorinia, or motionless, as in Diatoms,—which completely fuse, and a compound spore, or *zygospore*, results; or prolongations of the wall of two adjacent cells meet, the partition between the two gives way and the contents from the one pass into the other, and a zygospore is formed, as in Zygnema. Zygospores germinate only after a long period of rest.

Asexual reproduction. Amongst Thallogens especially, though it also occurs in other Cryptogams, the asexual mode of reproduction is very common. But the manner of formation and the nature of the spores is diversified.

Amongst Algæ two modes of asexual reproduction are seen,—by motile spores and by motionless or resting spores. In the former case the contents of a cell form a new cell, which escapes from the mother-cell, and moves about by means of cilia, which are formed either all round it, as in Vaucheria (fig. 337), or as a tuft at one end, as in Œdogonium. These are termed *swarm spores*, or *zoospores*, and frequently are of different sizes, being termed respectively *microgonidia* and *macrogonidia*. After swimming about for a time they fix themselves, and develop small rhizoids from one extremity, the other growing up into the plant. The motionless spores are seen in the Florideæ, where they are formed in cells, four in each, attached together in a row, or as a tetrahedron, constituting the *tetraspore* (fig. 338).

Amongst Fungi asexual reproduction is very common. Swarm spores are rarely formed; but the mode of formation of motionless spores is very various. They may be produced in the interior of distinct sacs called

Fig. 336.

Fig. 337.

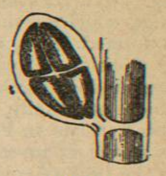

Fig. 338.

FIG. 336.—Basidia *a*, stylospores *b*, free stylospores *c*, from pycnides of Lecidia.
FIG. 337.—Zoospore of an Alga (*Vaucheria*), surrounded by moving cilia.
FIG. 338.—Tetraspore *t* of one of the rose-coloured Seaweeds (*Callithamnion cruciatum*).

thecæ, *asci*, or *cystidia* (fig. 339), when they are denominated *endospores* or *ascospores*, and the plants are said to be *thecasporous* or *ascosporous*. When they are developed on the exterior of sacs called *basidia* (fig. 340), they are denominated *exospores*, and the plants are *basi-*

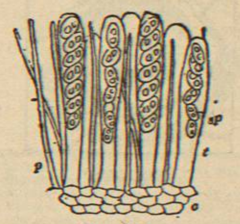

Fig. 339.

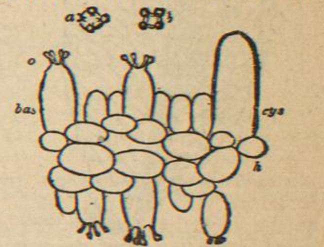

Fig. 340.

FIG. 339.—Vertical section of the fructification of a Fungus (*Peziza*), showing cellules *c*, bearing clavate spore-cases or thecæ *t*, which contain nucleated cells *sp*. These cells become sporidia, containing spores. Along with the thecæ are cellular filaments or paraphyses.
FIG. 340.—Portion of a lamella or gill of the Mushroom (*Agaricus campestris*), cut transversely, showing the two lateral surfaces bearing basidia *bas*, with four spores *spo* at their apices, and cystidia *cys* or sacs containing minute cells. The hymenium is marked *h*. At *a* and *b* are represented the four spores.

diosporous. When produced in the midst of a gelatinous mass, without any evident differentiation, they are called *myxospores*, the plants being *myxosporous*. Both the endospores and the exospores may by division become *septate*, and form *compound spores*, each of the secondary spores so formed being termed a *merispore*. Four or eight basidiospores are usually produced from each basidium. In the asci numerous spores are formed. Other forms of spores seen in Fungi are the *conidia*. These are stalked spores which arise from a mycelium.

In Lichens we find asci which produce spores or sporidia just as in Fungi; and in addition there also exist spermogones with their sterigmata and spermatia as well as pycnides and stylospores. Besides the spores there are organs called *soredia* in Lichens. These are groups of small round cells or *gonidia* (fig. 97), surrounded by hyphæ, which are capable of independent growth after removal from the thallus. These gonidia are now regarded by many as an Alga, upon which the hypha, which is supposed to be an ascomycetous Fungus, is parasitic.

In Chara a curious mode of asexual reproduction is seen which presents several well-marked modifications, the process always proceeding at the nodes, and consisting in the growth of a new axis from a nodal cell either isolated or united with other cells.

In all vascular Cryptogams, Muscineæ, and many Thallogens, that process of development in which successive different generations are produced finally returning to the original form, usually termed alternation of generations, is well seen. The number of such generations varies