Amongst Ferns the oospore germinates and produces an asexual generation. The embryo plant formed from this spore is a simple mass of cellular tissue, no cotyledons being formed. This, then, is an *Acotyledonous* embryo (fig. 54). The same happens in other vascular Cryptogams, which are therefore also Acotyledonous. The embryo so formed has a primary meristem, with an apical cell, by division of which it increases in size,—roots being formed downwards and a leaf-bearing axis upwards, upon which, eventually, the *fructification* (fig. 341) is formed. This consists in Ferns of the production of either stalked or sessile spore-cases or *sporangia*, from the epidermis on the back (Aspidium) or edges (Pteris) of a leaf (frond), or upon a special branching axis (Osmunda), or a spicate one (Ophioglossum). These, when situated on the frond, are arranged in definite clusters or *sori* (fig. 342), either

Fig. 341.

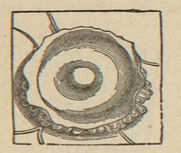

Fig. 342.

Fig. 341.—Frond (fructiferous leaf) of a Fern (*Niphobolus*), showing sori, or round clusters of sporangia at the ends of veins. As these sori are on the back of the frond, the Fern is called dorsiferous

Fig. 342.—Sorus or cluster of sporangia of a Fern (*Aspidium trifoliatum*). The sporangia are covered by an indusium or involucre, derived from the epidermis of the frond. The involucre is round (orbicular), and attached by its centre in an umbilical manner. The annulate sporangia are seen at the lower edge of the involucre.

rounded or elongated. With the sporangia are usually associated jointed cells or *paraphyses*. Frequently the sori are covered by a thin cellular layer forming an *indusium* or involucre, or the margin of the frond folds over them, forming a false indusium. Within the sporangium spores are produced, and when ripe these escape by the rupture of the sporangium, this in many cases being provided for by the formation, at a definite point, of an *annulus* or ring (fig. 343) of unequally thickened cells. Hence some Ferns are *annulate*, others *exannulate*. The cell-wall of each spore is divisible into an outer layer or *exospore*, and an inner or *endospore*. When the spore reaches the soil it germinates, and after a longer or shorter period produces the sexual generation. In this process the variously marked exospore is ruptured by the enlarging endospore, which divides so as eventually to form a flattened cellular expansion or *prothallus* (fig. 344) with small cellular *rhizoids*. Upon this, usually on the under surface, the sexual organs, consisting of antheridia and archegonia, are produced. A tendency to *diœcism* is observed in prothalli, frequently producing only one kind of sexual organs. By the mutual influence of those sexual organs an oospore is formed, from which a new asexual generation arises. Thus in Ferns the alternation consists of two dissimilar generations,—a sexual or prothallial generation, and an asexual generation.

In Equisetaceæ the same alternation of two dissimilar generations occurs. Upon an asexual generation the fructification is formed at the apex of a leaf-bearing axis. Peltate hexagonal stalked scales (fig. 345) are arranged in close whorls round the apex of the axis, forming a pyramidal head (fig. 346, *f*), the surface of the scales being

Fig. 343.

Fig. 344.

Fig. 345.

Fig. 343.—Mature sporangium of the Male Fern (*Lastrea Filix-mas*). It is supported on a stalk *p*, some of the cells of which form an elastic ring or annulus *a* round the spore-case. The spore-case *s* opens at the side to discharge the spores.

Fig. 344.—Young plant of a Fern (*Pteris palæacea*), showing the commencement of the sporangiferous frond *f*, arising from the impregnated ovule in the archegonium, the prothallium *p* being still attached.

Fig. 345.—Polygonal scale *s* of a species of Horse tail (*Equisetum*), bearing membranous sacs *t*, which open on their inner surface to discharge spores.

directed tangentially to the axis. Round the margin of the inner surface of these scales the sporangia are produced projecting towards the axis. When ripe each sporangium

Fig. 346.

Fig. 347.

Fig. 348.

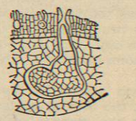

Fig. 349.

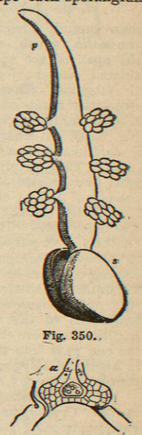

Fig. 350.

Fig. 351.

Fig. 346.—Fructification of a species of Horse-tail (*Equisetum maximum*). The stalk is surrounded by a series of membranous sheaths *s s*, which are fringed by numerous sharp processes or teeth. The fructification *f* is at the extremity of the frond, in the form of a pyramidal mass of polygonal scales, bearing spores on their under-surface.

Fig. 347.—Large spores of Club Moss (*Lycopodium*) enclosed in an involucre. It is sometimes called an oophoridium in consequence of containing germinating bodies (ovules). It represents the female organ. The involucre opens transversely to discharge the spores (macrospores).

Fig. 348.—Macrospore discharged from the oophoridium of a Lycopod (*Selaginella Mertensii*), with the outer coat removed to show the young cellular prothallium *p* at the upper end.

Fig. 349.—Vertical section of a small portion of the prothallium and upper part of the large spore of a Lycopod (*Selaginella denticulata*), showing the embryo *e*, developed from a central cell of one of the archegonia *a*, carried down by the growth of the suspensor, so as to be embedded in the cellular tissue at the upper part of the spore.

Fig. 350.—Fructification of a species of Pepperwort (*Marsilea Fabri*). The sporocarp *s* opens to give out a peculiar cellular cord or peduncle *p*, which at first was curved in a ring like manner. This cord bears spike-like fructification *f*, consisting of antheridia and pistillidia enclosed in sacs.

Fig. 351.—Archegonium *a* of a Rhizocarp (*Pilularia globulifera*) cut vertically after impregnation, showing the prothallium, with the embryo in its interior in an advanced state. This embryo gives origin to the leafy stem.

opens towards the stalk of the scale, and the spores are shed, each having attached to it four clavate filaments sometimes

termed *elaters* (fig. 3), which are very hygroscopic. By germination of these spores a sexual generation or prothallus is formed.

In Lycopodiaceæ a sexual process has not been observed in all genera; but in Selaginella and Isoetes, where it has been observed, it is exceedingly instructive, as it forms a connecting link between the process as seen in Cryptogams and that observed in Angiosperms. The asexual generation produces the fructification which consists in the formation of a single sporangium in the axil of each leaf of a certain part of the axis. In those genera in which sexual organs have been discovered these sporangia are of two sizes, termed *macrosporangia* (fig. 347) and *microsporangia* respectively. The whole fructification frequently forms a spike. In the *macrosporangium* or *oophoridium* few, usually four, large spores (*macrospores*) are formed, having each an exospore and an endospore. In the microsporangium (fig. 248) numerous small spores or microspores are formed of a similar structure. When the sporangia are shed the capsule decays, and the spores escape. Within the endospore of the macrospore, a development of cellular tissue takes place which eventually completely fills it and constitutes the *prothallus*, termed sometimes on this account *endothallus* (fig. 348). As it increases in size the exospore is ruptured triradiately, and the endospore projecting is also ruptured, and thus the prothallus is protruded, in the substance of which archegonia are formed. The microspores, on the other hand, produce within their endospore, sometimes after the formation of a rudimentary prothallus, antherozoid mother-cells, which are discharged by the rupture of the exospore and endospore (fig. 249). By fertilization of the oosphere of the archegonium an oospore is formed, from which the sexual generation arises. The embryo is formed from the lower part of the oospore, the upper half elongates and forms a *suspensor* (fig. 349) of several cells, by which the embryo is pushed downwards into the substance of the prothallium, and there develops into a young plant, rudimentary cotyledons being formed upon the young axis. It will be observed that this process resembles very much the mode of embryogeny in Phanerogams, and, indeed, from this it is but a step to the form found in Gymnosperms and thence to Phanerogams.

In Rhizocarps the sporangia are formed in the interior of ovoid sacs, termed *sporocarps* (fig. 350), which are usually supported on stalks, and rise from the leaves near their base, one or many on the same stalk. In each sporocarp, microsporangia and macrosporangia are formed in various positions; and a prothallium (fig. 351) is formed in the macrospore, as in Lycopodiaceæ. From the oospores formed in it the embryos are produced, but without suspensors.

In Characeæ there is an alternation of a sexual with an asexual condition. From the oospore a small proembryo is first formed, from a cell of which the sexual plant is developed.

In Mosses the sexual generations are produced as lateral shoots from a filamentous *proembryo* or *protonema* (fig. 352). Upon this leaf-bearing axis either at the apex (acrocarpous) or laterally (pleurocarpous) the sexual organs arise. The asexual generation rises from the oospore and constitutes what is usually termed the *fruit* (fig. 353) of the moss. It has been designated the *sporogonium*. The sporogonium is formed by the enlargement of the oospore into an ovoid embryo which presses against the epigone, finally rupturing it, and carries the upper portion upwards with it as the *calyptra* or cap, the lower portion forming a sheath or *vaginula* at the base. This calyptra may be either split on one side, *dimidiate*, or entire, then termed *mitriform*. The upper part of the sporogonium forms a *capsule*, *urn*, or *theca*; the lower portion acts as a supporting stalk or *seta*, which is often swollen, just beneath the capsule forming the *apophysis* (fig. 354, *a*). In Sphagnum the sporogonium is fully developed within the epigonal leaves, and when complete the axis beneath it elongates, forming the *pseudopodium*, and projects considerably beyond the perichætium. The walls of the capsule of the sporogonium consist of several layers of cells. It has a central axis or *columella*, surrounding which are the *spores*. When mature the capsule usually dehisces,

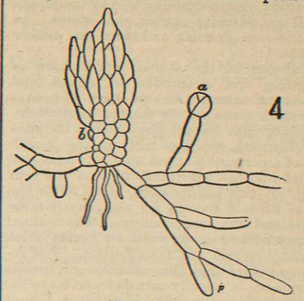

Fig. 352.

Fig. 353.

Fig. 352.—Moss (*Funaria hygrometrica*), showing the cellular protonema *p*, or proembryo, with its roots *r*, and buds *a*, *b*, whence arise leafy stems bearing the organs of reproduction.

Fig. 353.—Hygrometric Cord-Moss (*Funaria hygrometrica*), with its urn-like theca *a* supported on stalks *p*, which arise from perichætial leaves *f*. The theca are covered by a calyptra *c*, which splits on one side. The operculum or lid *o* is seen in one of the theca from which the calyptra has fallen. The seta is twisted, and displays hygrometric properties.

either by four longitudinal valves, as in Andræa, or most commonly by a lid or *operculum* (fig. 355), between which and the capsule an *annulus* or ring of cells is separated. On removal of the operculum the stoma or opening of the capsule is seen. The margin of this is sometimes entire (*gymnostomi*), more usually fringed with *teeth* or cellular prolongations, constituting a *peristome* (fig. 355, *p*), either in one row (*aploperistomi*) or in two rows (*diploperistomi*). Stretching across the mouth of the capsule is frequently seen a thin cellular membrane, the *epiphragm* or

Fig. 354.

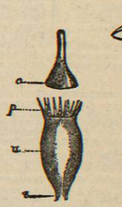

Fig. 355.

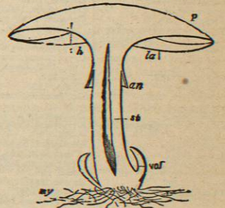

Fig. 356.

Fig. 354.—Fructification of the Hair-Moss (*Polytrichum*), consisting of an urn-like (urceolate) case or theca *a*, supported on a stalk (seta) *s*, and covered by a calyptra *c*, which splits at the base.

Fig. 355.—Theca *a* of the Extinguisher-Moss (*Encalypta*), showing the teeth of the peristome *p*, which fold inwards when moisture is applied.

Fig. 356.—Vertical section of a Mushroom (*Agaricus campestris*). *my*, mycelium or spawn; *vol*, remains of volva or wrapper; *st*, stipe or stalk; *an*, annulus or ring, being the remains of the velum, veil, or cortina; *la*, lamellæ or gills of the hymenium *h*; *p*, the pileus.

tympanum, as in Polytrichum. The spores shed from the capsule germinate and give rise to the proembryo which by budding gives off the sexual plants.

In Hepaticæ the sexual generation arises either directly

from the spore of the asexual generation, or a small pro-embryo is first formed. The *sporogonium* is of various forms, and originates differently in different groups from the oospore. It is always formed within a cellular covering or epigone. In Anthoceros the sporogonia are elongated and open by two valves, and there is a central cellular columella. In Jungermannia the sporogonia are globular, and open by four spreading valves. There is no central column, but the inner wall displays cellules, called *elaters*, fixed by one extremity, and containing one or two spiral fibres which by their elasticity scatter the spores. In Riccia the sporogonia are globular, and there are neither elaters nor columella.

Very little is known of the sexual reproduction of Fungi, and regarding the alternation of sexual and asexual generations in them. But we have abundant instances of alternation amongst the asexual generations, and along with this of that curious phenomenon included under the term *heteræcism*, which consists in the growth of one generation of a parasitic Fungus upon one host, and the development of another generation upon a different host. By tracing out this phenomenon, many forms, described formerly as distinct species, are now shown to be generations of one and the same Fungus. The asexual spores of Fungi are produced upon certain structures which have been frequently termed the fructification. For instance, in basidiosporous Fungi the collection of basidia forming the *hymenium* is usually situated on large receptacles. The structure commonly known as a *fungus* (fig. 356) is a receptacle produced upon a *mycelium* (*my*). In its young state it appears as a tubercle upon the mycelium covered by a *volva* (fig. 356, *vol*), or wrapper, which it bursts during growth. It consists of a *pileus* or cap (*p*), at the extremity of a stalk, the *stipe* (*st*). On the under surface of the pileus are the *lamellæ* (*la*) or gills, of various forms, which constitute the hymenial (*hy*) layer, to which the spores are attached. At first the hymenium is covered by a veil or *indusium*, which during the growth of the stipe is ruptured, the base remaining on the stipe as the *annulus* (*an*) or ring. When, as in the Mushroom, the hymenium is exposed, the fungus is said to be *gymnocarpous* (fig. 356). In other cases, as in Phalloideæ, it is covered over by a *peridium*, and the whole mass so enclosed is the *gleba*, and the fungus is *angiocarpous* (fig. 357). In ascosporous Fungi, as Sphæria, the asci are usually formed within small roundish receptacles, termed *perithecia;* and along with the asci are usually numerous abortive filaments or paraphyses. Sometimes these perithecia are situated upon cushions or branching masses of tissue, the *stroma*. In the myxosporous Fungi the *plasmodium*, or whole protoplasmic mass of the plant, forms receptacles, in each of which is a *capillitium*, or network of fine filaments, in the interstices of which are numerous spores.

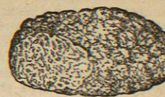

Fig. 357.

The Truffle (*Tuber cibarium*), a subterranean Fungus, with a black tuberculated or warty external covering, and a white cellular interior containing sporiferous cells.

In Lichens spores are formed in asci, which are arranged along with paraphyses, forming a hymenium in receptacles situated on the thallus, and termed *apothecia* or *lirellæ*, which are sometimes (fig. 95) supported on a stalk or *podetium*. The hyphæ, from which the asci arise, form a layer immediately beneath the hymenium, termed the *subhymenial* layer, the thick mass of hyphæ beneath being the *hypothecium*. The outermost layer of the tissue of the apothecium is termed the *excipulum*.

In Algæ

Amongst Algæ alternation of generations is very common; and here, as in the case of Fungi, it may pass through several generations before reaching the original form. This is well seen in Diatoms, also in Œdogonieæ, where three generations are passed through, and in Coleochæte, where there are four dissimilar generations,—sexual and various forms of asexual reproduction alternating.

(J. H. B.)

Index of Principal Subjects.

Explanation of the Plates.

Plate I. Papaver Rhœas, Common Red Poppy, belonging to the Nat. Ord. Papaveraceæ. The leaves are pinnatifid, the peduncles have spreading hairs, the calyx consists of 2 caducous sepals, enclosing 4 crumpled petals, the stamens are indefinite and hypogynous, and the ovary is surmounted by a radiating stigma.

Fig. 1. Stamens inserted on the thalamus, below the ovary with its sessile stigma. Fig. 2. Capsule opening by pores below the sessile radiating stigmas.

Plate II. Janipha Manihot and Eschscholtzia californica.

Fig. 1. Janipha Manihot, Cassava plant, belonging to the Nat. Ord. Euphorbiaceæ. The leaves are digitately-partite, and the flowers are in racemose cymes. Fig. 2. Racemose cyme, with a pentacoccous capsule, which separates in an elastic manner into 5 single-seeded carpels. The cyme bears male as well as female flowers. Fig. 3. Pistil with stigma. Fig. 4. Stamens and fleshy disk. Fig. 5. Seed with strophiole.

Fig. 6. Eschscholtzia californica (*nat. size*), belonging to the Nat. Ord. Papaveraceæ. It has a peculiar caducous calyx like a candle-extinguisher, and a tetrapetalous corolla, with numerous hypogynous stamens. Fig. 7. Hollowed end of the peduncle, with the pistil. Fig. 8. Section of ovary, with numerous seeds attached to 2 parietal placentas. Fig. 9. Ceratium or siliquæform capsule (*nat. size*), opening by 2 valves. Fig. 10. Section of the seed, with the Dicotyledonous embryo, which is shown separately in fig. 11.

Plate III. Malva sylvestris, Common Mallow, belonging to the Nat. Ord. Malvaceæ. The leaves have 5 lobes, the inflorescence consists of cymose fascicles, and the æstivation is contortive.

Fig. 1. Calyx with a three-leaved epicalyx or involucre. Fig. 2. Obcordate petal, with monadelphous stamens. Fig. 3. Tube of stamens formed by union of the filaments. Fig. 4. Pistil with numerous carpels and styles. Fig. 5. Stamen with reniform anther opening round the margin. Fig. 6. Section of ovary composed of numerous carpels.

Plate IV. Anacardium occidentale, Cashew-nut plant, belonging to the Nat. Ord. Anacardiaceæ.

Fig. 1. Branch (*somewhat reduced*), bearing flowers and fruit. The flowers are in cymes, and the peduncles are enlarged in a pear-like form, bearing the nut (the true fruit) at their apex. Fig. 2. Flower not expanded. Fig. 3. Flower expanded. Fig. 4. Stamen and pistil, with the calyx; one fertile stamen longer than the others. Fig. 5. Stamen separated. Fig. 6. Nut constituting the fruit. Fig. 7. Nut opened longitudinally. Fig. 8. Seed separated from the nut. Fig. 9. Cotyledons opened to show the radicle *a*, and the plumule.

Plate V. Sarothamnus scoparius, Common Broom, belonging to the Nat. Ord. Leguminosæ or Fabaceæ, Sub-ord. Papilionaceæ. The angled branches bear ternate leaves, papilionaceous flowers, and legumes.

Fig. 1. Two-lipped calyx. Fig. 2. Broadly ovate vexillum or standard. Fig. 3. One of the alæ or wings of the corolla. Fig. 4. Carina or keel. Fig. 5. Monadelphous stamens. Fig. 6. Hairy ovary with the long style, thickened upwards, and spirally curved. Fig. 7. Legume or pod.

Plate VI. Carica Papaya and Andromeda hypnoides.

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Fig. 6. Andromeda hypnoides (*nat. size*), belonging to the Nat. Ord. Ericaceæ. Fig. 7. Flower of Andromeda, with 5-parted calyx, and gamopetalous campanulate corolla. Fig. 8. Back view of stamen with its 2-horned anther. Fig. 9. Front view of stamen with bicornute and biporose anther. Fig. 10. Pistil with its ovate acuminate style. Fig. 11. Capsule, 5-celled; with a central 5-lobed placenta.

Plate VII. Œnanthe crocata, Hemlock Water-Dropwort, belonging to the Nat. Ord. Umbelliferæ. Leaves compound and sheathing, roots composed of fusiform sessile knobs, stem hollow, and flowers in compound umbels, with general and partial involucres.

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Plate VIII. Valeriana officinalis, Great Wild Valerian, belonging to the Nat. Ord. Valerianaceæ, showing the roots, which are officinal, the hollow stem, the alternately-pinnate leaves, and flowers in corymbose cymes.

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Plate IX. Leontodon Taraxacum, Common Dandelion, belonging to the Nat. Ord. Compositæ, Sub-ord. Cichoraceæ. The leaves are radical and runcinate, the flowers ligulate, and arranged in capitula. The outer phyllaries (involucral leaves) are reflexed.

Fig. 1. Capitulum with reflexed phyllaries and ligulate flowers. Fig. 2. A single flower, with inferior achene (cypsela), stipitate pappus, a ligulate corolla, 5 stamens united by their anthers, and 1 style with 2 stigmas. Fig. 3. Receptacle, become dry and convex, with deflexed phyllaries. Fig. 4. Linear-obovate achene.

Plate X. Cuscuta verrucosa, Warty Dodder, belonging to the Nat. Ord. Cuscutaceæ, which is often considered as a sub-order of Convolvulaceæ.

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Fig. 1. Male plant (*nat. size*) with oblong, nearly elliptical leaves, and flowers in axillary umbellate cymes. Fig. 2. Perianth of male plant laid open to show the stamens with their united filaments. Fig. 3. Anther, bilocular, and opening longitudinally. Fig. 4. Female flower cut open, showing the single pistil, with short style and 2-lobed stigma. Fig. 5. Young fruit. Fig. 6. Ripe drupaceous fruit in the act of bursting, and showing the mace or arillode. Fig. 7. Section of the ripe fruit. Fig. 8. The nut, consisting of a hard endocarp enclosing the seed. Fig. 9. The oval seed. Fig. 10. The seed cut vertically. Fig. 11. Vertical section of endocarp and seed, showing ruminate perisperm and the embryo. Fig. 12. Embryo, showing 2 large foliaceous plicate cotyledons. Fig. 13. Embryo with radicle and cotyledons.

Plate XIII. Euphorbia hypericifolia, Tutsan-leaved Spurge, belonging to the Nat. Ord. Euphorbiaceæ.

Fig. 1. Plant (*nat. size*) with opposite oblong leaves, and flowers in corymbose cymes. Fig. 2. Involucre with appendages, enclosing male and female flowers. Fig. 3. Involucre cut open, to show the insertion of the numerous achlamydeous male monandrous flowers, and the single naked female flower, all pedicellated. Fig. 4. Involucre deprived of its petaloid appendages, with female flower showing forked styles. Fig. 5. Involucre enclosing the ripe fruit (regma). Fig. 6. Stamen. Fig. 7. Fruit with one of the cocci separated from the columella. Fig. 8. Seed. Fig. 9. Seed cut open, showing fleshy perisperm and inverted embryo.

Plate XIV. Artocarpus incisa, the Bread-fruit tree, belonging to the Nat. Ord. Artocarpaceæ.

Fig 1. Branch reduced to $\frac{1}{3}$rd its natural size, with cuneate-ovate pinnatifid leaves, male flowers in a club-shaped deciduous catkin, female flowers in rounded clusters. Fig. 2. Transverse section of the male amentum with numerous flowers. Fig. 3. Male flowers. Fig. 4. Single male flower separated, with a perianth in 2 segments and a single stamen. Fig. 5. Female flowers. Fig. 6. Single female flower separated, with ovary, style, and bifid stigma. Fig. 7. Ovary. Fig. 8. Ovary laid open to show the ovule. Fig. 9. A variety of the ovary with 2 loculaments. Fig. 10. Transverse section of a bilocular ovary.

Plate XV. Cycas circinalis, a species of false Sago-plant, belonging to the Nat. Ord. Cycadaceæ.

Fig. 1. Plant reduced to $\frac{1}{40}$th its natural size. The leaves are pinnately-divided and form a crown round the stem. Fig. 2. Male amentum (*nat. size*), consisting of scales bearing on their under side 2-valved anthers. Fig. 3. Upper side of one of the scales. Fig. 4. Under side of a scale, bearing anthers. Figs. 5, 6, and 7. Anther. Fig. 8. Pollen magnified.

Plate XVI. Arum maculatum, Cuckow-pint or Wake Robin, belonging to the Nat. Ord. Araceæ. Fig 1. Flowering stalk, with hastate-sagittate spotted leaves, and spathe enclosing a spadix bearing male and female flowers. Fig. 2. Amylaceous corm, whence arise buds and roots. Fig. 3. Berried fruit, after leaves and spadix have decayed, in an oblong spike, of a bright scarlet colour.