BOTANICAL TYPES

DESCRIPTIONS OF THE STRUCTURE AND LIFE HISTORY OF TEN TYPES, WITH SUMMARIES OF THE IMPORTANT GROUPS AND CLASSES

WITH PLATES

BY

W. E. FOTHERGILL, M.A., B.Sc.

Edinburgh:
JAMES THIN, PUBLISHER TO THE UNIVERSITY.
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PREFACE.

WHILE the morphology, physiology, and classification of the Phanerogams are conveniently dealt with in the usual text-books, concise and consecutive descriptions of the life histories of typical plants are not so easily available. Accordingly, the first mentioned parts of the subject are untouched in the following pages, which give only the life histories prescribed for Botanical students in Edinburgh, with short summaries of the points necessary for a clear conception of the important groups and classes. These descriptions are not intended to be an introduction to Botany, but to help in completing, clearing up, and arranging for use some previous knowledge of the subject.

Many of the diagrams are modified and rearranged from well-known sources, such as the text-books of Sachs, Gœbel, and De Bary; the rest have been specially prepared.

W. E. F.

UNIVERSITY HALL, *June* 1889.

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I.—THALLOPHYTA.

1. CLASS SCHIZOPHYTA.

LIFE HISTORY (1.) *BACTERIUM.*

THE name *Bacteria* is loosely given to a class of the smallest plants properly called the Schizomycetes. Each individual consists of a single cell, so minute that the microscope can hardly show more than the cell wall and its protoplasmic contents. They are the micro-organisms which cause **putrefaction** and **fermentation**, and many of them are now being definitely associated with specific diseases.

The most obvious distinction between plants and animals is that most plants can manufacture organic compounds of carbon by taking CO_2 from the air, combining it with water in their cells, and setting free the superfluous oxygen. This process of **carbon-assimilation** is rendered possible by the presence in the plant cells of **chlorophyll**, the colouring matter which gives the characteristic **green** to vegetation. The *Bacteria* have no chlorophyll, and thus have to obtain, ready-made, the organic compounds of carbon necessary for their life. This they do by stealing from other living organisms, in which case they are **parasitic**; or they live in fluids containing dead organic matter, which is fermented or putrefied by their action upon it. In this case they are **saprophytic**.

The name *Bacterium* is properly applied to a genus of *Schizomycetes*, whose individuals are cells a little longer than they are broad—short rods. They often become constricted in the middle, and look like dumb-bells, and their division is always preceded by this appearance. The constriction deepening, the two ends separate, and each elongates into a new individual. After several rapid divisions, the individuals may remain attached to one another in a short chain. This is the only mode of multiplication. Free individuals move rapidly by means of one or two large cilia. They only move, however, when free oxygen is present, showing a need for **respiration**, which they share with all plants and animals. Masses of a gelatinous substance called **zooglea** are formed by the breaking down of the cell walls of multitudes of individuals, which lie in it for a time, motionless and without cilia.

Bacterium Termo is the species which most commonly causes putrefaction. It is 0·0015 mm. long, and a third less in breadth. It has a thick membrane, is dumb-bell shaped and flagellate. Present almost everywhere, it forms a **pellicle** or **scum** on the surface of decomposing fluids, but after a certain time dies, unlike any of the other forms. *B. Lactis* causes milk to turn sour. Another *Bacterium* is the cause of Fowl Cholera.

Note.—Bacteria	as broad as long	are called	Micrococcus.
,,	longer than broad	,,	Bacterium.
,,	elongated	,,	Bacillus.
,,	twisted	,,	Vibrio, Spirillum.

THALLOPHYTA.

1. CLASS SCHIZOPHYTA.

The class *Schizophyta*, of which *Bacterium* is a type, are amongst the simplest and smallest of single cell forms. Their cell wall is sometimes hardly distinguishable from the protoplasm it surrounds, and there is often no nucleus. Some *Schizophyta* possess **chlorophyll**, and some have also a blue colouring matter called **phycocyan**. These are all much larger than the Schizomycetes, which have neither. Numerous individuals are often grouped into colonies, in which the cells may be merely aggregated, or may be definitely arranged in **rows, surfaces**, or **masses**. The colonies are frequently encased in gelatinous masses, formed by alteration and swelling of the cell wall. Free individuals usually have one or two **flagella** by which they swim.

There is no suggestion of sexual reproduction, the only means of multiplication being division or fission of the individual into two new ones, whence the name Schizophyta—splitting plants.

Schizophyta.

With Chlorophyll.	Mostly without Chlorophyll, Schizomycetes (Bacteria).

2. CLASS ALGÆ.

LIFE HISTORY (2.) *VAUCHERIA*.

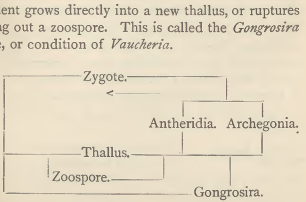
Vaucheria is the name of a genus of green algæ. Its thallus or plant body is an elongated branched tube, not divided into compartments by septa. The protoplasm filling it contains many nuclei, and is crowded with chlorophyll corpuscles (chloroplasts). Oil globules, and vacuoles containing fluids are also frequent. Typically, *Vaucheria* floats in fresh water, and sends out over the surface of any solid it may touch delicate branches without chlorophyll, which form a fixing structure. The plant also grows very well in moist air, and its filaments are often found spreading over flower-pots.

Asexual Reproduction by Zoospores. The protoplasm at the end of a branch may round itself off into a dense mass, which is soon cut off by a septum from the rest of the filament. The wall rupturing, the protoplasm escapes as a large ovoid spore covered with cilia—a **zoospore**, which grows directly into a new thallus. This asexual reproductive process occurs only in water.

Sexual Reproduction. Two kinds of protuberances appear close together, sometimes on the same filament. The female organs are rounded **oogonia**, each producing one egg. Each has a beaked process where the cell wall ruptures to admit the male element at fertilisation. The **oogonium** is

cut off by a septum from the rest of the filament, and a portion is always cut off from the egg and extruded before fertilisation. (Compare ventral canal cell of archegonia, and polar bodies of animal egg.) The male organs are tubular processes called **antheridia**, cut off by septa from the filaments on which they grow. The apex of an **antheridium** bends over till it almost touches the beak of an **oogonium**, when its wall ruptures allowing spermatozoids to escape. One of these, entering the oogonium through a rupture in its wall, fertilises the egg, which is then a **zygote**, and grows into a new thallus as soon as it finds a suitable position or nidus.

Gongrosira Condition. In extreme cold, or otherwise unfavourable conditions, the thallus becomes divided into a septate filament, with thick cell walls, which protect the protoplasm until more favourable conditions recur. Then each cell of the filament grows directly into a new thallus, or ruptures letting out a zoospore. This is called the *Gongrosira* stage, or condition of *Vaucheria*.



THALLOPHYTA.

2. CLASS ALGÆ.

The Algæ, of which *Vaucheria* is a type, are plants whose body is not differentiated into leaves, stem, and root. Having no roots by which to absorb moisture from the soil, they all live in water or in damp situations. The Algæ all possess chlorophyll, and are able to manufacture their own carbonaceous food by the absorption of CO_2; they can thus live independently of other organisms, and are neither parasites nor saprophytes. The green colour of chlorophyll is masked in some Algæ by red, and in others by brown pigments, which can be removed in the laboratory to show the presence of chlorophyll. The varied forms and their developments show some genetic relationships upon which the class is based and sub-divided. The vegetative body is constructed upon one of three types,—the **single cell** type, the **cœnobium type**, or loose aggregation of cells into a colony, and the true **thallus type**, in which cells are closely united into a plant body which may be either a **filament**, a **cell-surface**, or a **cell-mass**, according as cell division occurs in one, in two, or in three planes.

Asexual Reproduction. The asexual reproduction of Algæ is usually by **zoospores**,—freely motile cells, with no cellulose walls. Their protoplasm contains a vacuole, and is furnished with one, two, or

more cilia. They are formed, one in a cell by the process called **rejuvenescence**, or many in one cell by **free-cell multiplication**. On the rupture of the wall of the mother cell, they escape, swim about, come to rest, secrete a cellulose wall, and finally begin dividing to form a new colony or thallus. Non-motile **tetraspores** (produced four in a cell) form the means of asexual reproduction in the Red Algæ (Florideæ.)

Sexual Reproduction. The dawn of sexual reproduction is seen in the various forms whose reproductive process is transitional between the union of two similar cells (**conjugation**) to form a **zygospore**, and highly complex processes in which a female cell is fertilised by a male element produced perhaps by a different plant. In many Algæ a stationary **oosphere** produced in a female organ called an **oogonium** is fertilised by a motile **antherozoid** from a male organ called an **antheridium**. In others the female **carposperm** of a **carpogonium** is fertilised by non-motile male **pollinodia**.

3. CLASS FUNGI.

LIFE HISTORY (3.) *SACCHAROMYCES CEREVESII.*

(THE YEAST OF BEER.)

The Yeast plant is a fungus of very much reduced type. It consists of cells floating separately, or united to one another forming small chains and groups. The cells are ovoid or round, larger than Bacteria, but smaller than many unicellular forms. Their walls are smooth and thin; the protoplasm enclosed contains one or more vacuoles, but has no nucleus. There is, of course, no chlorophyll. The plant does not steal its carbon compounds from living organisms, but lives saprophytically in fluids containing certain organic matters which the cells decompose, causing alcoholic fermentation and nourishing themselves at the same time. The process is not understood; the facts are simply that CO_2 and **alcohol** are produced, and that the presence of a certain proportion of alcohol in the fluid causes the death of the organism. The process of yeast fermentation thus terminates itself at a certain point, viz., when the greatest proportion of alcohol is reached which is compatible with the life of the plant.

Asexual Reproduction by Budding. **Budding** or **pullulation** is the main reproductive process of Saccharomyces. A small protuberance from the cell wall increases till it nearly equals the mother

cell in size, when the point of union is constricted, and the daughter cell is cut off as a new individual. When budding is repeated several times in rapid succession, the daughter cells produced may remain attached to one another in a chain or group.

Reproduction by Spores. When yeast is grown on a moist cut surface of carrot or potato, individual cells may become enlarged, and **spores** (two or four) may form inside them. In this case the whole plant forms itself into an **ascus** or spore-sac. The spores when liberated grow and bud freely.

There is no attempt at sexual reproduction.

LIFE HISTORY (4.) *MUCOR.*

(White Mould.)

Mucor is a saprophyte living on decaying organic matter such as horse-dung. Its plant body is made up of a multitude of filaments, which are not divided by septa, so that each filament though it branches freely is a single tube. Such a plant body is called a **mycelium.**

Asexual Reproduction. At certain points stalks called **sporophores** grow straight up, bearing at their apices spore-sacs or **sporangia.** On the rupture of these sacs, spores escape and germinate, giving fresh **mycelia.**

Sexual Reproduction. There is also a process of sexual reproduction, in which two like cells (**gamete** cells) are cut off by septa from the ends of two filaments. These unite and form a single cell called a **zygospore**. This is the lowest form of the sexual process, and, indeed, it can hardly be called sexual, since the uniting elements are not differentiated into male and female. Such union of similar cells is always called **conjugation**.

Torula Condition. When grown in a nutritive fluid, the spore, instead of growing into an elongated tube, breaks up into a number of separate rounded cells, which multiply asexually by budding like yeast. This mode of growth produces **mucor yeast**, which is called the **Torula condition** of the mycelium.

LIFE HISTORY (5.) *EUROTIUM.*

(*Aspergillus Glaucus.*)

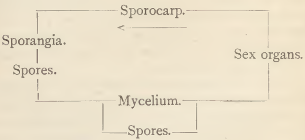
Eurotium, or blue mould, is like *Mucor*, a saprophyte. Its thallus or plant body is a colourless filament, branching freely, and divided into cells by numerous septa. The thallus spreads over substances such as bread, and sends branches into them. The mycelium of *Eurotium* sometimes grows in the outer ear of man; not as a parasite, but as a saprophyte living in the secretion of the ear. It causes a form of irritation called **mycosis**.

Asexual Reproduction. Any cell of the mycelium may grow upward as a unicellular stalk or **sporophore**, swollen out at its apex, which is covered with small protrusions called **sterigmæ**. The ends of these are cut off repeatedly by septa, a spore being formed of each cell so cut off, or **ab-jointed**. The spores remain attached to the **sterigmæ** until ripe,

and acquire a blue colour, giving the characteristic appearance of blue mould. When ripe they fall off and germinate. They have two coats, the **exosporium**, which bursts, and the **endosporium**, which grows out through it into a septate tube, and so begins the formation of a new mycelium.

Sexual Reproduction. The union of two sexual elements occurs under certain conditions, and results in a spore-forming structure called a **sporocarp**, which is not a distinct asexual generation ; for, as in Eurotium, the mycelium is by turns an oophyte and a sporophyte, *i.e.*, produces spores now by a sexual, now by an asexual process.

One of the filaments coils itself into a close **spiral of four or five turns**, separated by septa, so that each turn of the spiral is one cell. Several branches then spring from the base of the coil, and grow up enclosing it in a spherical mass of **false tissue**. One of the branches is larger than the rest, and its apex curls over and enters the opening at the top of the coil. The spiral is a female sexual organ, which, however, produces no distinct egg, and which is called an **archicarp**. The largest branch is the male sex organ which fertilises it, and is called a **pollinodium**. After fertilisation, the spiral bears branches, from each of which a spherical cell—a **sporangium**—is cut off by a septum. Within each sporangium eight spores are formed. Such a sporangium is called an **ascus**. The spores within the asci develope at the expense of the ascus wall, and of the surrounding cells. They absorb the material forming the branches and finally the spiral itself, so that what remains when the spores are ripe, is a hollow spherical box, or **sporocarp,**—the outer part of the sphere of false tissue which first grew up round the spiral. This is full of dry dust, each particle of which is a spore, which can germinate and form a new mycelium as soon as it finds itself in suitable conditions as to food, warmth, and mixture.



THALLOPHYTA.

3. CLASS FUNGI.

"The term *Fungus* denotes a group of lower plant forms distinguished by definite characteristics of structure and development, and recognised at once when we see a mushroom or a mould." Most Fungi consist of one or more branching filaments called **hyphæ**, which may or may not be divided by septa. There may be numerous nuclei in a non-septate hypha, as also in single cells of a divided one, specially in reproductive cells. Some of the simplest

Fungi have not hyphæ, but are simply ovoid cells, such as yeast, for example. The higher forms, however, can all be shown to consist of hypha-like structures massed together so firmly as to resemble the true tissues of higher plants, which are masses of cells formed from one another by division after which they remain in contact. Such a felted mass of originally separate hyphæ, *e.g.*, the flesh of mushrooms, is called **"false tissue,"** or **pseudo-parenchyma**. None of the Fungi possess chlorophyll, and being thus unable to absorb and assimilate CO_2 for themselves, they have to feed on organic compounds of carbon. These they can get either by stealing them from other living organisms, when they are **true parasites**; or they may feed on dead and decaying organic matter, when they are called **true saprophytes**.

Some Fungi live partly on living and partly on dead organisms, and indeed we have, between true parasites and true saprophytes, intermediate forms combining the two modes of life in every degree. **Facultative parasites** are plants usually saprophytes, which can, upon occasion, live parasitically; and **facultative saprophytes** are, similarly, parasitic plants, which sometimes become saprophytic. Like all other organisms, Fungi need a supply of oxygen; and the process by which they make use of oxygen, forming CO_2 which is set free, is, as usual, called **respiration**. In most plants respiration is veiled, because after CO_2 has been absorbed as material for carbon assimilation, more oxygen is set free as surplus from this process than is needed for respiration. But the Fungi taking in no CO_2 give out no oxygen, so that they can easily be shown to take a certain quantity of it from the air for respiration. The cell walls of Fungi are of a substance not exactly like the cellulose of other plants, though generally resembling it. This has been called **fungus-cellulose**, and is probably a mixture of ordinary cellulose ($C_6H_{10}O_5$) with some complex substance.

LICHENS.

Some Fungi always live in close union with certain Algæ, in an intimate physiological relation, which is one form of **symbiosis** or **consortism** by which both organisms benefit. The Alga absorbs the CO_2 formed by the respiration of the Fungus, which in turn feeds on the organic waste products of the Alga. The Fungus, however, gains more by the partnership than the Alga, which could live an independent existence in virtue of its carbon-assimilating powers, while the Fungus could not subsist without some supply of ready-made organic matter. Such mixtures of Algæ and Fungi are called *Lichens*. The best known are the gray or white forms that spread over trees and walls.

SUMMARY OF GROUP THALLOPHYTA.

The *Thallophyta* are those lower plants which are not differentiated into stem, leaves, and roots, and whose cells are not grouped into distinct tissues, such as the limiting or protective, the vascular, fibrous, and

ground-mass tissues of the higher plants. The body of such a plant is called a **thallus**. The lowest plants included in the group *Thallophyta* have, however, no proper **thallus**, since their body consists of a single small rounded cell, hardly differentiated into cell wall, protoplasm, chlorophyll, and cell sap. While still a single cell, a plant may be very large, and enormously branched, and the contents of its cell wall may be highly differentiated. When cell division occurs, and the daughter cells remain attached to one another, a thallus of very large size may result. Repeated divisions parallel to one another give a **row of cells** or a **filament**; divisions in two planes give a **cell-surface**; and divisions in three planes produce a **cell-mass**, capable of growing in any direction. The immense numbers of forms which the thallus assumes are all variations from one or another of these three types of structure. The reproductive processes of the Thallophyta are very varied. From the simple **fission** of the *Schizophyta*, through many forms of **asexual multiplication**, which is simply discontinuous vegetative growth, we pass to the union of two simple cells which are not differentiated into sex elements (conjugation), and thence through various stages of specialisation to elaborate processes with highly complex organs of sexual reproduction.

The Thallophyta, without chlorophyll, are the *Mycetozoa*, some of the *Schizophyta*, namely, nearly all the *Schizomycetes* or *Bacteria*, and all the *Fungi*. The *Diatomaceæ*, the rest of the *Schizophyta*, and the *Algæ* all assimilate carbon in the usual manner.

II.—MUSCINEÆ (BRYOPHYTA).

LIFE HISTORY (6.) FUNARIA.

Sexual Generation or *Oophyte* developed from the asexually produced Spore, and bearing Sexual Organs.

The spore of *Funaria* is a small rounded mass of protoplasm enclosed in a double wall. Under the influence of heat and moisture the exosporium or outer wall bursts, and the inner wall or endosporium protrudes in the form of two small tubes, one of which simply elongates, and is divided by septa into a multicellular filament. The other goes beyond this stage, and, branching very freely, spreads over the moist nidus where the spore has germinated. Where above ground the cells of this organism contain chlorophyll, it can thus live independently for an indefinite time without further change. This stage in the development of the moss plant is called its **protonema.** It must be carefully distinguished from the prothallus of other plants, for while the prothallus is the whole sexual generation of a fern, for instance, the protonema is only a preliminary stage in the development of the sexual generation of the moss. It is, in fact, a moss stem, only one cell in thickness, while the later branches are several cells thick and covered with leaves. The septa dividing the protonema are placed obliquely, and behind some of them small outgrowths of the cell appear. One of these protru-

sions being divided into two cells by a septum, from the posterior half of it a branch grows upward, by repeated cell divisions. From the lower end of the branch numerous multicellular hairs grow. These act as roots, fixing the branch to the ground, and they are called **rhizoids.**

At the apex of the branch is a large three-sided cell, from which new cells are always being cut off, first from one side and then from another, round and round the stem, which thus grows by an **apical cell.** A section through a branch shows that its outer cells are thick walled and closely packed to form a covering for the larger thinner walled cells inside. In the centre of the stem is an axile bundle of very narrow cells, with very thin walls. Beyond this there is no differentiation into tissues.

The **leaves** are simple, pointed, closely crowded on the branch, on which they are sessile, with a broad insertion. These upright leafy branches are called the moss plant, for the sexual generation in the Muscineæ is the actively vegetative one, contrary to the rule in the higher groups, where the sexual generation is reduced to the small prothallus, and the asexual generation or sporophyte is the conspicuous leafy one. The moss plant can, however, propagate itself asexually in many ways.

The formation of new leafy branches is almost always preceded by the growth of a protonema. The original protonema can grow indefinitely, producing new branches, and so is a means of vegetative propagation. Its cells sometimes separate, become rounded off, rest a while, and then grow like spores. A secondary protonema may be produced from any rhizoid, which may also produce leaf buds. A leaf, while attached to the plant, or even if cut off from it, may produce a new protonema. **Gemmæ** are found on the branches above ground, and, falling off, produce protonemæ. Even detached pieces of the asexual generation or sporophyte will grow, so missing out of the life cycle the process of spore production (apospory).

Sexual Organs. The sexual organs are produced at the apices of branches. With them grow club-shaped hairs called **paraphyses**, which act as a protective padding, and the organs are surrounded by a tuft of leaves usually somewhat different in size and shape from the ordinary ones, and often coloured. The whole is called the "moss-flower," though, of course, it is in no way comparable to the flower of phanerogams. The male organs or **antheridia** of *Funaria* grow on plants which are smaller and shorter lived than those bearing the female organs, or **archegonia**. The antheridia are club-shaped sacs, having a wall one layer of cells in thickness, and containing numerous free cells or cysts, **spermatocytes**, within each of which a **spermatozoid** is formed. When these are ripe, the sac ruptures at its apex on the application of moisture. The cysts escape in a thick mucilage, which is dissolved in water, allowing the spermatozoids to escape

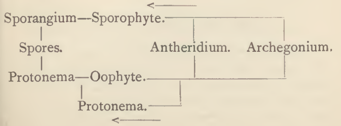
—little masses of naked protoplasm, thick at one end, spirally coiled, and tapering off into two cilia, by which they swim freely.

The **archegonium** consists of a short stalk, bearing a rounded portion called the **venter**, with a long neck. The wall of the venter is two cells thick, that of the neck one cell thick. The whole, then, is like a flask on a short stalk. It contains an axile row of cells. The protoplasm of the lowest of these forms an **oosphere** in the venter. A small portion cut off from this (compare the polar bodies of animal eggs), forms the **ventral canal cell**, and the cells in the neck of the flask are called **neck canal cells**. The canal cells are converted into mucilage, which is discharged at the flask mouth, and attracts the spermatozoids by a sugary substance which it contains. One of them swims down the neck into the venter, fuses with the oosphere, and fertilises it. The segmentation and growth of the oosphere forms the **sporophyte**, which produces asexually a large number of spores, each of which produces a plant of the sexual generation, so completing the life cycle.

Asexual Generation, or *Sporophyte*. The sporophyte, which is usually, as above mentioned, the leafy and vegetative generation, is in *Funaria*, as in all the Muscineæ, a small structure, remaining attached to the oophyte, and incapable of independent life. Its development begins by the division of the fertilised oosphere into two cells by a transverse septum called the **basal wall**. The **hypobasal** half—

that next the oophyte—divides further and forms an organ called **the foot**, which grows downwards into the top of the moss-branch, and thus remains embedded in the oophyte, attaching to it the growing sporophyte. The **epibasal cell** divides again twice parallel to the basal wall, and then a series of oblique divisions cuts off two rows of cells, forming a rod of tissue continuous with the foot. This rod, the embryo of the sporophyte, is at first enclosed within the wall of the archegonium, which continues to grow after the fertilisation of the oosphere. Soon, however, the sporophyte outgrows its case, and by its increase in length the wall of the archegonium is ruptured transversely. Its basal portion, clinging round the base of the sporophyte, is called the **vaginula**; its upper part, carried upwards on the growing apex, is known as the **calyptra**. As the sporophyte continues to grow it becomes differentiated into two parts,—the **seta**, or stalk, which is attached by the **foot** to the moss branch and is surrounded at its base by the **vaginula**, and the **theca**, or **moss-capsule**, a swollen portion borne at the apex of the seta and covered by the hairy **calyptra**. On removing this the ripe theca is seen to be an ovoid box, with a wall several cells thick. The outer layer is epidermal in character, and contains numerous stomata like those under the leaves of higher plants. The upper end of the box is easily removed, being in fact a lid—**the operculum.** Under it is a circle of teeth opening outwards and composed of rows of cells with much thickened walls.

These form an inner lid called the **peristome**. Inside the capsule is a central mass of tissue called the **columella**, and round it is a cylindrical **sporangium**. Between this wall of spore-forming tissue and the outer wall is a cylindrical **air space**, crossed by numerous threads, which sling the sporangium in the centre of the capsule. The spores are formed from free cells,—**the mother-cells**,—which are developed from a tissue called the **archesporium**. Within each mother-cell four spores are formed by free cell multiplication, the protoplasm first showing signs of dividing into two parts, but the four portions being finally separated before the new spore walls are formed. The mother-cell walls and the tissue whose disappearance leaves the air spaces round the sporangium, are absorbed as nutriment by the growing spores, leaving only the solid columella, surrounded by spores, in the hollow capsule. The spores escape by the removal of calyptra and operculum and the rupture of the peristome, and on germination each produces a protonema, as before described, completing the life-cycle.



MUSCINEÆ.

1. CLASS MUSCI.

The *Musci*, of which *Funaria* is a type, are more highly developed than the *Hepaticæ*, the other class of the group Muscineæ. They all rank as **cormophyta**, seeing that the plant body is differentiated into stem (branch) and leaves. The germination of the spore always results in a **protonema**, which is clearly distinguishable from the leafy branches of the moss-plant. The mode of growth is most commonly **radial**, the leaves being equally arranged all round the upright axis, whose position is called orthotropic. The venter of the archegonium ruptures transversely, early in the growth of the sporophyte, forming vaginula and calyptra. There is a central columella in the capsule, which does not rupture, but opens by the operculum and peristome. There are no elaters amongst the spores. The leaves of mosses commonly have a sort of midrib, which is not usual amongst the *Hepaticæ*.

2. CLASS HEPATICÆ. (Liverworts.)

In the *Hepaticæ* the protonema is scanty or absent. The plant body is either flat and dichotomously branched, spreading over the ground, or it is a stalk with two or three rows of small leaves. The class thus contains some members whose body is a thallus,

and others, which, being differentiated into stem and leaves—axis and appendicular organs, rank with the *Musci* and higher plants as Cormophyta. The growth of *Hepaticæ* is usually **bilateral**, the stalked as well as the thalloid forms having dorsal and ventral surfaces, and the axis usually being horizontal or of plagiotropic position. Instead of rupture occurring early across the wall of the venter, as in the mosses, the archegonium of *Hepaticæ* remains unbroken throughout the development of the sporophyte, and ruptures at its apex when the spores are ripe. There is no columella in the capsule, and some of the mother cells, instead of dividing into spores, form elongated structures marked with spiral bands. These are called **Elaters**. They are never found in the *Musci*. The capsule of *Hepaticæ* usually splits into four valves to allow the escape of the spores. The oophyte is usually bright green, the upper cells being full of chlorophyll, and sometimes being formed into remarkable stomata. The under surface has little chlorophyll, but gives rise to numerous unicellular root hairs. The leaves are often without any midrib, and when this is absent the leaf usually consists of a single layer of cells.

SUMMARY OF GROUP *MUSCINEÆ* (BRYOPHYTA).

Amongst the *Muscineæ* occur all transitional forms between a flat, leafless thallus, and a much branched, leafy stem. None of them have true roots or vascular tissue. The plant is attached to the substratum by numerous hair-like rhizoids. The thallus or leaves are well supplied with chlorophyll, and so can assimilate carbon. They also absorb water freely, so differing from the leaves of the higher plants, for these get all their moisture through their roots.

The **alternation of generations** is specially well seen in the Muscineæ, where a vegetative and conspicuous **oophyte** (generation bearing sexual organs) is followed by a less conspicuous **sporophyte** (structure producing spores asexually) which does not live an independent life, but remains attached to the oophyte and draws nutriment from it. Each generation ends in the production of a number of single cells, each of which can reproduce the parent. The **oophyte** produces fertilised oospheres, **sexually**; they give the **sporophyte**, which produces spores **asexually**, and these give the oophyte, an alternation of sexual and asexual generations. A great contrast between the *Muscineæ* and the higher plants is that in the latter the asexual sporophyte is the conspicuous and leafy generation, while the oophyte is a much reduced structure, the prothallus, only sometimes capable of independent existence.

III.—PTERIDOPHYTA.

1. CLASS FILICINEÆ.

LIFE HISTORY OF *ASPIDIUM*.

Structure of Adult Sporophyte. Stem. The underground stem of the fern — a **rhizome**, — is placed obliquely, with its unbranched apex pointing upwards. It is covered by the persistent bases of the leaves, which bear numerous brown, scaly **hairs,—ramenta.** The posterior end of the stem dies and rots away; but the anterior end lives through winter, and its apex puts out new leaves in spring, and in this manner the plant **perennates** through an indefinite number of years. Lateral buds arise posteriorly upon some of the leaf stalks, and, when the stem rots away, these buds are left isolated in the soil, and, putting out roots and leaves, form new plants.

Roots. The roots are inserted on the bases of the leaves. They are thin, brown-coloured, and covered with root hairs. The transparent apex is protected by the usual **root-cap** or **pileorhiza**, which is formed from segments cut off anteriorly from the single **apical cell.**

Physiology and Structure. The root hairs have a chemical as well as a mechanical action on the soil, disintegrating it and aiding the solution of its constituents. The essential elements of plant food absorbed by the root hairs, variously combined, and passed up the vascular elements of the **xylem** as crude sap, are **H. N. S. and P.**, the accessory ones being **K. Mg. Fr. Ca. and Cl. C** and **O** are, of course, absorbed by the leaves. The compounds formed of these elements in the leaves pass down the petiole, and to various parts of the plant in the sieve vessels of the **phloem**. Besides supplying the elements of crude sap, the roots perform the mechanical function of fixing the plant in the ground. To do this, it must be able to resist pulling strains. Thus it has, throughout its length, a cylinder of the hardened tissue of elongated, thick-walled cells, called **sclerenchyma**. Within this, and protected by it, is an axile vascular bundle for the passage of fluids, in which the bast or **phloem**, consisting of bast cells and sieve tubes, surrounds the **xylem**, which is vessels mostly with **scalariform** thickenings, also a few spiral vessels. The bundle is surrounded by a cortex of undifferentiated cells, forming parenchymatous tissue.

The **rhizome** has to bear lateral strains from the leaf stalks, whose bases, set close round it and pressing into its surface, give it an irregular transverse section. A strengthening layer of **sclerenchyma** is round the outside of the cortex just under the **epidermis**, and the vascular bundles are in a circle inside the **cortex** and round the **pith**. Each bundle has a thin protective layer of **sclerenchyma** round it, and a layer of cells called the **bundle sheath**. The

bundles are of the **concentric** type, the **phloem** surrounding the **xylem**; they anastamose frequently forming a **"netted cylinder."** Each leaf stalk springs opposite a mesh of the net, and several small bundles pass into it, from the margins of the mesh.

Leaf. In the **petiole** or leaf stalk, there is a sheath of **sclerenchyma** surrounding the bundles, which here are arranged in a cylinder, while in the lamina they spread out and form a network which is filled in by loose **parenchyma** with large intercellular spaces. The cells contain corpuscles of chlorophyll (**chloroplasts**), which colour the leaf green. The upper and lower surfaces are covered by flattened epidermal cells which contain chlorophyll. In the lower epidermis are numerous **stomata** or openings communicating with intercellular spaces, each protected by two crescentic guard-cells. **Transpiration** is the name given to the exhalation of water vapour by the stomata.

Respiration is the oxidisation of substances within the plant, setting free CO_2 and reducing the weight of the plant; while **carbon assimilation** is the taking in of CO_2 by the leaves, O being set free, and **starch** ($C_6H_{10}O_5$) and other **carbohydrates** being formed.

Reproduction. The propagation of individuals is secured by the **leaf-buds** mentioned above, but the species is widely spread by the production of **spores** on the under surfaces of the leaves. These germinate and produce the sexual generation of oophyte, which bears male and female organs, and produces the embryo by a true sexual process.

Fructification. On the under surfaces of the pinnae of some of the leaves **sori** occur. The **sorus** is a group of **sporangia**. A swollen portion on one of the veinlets or vascular bundles of the leaf forms a cushion called the **placenta**, from which grow stalks supporting **sporangia**, and also hairs or **paraphyses**, which act as padding protective to the sporangia. The whole is covered and protected by an umbrella-like outgrowth from the placenta called the **indusium** ; but the ends of the paraphyses project beyond the edges of this.

The **sporangium** is a rounded sac containing numerous spores, four of which are formed by successive bipartitions within each of the sixteen **mother cells**, which are developed from a certain cell in the young sporangium called the **archesporium**. The walls of the mother cells, and the cells immediately surrounding them, the tapetan layer, are absorbed in the formation of the spores. The ripe sporangium is thus a hollow capsule filled with sixty-four dry brown spores. Several cells, forming a row round the wall of the sporangium, have their outer walls much thickened and very elastic. This structure, which is called the **annulus**, has the peculiarity of straightening itself out when water is abstracted from it, and thus, when the sporangium is ripe, the annulus bursts it with a small explosion, and scatters the spores widely. The ripe spore has two coats, a rough brown **exospor-**

ium, and within it a smooth **endosporium**, enclosing a small dense mass of protoplasm.

Oophyte Germination. In conditions of moisture and warmth, the cuticularised exosporium bursts, and the contents of the endospore, having formed a new cellulose coat, divides rapidly, forming a plate of cells. This grows into the **oophyte** or organism bearing the sexual organs, and is called the **prothallus**. It is a somewhat heart-shaped plate of cells, the spore being at the point, and the **organic apex**, where growth takes place, being in the **notch** opposite to it. The edges are thin, while the central portion forms a cushion several layers of cells thick. The cells are filled with chlorophyll, and thus the prothallus can assimilate carbon and grow independently on the surface of the soil, to which it is fixed by numerous **rhizoids** which descend from the under surface of the cushion. Round the margin of the prothallus are a few unicellular hairs.

Amongst the Rhizoids are the **antheridia**, or **male sexual organs**, which are globular sacs with walls one cell thick supported on short stalks. A mass of rounded cells, **spermatocytes**, fills the sac; each escapes when the antheridium is ripe, and then bursts, letting out a little coil of protoplasm, thick at one end and provided at the other with a tuft of **cilia**, by which it moves. These male sex elements, called **spermatozoids**, are developed from nuclei of the **spermatocytes**. Nearer the edge of the prothallus, and also on the under surface, are less numerous **archegonia.** The ventral portion is embedded in the tissue of the prothallus, and the elongated neck is always curved, so as to open away from the apical notch.

The venter contains the **oosphere,** and a portion cut off from it corresponding to a polar vesicle, which is called the **ventral canal cell.** In the neck, which consists of four rows of cells, is a mass of protoplasm with **three large distinct nuclei.**

The **antheridia** burst only in water, and thus the **spermatozoids** are always received into an element suitable for their locomotion. Water enters the neck of the **archegonium** and swells up its contents, so that a **mucilage** is extruded; this contains **malic acid,** which is thought to attract the spermatozoids. One of these, swimming down the neck of the archegonium, reaches the venter, and fuses with and **fertilises the oosphere** contained in it.

Segmentation of the Oosphere producing Embryo Sporophyte.

The **sporophyte** produced spores, single cells which germinated and produced the **oophyte.** This has now produced a single cell, the fertilised **oosphere,** whose subsequent growth reproduces the **sporophyte.** Note that the sporophyte here is the fern plant, the large and **vegetative organism,** the oophyte, or **prothallus,** being the small generation; while in the moss the conditions are reversed, the **vegetative oophyte** of the moss plant corresponding to the **prothallus** of the fern, and the **moss capsule** representing the **fern plant.**

In the development of the sporophyte, note the following points :—

The ovum is first crossed by a **basal** wall at a **slight angle** to the axis of the archegonium, dividing it into an anterior or **epibasal** cell next the apex of the prothallus, and a posterior **hypobasal** cell next its rhizoid-bearing end.

The second wall is in the plane of the prothallium, and divides the ovum into four parts; while a third, vertical to the others, forms eight **octants**. This is a case of **holoblastic** segmentation of the ovum, the whole cell dividing.

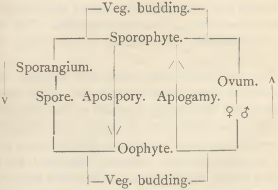
Under the prothallus, then, the **embryo** fern is developed from these eight cells. The **stem**, **root**, and **first leaf** being attached to the prothallus by a stalk penetrating into its tissue, and absorbing from it nutriment for the embryo until its own root enters the ground and becomes functional as an absorbing agent, and the first leaf becomes large and green enough to perform the necessary carbon assimilation. This stalk is called the **foot**, and its function is the **nursing** of the embryo.

Two anterior inferior octants = 1st leaf.
One anterior superior = stem.
Two posterior superior = foot.
One posterior inferior = root.

The stem and root octants are opposite one another. The two octants not mentioned have **no definite function**.

Apospory is the shortening of the life cycle by **missing out the development of the spore**—the frond bearing sexual organs on a prothalloid outgrowth. This has not been observed in *Aspidium.*

Apogamy is the shortening of the cycle by **missing out the sexual organs,** a young plant growing from the prothallus without the formation of functional sex organs.



I. CLASS FILICINEÆ.

Aspidium is typical of the majority of Filices. These produce **spores** of **one kind,** which develop into an **independent prothallium,** bearing both male and female organs. The Ophioglossæ and Marattiaceæ differ from the Filices proper, in having their sporangia developed from **groups of cells** instead of from **single ones,** and in that the sporangia are sunk into the tissue of the leaf or raised from its surface

in spherical capsules. Some Filicineæ (the Rhizocarpæ) have **two sorts of spores—macrospores** and **microspores** — produced in sporangia of **different kinds**, macro- and micro- sporangia. The female prothallia **protrude only slightly** from the macrospore, and do not grow independently, while the spermatozoids are produced upon very **rudimentary prothallia** of a few cells cut off from the microspore. Salvinia, one of the Rhizocarpæ, has no roots, and floats on the surface of water with two rows of vegetative leaves exposed, and a ventral row of leaves submerged and metamorphosed into rounded capsules containing the sporangia.

2. CLASS EQUISETACEÆ (HORSE-TAILS).

The spores are of one kind, and produce **independently growing prothallia of two kinds**, the female larger than the male. The fertilised **oosphere** segments **holoblastically** into octants, from which the sporophyte arises as a branching stem bearing **true roots**, and distinctly **marked into internodes**, each bearing a whorl of very small sheathing leaves. A number of branches may spring from each node, and a root may be given off beneath each branch. The spore-bearing leaves—**sporophylls**—occur only at the apex of the stem, where several whorls of them form a compact spike. The leaves are umbrella-shaped or **peltate**, and five to ten sporangia are born on the under surface of each surrounding its stalk.

Stem and root grow from **large apical cells**, from which segments are cut off in three rows. The stem is hollow, and its fibrovascular bundles, which have phloem outside and xylem vessels inside like monocotyledons, are arranged in a circle round the cavity of the stem.

3. CLASS LYCOPODINEÆ.

The spores are **alike**, and produce **independent** prothallia; or else they are of **two kinds**, in which case the **prothallia are very minute**, never grow alone, and **do not emerge from the wall of the spore**. The sporophore is a simple or branching stem — if branching, **often dichotomous**. It bears true roots and numerous small simple leaves. The sporangia occur either on the upper side of the leaf near its base, in the axil of the leaf, on the stem near it, or sunk in the tissue at the end of a short branch, showing how the **sporangium-bearing organ or placenta** may **vary in position** from **leaf** to **axis** in very nearly allied plants. The most interesting Lycopodineæ are the Club-mosses, seeing that they are the nearest living relatives of the gigantic Carboniferous forms whose growth formed our coal-fields. Lepidodendron was a huge tree-like plant, branching dichotomously, and bearing sporangiferous spikes (called Lepidostrobus) on the ends of its branches. The spores were probably of two kinds.

SUMMARY OF GROUP PTERIDOPHYTA.

The Pteridophyta or Vascular Cryptogams have **tissues well differentiated.** Stem, branches, and leaves are well defined, and **true roots** occur. **Fibro vascular bundles** are always well developed. The alternation of generations is clearly marked, the **sexual oophyte** being small and **inconspicuous**, often incapable of independent growth and retained partially or completely within the wall of the spore. The oophyte bears antheridia and archogonia. It is never anything but a thallus (**contrast** moss oophyte), and usually dies soon after the formation of the embryo sporophyte. The oosphere segments producing the sporophyte, which is large and conspicuous, and may **perennate** through many years. It has various modes of asexual reproduction. Stem and root grow from **apical** cells, and the rootlets grow from the inner tissue of the root.

In many the spores are all alike—**isosporous** condition; in others they are macro- and micro- spores —**heterosporous** condition. Macrospores produce female prothallia bearing only archegonia; microspores, male prothallia bearing antheridia. Fertilisation in the Pteridophyta is always by water, the male elements being motile spermatozoids. In Filicineæ the **stem** is underground, and its uses are to support the **large** cercinate **leaves,** connect them with the roots, and store nutriment. In Equisetineæ and Lycopodineæ the **stem** is the conspicuous part which gives character to the plant, the leaves being comparatively small.

PTERIDOPHYTA.

FILICINEÆ.	EQUISETINEÆ (HORSE TAILS).	LYCOPODINEÆ.
Sporangia collected into sori, on edges or under sides of leaves.	Sporangia round lower edge of peltate leaves.	Sporangia on axils of leaves, or on stem or leaf near them.
Fertile leaves never confined to special part of stem.	Fertile leaves in whorls forming a spike at apex of stem.	Fertile leaves often confined to one part of stem.
Spores all of one kind (isoporous), or of two kinds (heterosporous).	Spores all one kind (isosporous).	Spores of one or of two kinds.
	Prothallia, two kinds— Large female. Small male.	
Leaves large.	Leaves small.	Leaves small.
Filices (ferns) Isosporous Prothallus independent. Rhizocarpæ (pepperworts) Heterosporous Prothallus not outside spore.	Sporangia developed from more than one cell.	Sporangia developed from more than one cell.

IV.—PHANEROGAMÆ (SEED PLANTS OR SPERMAPHYTA).

1. CLASS GYMNOSPERMÆ.

LIFE HISTORY (8.) *PINUS SYLVESTRIS.*

Pinus is a forest tree whose shiny **acicular leaves** remain functional for more than one season, and give it the **evergreen** habit.

Foliage. The branch is covered with the bases of **scale leaves** which are crowded at the termination of each year's growth. This expresses, on the one hand, the check to vegetation during winter, leaves being produced as usual, but the stem not growing enough to separate them; on the other hand, the crowded leaf scales form a protection to the bud of the next year's wood. Lateral branches grow from the nodes together with the new wood continuation of the main branch.

In the axils of some of the scale leaves, **small branches** occur, each of which bears a **few scale leaves** and **two** of the characteristic **pine needles**. These shortened branches are called accordingly, **bifoliar spurs**. After a functional life of one or two years they are shed **complete**, with their pairs of leaves attached.

Stem. The stem of *Pinus* has the arrangement of tissues common amongst Dicotyledons, namely, a **cylinder** of **collateral bundles** growing from a **cambium** and separated by thin **medullary rays.** This is surrounded by a **parenchymatous cortex,** and the **limiting tissue** outside this is in the first year an **epidermis,** which is replaced in succeeding years by a **cork layer** formed from a **cork cambium (Phellogen),** which appears in the cortex. The whole stem is perforated with longitudinal "**resin canals**" formed by the breaking down of rows of cells to form resin. The only **xylem vessels** in pine wood are the **spiral** ones forming the wood of the first year or **protoxylem.** The wood formed from the cambium consisting of spindle-shaped **tracheids,** whose ends overlap, and whose cavities communicate by numerous holes through the sides that are parallel to medullary rays. These holes are surrounded by rings of secondary cell wall, and each gives in a radial longitudinal section, the appearance of two small concentric circles. These structures are known as **bordered pits.**

Root. The root of *Pinus* is of the ordinary dicotyledon type. A **radial bundle,** in which patches of bast alternate with the rays of the wood, is surrounded by a **pericambium** from which **lateral roots** grow, and outside this is a thick parenchymatous cortex. Secondary growth in thickness is produced by division of the cells of a **cambium** which runs in a wavy line between the wood and the bast, outside the former and inside the latter as in the stem.

Reproduction. The adult plant as above outlined is the sporophyte, which bears macrospores and microspores as follows. At the beginning of a year's growth of new wood, some shoots are specialised for reproduction, and the leaves they bear are called **sporophylls**. The male spikes, which are deciduous (*i.e.*, fall off at the end of the year after bearing microspores), are lateral shoots at the **base** of the new wood. They correspond to **bifoliar spurs** and occur in the axils of scale leaves, but bear several scale leaves, and then numerous **sporophylls** instead of two needles. On the **under** surface of each **sporophyll** are two **microsporangia anthers**, and each of these contains numerous mother cells. From each mother cell four **microspores** or **pollen grains** are produced. Each **pollen grain** is a mass of protoplasm with an inner coat, the **intine**, and an outer, the **extine**, which is swollen out into two **bladder-like expansions** which enable the pollen to be carried long distances in currents of air. The sulphur showers of tradition are wind-borne clouds of pine pollen.

The female spikes or **cones** are modifications of bifoliar spurs occurring at the apices of new wand shoots. Each bears a few scales, and then a close spiral of **sporophylls**. Each sporophyll has on its **upper** surface a **cushion-like placenta**, or **sporangium-bearing organ**. The placenta bears two **macrosporangia** (**ovules**), which are not enclosed in any structure comparable to the ovary of angiospermæ. Each ovule is enclosed, except at one point, by a **single**

integument. The tissue of the ovule is called the **nucellus**, and within it is formed a single **macrospore**—the **embryo-sac.**

Germination of the Spores.

The **germination** of the spore always results in the **oophyte** or sexual generation, which produces, by the union of sexual elements, a single cell, whose segmentation forms the embryo of the sporophyte. *Pinus* is no exception to the rule. The **microspore** is divided into **two** cells by a septum. The **smaller** cell in this case is the **male prothallus**, and the larger one is a **male reproductive organ.** The nucleus of the **macrospore** or **embryosac** divides repeatedly, forming within this a tissue called the **endosperm**, which is the **female prothallus.** At the end of the **endosperm** nearest the opening in the integument, several **archegonia** are formed, each consisting of an **ovum** and **four neck cells.** The **oophyte** is reduced to these very narrow limits, and in neither case does it escape from the spore wall of **pollen grain** and **embryo-sac.**

Fertilisation.

Some **viscid mucous** is produced above the **nucellus**, and it protrudes through the opening in the integument. Wind-borne pollen grains are caught on the drop of viscid matter, and when this dries up they are moored on the naked surface of the nucellus. Then the reproductive cell of the pollen grain begins to grow—the **intine** pushes out through the **extine** as a pollen tube, and the nucleus passing down this tube enters the neck of the **archegonium**, fuses with the nucleus of the **ovum**, and

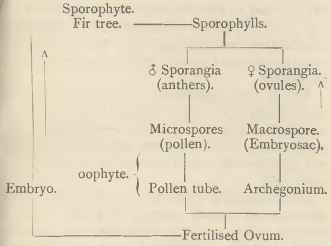
fertilises it. The **ovule**, it should be remembered, is formed one year, fertilised the next, and ripens into seed in the third.

Sporophyte. **Segmentation of the ovum, embryogeny, and ripening of seed.**

This ripening of the ovule into the seed begins the new sporophyte generation. Usually only one of the archegonia produced in the embryo-sac is fertilised. The segmentation of the ovum is **meroblastic**,—*i.e.* only a small portion of it segments, the rest acting as yolk. First a **transverse** cell wall cuts off the lower end of the ovum—that farthest from the opening in the integument. This is then divided into **four cells** by longitudinal walls, and then each of these is divided into **three** by transverse walls. The four rows of three cells thus formed elongate, and, growing down into the tissue of the embryo-sac, form the **suspensor** of the embryo. The four terminal cells can each divide further, and so form **four embryos** from **one ovum**—a case of **polyembryony**, but it is usual for only one of these to be developed, the growth of the other three ceasing at this point. Of the further changes that occur the following are the most important:—Repeated division of one of the four cells forms an **embryo** attached by the **suspensor** to the apex of the embryo-sac. Its **radicle** is next the suspensor, and the other end is divided into **ten or twelve cotyledons.** The **endosperm** or **prothallus** continues to grow within the enlarging embryo-sac, and forms a mass of "**albumen**" for the early nutriment of the embryo after germination, so that the **seed** formed by the maturing of the ovule is an **albuminous** one. Further, the whole female spike enlarges greatly, forming the large **fir-cone**, between whose dry leaves the ripe seeds are wedged.

Germination. The ripe seed may remain without further development for an indefinite time, but under the influence of warmth, moisture, and light the **radicle** protrudes from the integument, covered by the embryo-sac wall, elongates, and breaks this across, carrying a portion of it down upon its point. As the **radicle** elongates to form the **primary root** of the growing sporophyte, or young fir-tree, it develops a **root cap (Pileorhiza)** and numerous **root hairs**. The bases of the **cotyledons** are gradually pushed out of the seed as they grow, while their points **remain in the seed** embedded in the **albumen,** which they absorb for the nutriment of the plant. By the time it is all used up the root has become a functional fixing and absorbing organ, and chlorophyll has appeared in the bases of all the cotyledons, and throughout those whose points have already escaped from the seed. The stem (**plumule**) grows up from between the bases of these first leaves, and the plant goes on developing independently into the adult structure.

LIFE CYCLE OF *PINUS*.



PHANEROGAMÆ OR SPERMAPHYTA.

I. CLASS GYMNOSPERMÆ.

The **floral axis** (shoot bearing sporophylls) is usually elongated producing a **cone**. The flowers are usually **unisexual** or **diclinous** (*i.e.*, male sporangia produced alone in some, females alone in others). The ovules before fertilisation are **not enclosed** in an **ovary** formed by the cohesion of carpellary leaves (female sporophylls), though these may grow considerably after fertilisation so as to conceal and protect the seed. The **ovule** (macrosporangium) is either the extremity of the floral axis or a lateral shoot from below its apex, or else it springs from the axil of a leaf, or from the upper side or margin of the leaf. It has only **one integument.** The **endosperm** (prothallium here) is formed within the single macrospore (embryo-sac) before fertilisation, and produces **archegonia.**

Two or more **pollen-sacs** (microsporangia) appear on the under side of each staminal leaf, and they **do not unite** into one cavity during development. The pollen grain divides into **two cells** (male prothallus and reproductive organ) before the growth of the pollen tube.

Polyembryony is common, *i.e.*, the formation from **one** ovum of **several** embryos, only **one** of which, however, developes. The embryo-sac and its contained prothallium continue to grow as the embryo developes, displacing the nucellus (perisperm), so that in the ripe seed the embryo is surrounded by a large amount of **endosperm**; but outside this there is no **perisperm.** The embryo is always straight, with its root pointing towards the micropylar opening in the integument of the ovule, through which the pollen tube entered at fertilisation. There are two or more and often several cotyledons (first leaves). At germination the root bursts the seed coat and appears first. The tips of the cotyledons remaining embedded in the **albumen** (endosperm) and absorbs it as nutriment after the plumule has been freed from the integument by their elongation.

PHANEROGAMÆ OR SPERMAPHYTA.

2. CLASS ANGIOSPERMÆ.

LIFE HISTORY (9.) *SCILLA.*

Scilla is a **Monocotyledon** of the Liliaceous type, which dies down every autumn, but **perennates** by means of a **bulb**, from which a new plant springs up in the following year. The **base** of the **stem** is somewhat **swollen**, and the roots pierce the membrane which covers it. It is closely surrounded by the **fleshily-thickened bases** of the green **leaves** of the plant, these with the swollen base of the stem forming a **tunicated bulb**. The leaf bases are filled with stores of nutriment formed in the upper part of the leaves, and sent down to be reserved for the use of next year's young plant. In the axils of one or more of the youngest leaves small **buds** are formed, and when the leaf tops die down in autumn, these are left attached to the **bulb** formed during the summer. Next spring, when a **bud** begins to grow, it puts out roots into and finally through the old bulb, and feeds upon its store of reserved material, while it sends up a stem surrounded by numerous new leaves. The bases of these in time become thickened with food store, which will in turn be utilised by a bud which will grow in the axil of one of them.

The stem grows straight up, surrounded by the leaves whose bases form the bulb, and bears no more for some distance. The leaves next produced are organs accessory to reproduction, namely, **bracts**, and in the axil of each of these a **flower stalk** springs. An indefinite number of these floral axes may be produced before the stem ceases to grow, and devotes all its strength to the maturing of the essential reproductive leaves. This produces the form of **indefinite inflorescence** called a **raceme**. Each flower stalk bears a second and smaller coloured leaf called a **bracteole**, and then elongates no further, but forms a shortened **torus** or **receptacle**, on which grow two whorls of accessory reproductive leaves—the **petals** forming the **perianth**. In each of these whorls, the outer and the inner, there are three **perianth segments**, whose colour attracts to the flower the insects whose visits ensure cross fertilisation. The petals are not united into a tube. Next the **shortened shoot** or **floral axis** bears an outer and an inner whorl of **staminal leaves (male sporophylls)**, three in each whorl. Each **stamen** is slightly attached to the petal opposite to it, and consists of a **filament** or stalk and two **anther lobes**, which are **microsporangia**. The **mother cells** of their inner tissue each produce four pollen grains or microspores, each with its intine and extine for covering. A layer of cells called the **tapetum**, which surrounds the mother cells, is absorbed in the production of the pollen grains.

The members of each whorl of reproductive leaves **alternate** with those of the next, and alternating with the three stamens of the inner whorl are three **carpellary leaves (female sporophylls)**. These are united into a superior **ovary**, topped by a trifid **stig-**

matic surface for the reception of pollen, and divided into three "cells" or **loculi** by **septa** running from the wall or **pericarp** to a central **axis**, which is the sporangium-bearing organ or **placenta**. Numerous ovules (**macrosporangia**) are borne on this **axile placenta** in each of the three **loculi**. Each **ovule** has two coverings or **integuments** (**primine** and **secundine**), and within the tissue of each **nucellus** is matured **a single macrospore**, the **embryo-sac**. The **micropyle** is an opening through both the integuments, and this is close to the point (**hilum**) where the ovule is attached to its stalk (**funiculus**). Ovules of this type are called **anatropous**, and the end of the embryo-sac nearest the micropyle is its apex.

This terminates the spore-producing or sporophyte of an angiosperm. The germination of the pollen grain or microspore, and the embryo-sac or macrospore, to form pollen tube and ovum, is the **whole of the oophyte** generation in these higher plants.

Oophyte germination of the macrospore.

The **nucleus** of the **embryo-sac** or **macrospore** now divides; one half travels to each end of the sac and there divides into **four**. Of the **eight** cells now in the embryo-sac, which may be said to correspond to the female prothallus (result of cell division of the macrospore), **two return to its centre**, and there **fuse**, forming the **secondary nucleus** of the embryo-sac. **Three** remain at the **lower end** of the sac, and are called **antipodal cells**. The **three** remaining at the **apical end** of the sac next the micropyle form the **female reproductive organ** of angiosperms which corresponds to the archegonia of lower forms. One of them is, of course, the **ovum**, the two others remain one on either side of it, and are called **synergides**; they may be compared to neck cells.

Germination of the microspore and fertilisation. **Pollen grains** are carried from plant to plant by insect visitors in search of the **nectar** which is secreted by glands in the wall of the ovary. Some of these adhere to the sticky **stigmatic** surface above the ovary, and there **germinate**. In angiosperms the microspore is not even divided by a cell wall as in gymnosperms, for the **nucleus simply divides**, the smaller part of it **remaining within the spore**, and corresponding to the male prothallus. The **intine** protrudes through an opening in the **extine** as a **pollen tube**, the male reproductive organ. This passes through the tissue of the ovary into its cavity, and continues to elongate until, entering the ovule at the **micropyle**, its point reaches the surface of the nucellus close to the apex of the embryo-sac. The **larger nucleus** formed by division in the pollen grain passes down the **pollen tube**, and, entering the embryo-sac, fuses with and **fertilises the ovum**, thus completing the angiosperm **oophyte**.

Commencement of the sporophyte formation of seed and fruit. As in the gymnosperms, so in the angiosperms, the development of the new sporophyte commences and advances to a considerable extent

within the integuments of the ovule or macrosporangium. The **matured ovule** containing the embryo plant, and usually some store of food material for its further growth (**albumen**) is, in both, **the seed.** The ovum in *scilla* segments **holoblastically,** *i.e.*, all of it divides, none remaining comparable to yolk. First a **transverse** wall divides it into **two,** and further transverse divisions form a **row** of cells, the **suspensor** attaching the embryo to the apex of the embryo-sac, down into whose cavity the suspensor grows. Division of the terminal cell forms a little mass of cells which developes into the **embryo.** This, in *Scilla*, and all monocotyledons, consists of a **radicle** next the suspensor, and a single **cotyledon,** or first leaf, enclosing the **plumule** or point of the stem. **After fertilisation the secondary nucleus of the embryo-sac divides,** and produces within its cavity a mass of cells called **endosperm.** This is not comparable to the "endosperm" of gymnosperms, which is simply the female prothallus, being formed by the division of the embryo-sac before fertilisation. In both cases the tissue of the ovule surrounding the embryo-sac is called **perisperm.** "**Albumen**" is a name given to any endosperm or perisperm that may remain surrounding the embryo in the ripe seed. In *Scilla*, then, the development of the embryo is accompanied by the growth of the embryo-sac which contains it together with a growing mass of endosperm. When the seed is ripe much of this remains round the embryo to form its first food on the germination of the seed, which is therefore called **albuminous**. While the fertilised ovules are maturing into **seed**, the wall of the ovary, or **pericarp**, has also been growing, for the effect of fertilisation extends to this also. The result is the **fruit**, a dry-walled **capsule**, with three cells, each of which bursts to allow the seed to escape (**loculicidal dehiscence**).

Germination of the seed. It must be remembered that when the seed germinates, and the seed coat bursts at the micropylar end, allowing the embryo to protrude, the **radicle never breaks through** the tissue covering it at the base of the embryo. There is thus **no primary root**; but a number of **adventitious roots** break through from the base of the stem and fix the growing embryo, which soon absorbs all the albumen from the seed, and escaping from its wall begins to put out green leaves round its lengthening stem.

LIFE HISTORY (10.) *HELIANTHUS.*

Helianthus is an **annual** of the order **compositæ**. After shedding seeds in autumn the plant dies completely, and the species is maintained by the seedlings of the following spring. A tall stem is raised with large vegetative leaves, and this is crowned by a large **composite inflorescence**. The flower stalks are suppressed, and also the main axis which bears the

flowers, so that a multitude of these are borne close together on a **flattened receptacle**, forming a **capitulum.** Under the capitulum grow numerous bracts, forming a sheath of green organs resembling the calyx of a simple flower. This is called an **involucre** of bracts. The flowers forming the capitulum are of **two sorts, ray florets** and **disc florets.** A **disc** floret consists of a floral axis which is hollowed at its apex, and bears the floral whorls on the edge of the cup so formed. The hollow of the cup forms the ovary, which being thus below the insertion of the stamens, is called **inferior.** The **calyx** is represented by a whorl of **hairs** springing just above the ovary (**pappus**). There are five **petals** united into a tube, the **corolla**, their five apices showing as five teeth. Five stamens are attached to the corolla; they alternate with the petals in position, and their anthers unite by their edges and form a sheath round the pistil (**synantherous** condition). Above the ovary is the **style**, which is surrounded by the anthers, and which terminates in a **bifid stigma,** whose two points show that two carpellary leaves enter into the composition of the pistil. The stamens are ripe before the style is fully developed, and as this elongates, it pushes up between the anthers and sweeps out their pollen. An insect then carries this away to some other flower which is still further advanced, its pollen having already been removed, and its stigmatic surfaces having expanded ready to receive that of another flower. This device for securing cross-fertilisation by the ripening of the stamens before the pistil is called **protandry**. Protandry and Protogyny are the two forms of sexual dichogamy.

The florets round the edge of the capitulum, **ray** florets, differ from those forming the central disc as follows. The corolla is much longer, and is split up one side, so that it is not a tube, but a flat, **strap-like** union of five petals, whose points show at the apex (**ligulate corolla**). There are **no stamens**, the ray floret being **female**; the style and bifid stigma, and some hairs surrounding it are the only organs within the corolla.

In the development of pollen and ovules *Helianthus* so closely resembles *Scilla*, that it is only necessary to mention that the inferior ovary contains only **one anatropous ovule**, which stands **erect** on the floor of the inferior ovary. The embryo during development uses up all the endosperm, so that the seed is **exalbuminous**. The **pericarp** (ovary wall) in the ripe fruit is dry, and it does not split for the escape of the seed (**indehiscent**). Dry indehiscent fruits containing a single seed are called **achenes**, and inferior achenes like that of Helianthus receive the name **cypsela**.

PHANEROGAMÆ.

2. CLASS ANGIOSPERMS.

The floral axis of angiosperms is usually shortened, and may be flattened or even hollowed.	In gymnosperms floral axis elongated.
The floral leaves are usually whorled.	Leaves in spiral.
There are usually two whorls of accessory floral leaves, sepals and petals, the inner or both whorls coloured and attractive. Cross fertilisation is the rule, insects and wind being the principal agencies employed. For attraction of insects, nectaries are often developed.	Scale leaves only organs besides sporophylls.
The flower is usually hermaphrodite, but diclinism (monoecism and divecism) is common.	Usually diclinous flowers.
The ovules are enclosed in an ovary,	No ovary.
and have two integuments.	One integument.
The ♀ prothallium is reduced to a few free cells lying in the embryo-sac. The female reproductive organ is reduced to three cells, an ovum and two Synergides.	♀ Prothallium, a mass of cells filling embryo-sac (endosperm), and producing several archegonia.
The secondary nucleus of the embryo-sac divides after fertilisation forming endosperm.	No such secondary endosperm.
The pollen grain (microspore) is not divided by any cell wall,	Pollen grain divided by a cell wall.
the nucleus simply dividing into two parts, one representing the ♂ prothallus, and the other the reproductive one travelling down the pollen tube.	Pollen tube growing out from the larger of the two cells thus formed.

ANGIOSPERMÆ.

Monocotyledons.	Dicotyledons.
Usually one first leaf or cotyledon in embryo.	Usually two first leaves or cotyledons.
Fibrovascular bundles closed or simultaneous, *i.e.*, not increasing after formation by division of cells of a cambium.	Bundles usually open, *i.e.*, secondary thickening produced by divisions of cells of a cambium.
Bundles scattered throughout stem.	Bundles arranged in a cylinder round pith, and inside cortex separated by medullary rays.
Venation of leaves usually parallel.	Venation of leaves usually reticulate.
Floral parts usually in whorls of three.	Floral parts usually in whorls of five, less frequently four, and sometimes other numbers.
Primary root not developed, but replaced by numerous adventitious ones.	Primary root usually developed.

SUMMARY OF GROUP PHANEROGAMÆ.—Seed Plants.

The alternation of generations obvious in vascular cryptogams is here concealed. The macrospore is retained within the macrosporangium, and the prothallus having the female sexual organs is produced within the macrospore; after fertilisation the oosphere developes into the embryo of the sporophyte, and this, with its coverings or integument, forms the seed which is characteristic of phanerogams.

In the moss the oophyte (prothallium) was the important and vegetative portion of the life cycle. In the ferns and equisetums the sporophyte was the leafy and actively vegetative stage, while the prothallus was small and inconspicuous, though still able to lead an independent life. In the Rhizocarps and heterosporous Lycopodineæ, like Selaginella, the ♀ prothallus is formed inside the spore, and only protrudes slightly from it. In the phanerogams this reduction of the oophyte is carried still further. The female prothallus is reduced to a mass of cells, filling the macrospore, and producing female reposed organs or oospheres and archegonia within its wall in the gymnosperms. In the angiosperm the oophyte is only represented by three cells, while other three cells represent the reproductive organ. The male spores, or microspores, of phanerogams divide into two cells only, one of which represents the male prothallus, the other the male reproductive organ. In angiosperms these are not even separated by a cell wall.

In the phanerogams the sporangia are produced on specialised leaves, the flower being a shortened axis bearing these leaves. The microsporangia are called pollen sacs, and the microspores — four of which are, as usual, produced from each mother cell, —are called pollen grains.

The macrosporangia are called ovules. Each ovule is enclosed in one or two integuments—parts of the macrosporangium, and not an outgrowth of the leaf like the indusium of ferns. Several macrospores are, as usual, produced in each macrosporangium, but one only of these survives in development, and is called the embryo-sac.

In gymnosperms the ovule or macrosporangum is naked; in angiosperms, one or more ovules are enclosed in a case, the ovary, formed of one or more carpellary leaves, sometimes together with part of the axis bearing them. The integuments of the ovule enclose tissue called the nucellus, and within this nucellus lies the single macrospore or embryo-sac.

The male fertilising element is not a motile spermatozoid as in Pteridophyta, but the whole microspore (pollen grain) is placed directly upon the ovule (gymnosperms), or upon the top of the ovary (angiosperms), which has a surface specially suited for its retention (stigma). The pollen grain germinates and sends out a tubular prolongation (pollen tube) which enters through an opening left in the integument of the ovule, and transmits to the oosphere in the embryo-sac the fertilising element necessary for its growth. On being fertilised the ovum segments, pushes down into the embryo-sac a pro-embryo which differentiates into two portions, an embryo and a suspensor. The seed matures by the development of this embryo at the expense of the surrounding tissue. If in the ripe seed any of the nucellus (tissue outside the embryo-sac) remains, it is called perisperm; if any tissue remains round the embryo within the embryo-sac it is called endosperm (albumen). In

gymnosperms the endosperm is simply the tissue of the female prothallus, as it is formed before fertilisation. In angiosperms, it is a mass of cells formed after fertilisation by the division of the nucleus of the macrospore or embryo-sac. In the ripe seed the embryo usually shows differentiation into radicle or first root and first leaves or cotyledons, united by a hypocotyledonary portion of the axis, whose apex is the plumule.

DESCRIPTION OF PLATES.

PLATE I.

I. **Vaucheria.**

A. 1. Formation of resting spore.
2. Escape from cell of zoospore.
3. Zoospore.
4, 5. Germinating spore.
6. Thallus, with fixing structures, *a.*, and sexual organs, *b.*

B. 1-5. Sexual reproduction—*a.* antheridium ; *o.* oogonium.
3. Oogonium expelling mucilage,
4. Receiving antherozoids, *an.*
5. Containing fertilised oosphere.

II. **Eurotium.**

1-4. Development of thallus—*a.* sporophore ; *a'.* same, larger ; *s.* sterigma ; *sp.* spores ; *h.* archicarp.
5-10. Development of carpogonium—*an.* antherid ; *n.* branches forming envelope ; *p.* perithecium ; *a.* ascus ; *a'.* ascus, larger, with spores, *sp.*

III. **Saccharomyces.**

1, 2, 3. Budding.
4. Chain formed by repeated budding.
5, 6. Formation of spores.
7, 8. Germination of spores and repeated budding.

IV. **Mucor.**

1. Sporophore, with spores.
2-5. Formation of zygospore by conjugation.
2, 3. Forming of a zygote, *a.*; supported by suspensors,
6. Germination of zygospore, producing filament a sporophore, *sp.*

PLATE II.—*FUNARIA.*

I. **Oophyte.**

1-4. Development of protonema from spore—*a.* spore *b.* hair; *c.* beginning of leafy branch.
5. Leafy branch.
6. Transverse section of same—*p.* protective layer; *a* loose parenchyma; *b.* narrow central cells; *h.* hairs
7. Male "flower."
8. Female "flower"—*l.* leaves; *p.* paraphyses; *an* antheridium; *ar.* archegonium.
9. Antheridium, expelling spermatocytes (*b*) and spermatozoids (*c*).
10. Archegonium—*v.* venter; *n.* neck; *a.* ovum; *b* neutral canal cell; *c.* neck canal cells; *s.* stalk.

II. **Sporophyte.**

1, 2. Segmentation—*n.* basal or first wall; *s.* developing seta; *b.* developing foot.
3. *s.* seta; *n.* neck; *v.* venter; *f.* foot; *o.* oophyte.
4, 5. *s.* seta; *c.* calyptra; *v.* vaginula; *f.* foot; *o.* oophyte.
6. Capsule—*s.* seta; *e.* epidermis; *op.* operculum; *p.* peristome; *a.* air chamber; *s.* sporangium; *c.* columella.
7. Oophyte supporting sporophyte; *c.* capsule; *op.* operculum; *s.* seta; *o.* oophyte; *h.* hairs.

PLATE III.—*ASPIDIUM.*

I. **The Oophyte.**

1-5. Development of the Prothallus from the spore—*s.* spore; *h.* hair; *n.* notched apex of Prothallus; *r.* rhizoid; *ar.* archegonium; *an.* antheridium.

5. Under surface of Prothallus.

6. Antheridium containing spermatocytes.

7. Spermatocyte and spermatozoid.

8. Archegonium, with sunk venter, *v.*, and projecting neck; *n.t.* neck in transverse section; *o.* ovum; *v.c.* ventral canal cell; *n.c.* neck canal cell.

II. **Embryogeny of Sporophyte.**

1. Segmentation of ovum—*a.* first or basal wall; *b.* second wall.

 (1) Anterior upper octants, forming stem.

 (2) ,, lower ,, ,, first leaf.

 (3) Posterior upper ,, ,, foot.

 (4) ,, lower ,, ,, root.

2. Longitudinal section of Prothallus and embryo—*r.* root; *f.* foot; *s.* stem; *l.* first leaf.

III. **Apogamy**. Formation of an embryo of sporophyte of *Pteris* on the Prothallus without the formation of sexual organs.

IV. **Adult Sporophyte.**

1. Transverse section of rhizome—*p.* petiole; *b.* bundle; *s.* sclerenchyma.

2. Arrangement of bundles.

3. Longitudinal section of apex of rhizome.

4. Petiole with bud.

5. Growing point of leaf—*a.* apical cell.

6. Transverse section of bundle—*x.* xylem; *ph.* phloem; *s.* sheath; *scl.* sclerenchyma; *p.* parenchyma.

7. Growing point of root—*a.* apical cell; *r.c.* root cap.

V. **Apospory.** Prothalloid growth on pinnule of *Polystrichum* without production of spores.

VI. **Spore formation.**

1. Pinnule with sori, *s*.
2. Transverse section of sorus—*i*. indusium; *pl*. placenta; *sp*. sporangia; *p*. paraphyses; *l*. under side of leaf.
3. Sporangium—*l*. lip cells; *a*. annulus; *s*. spores.
4. Formation of spores from mother-cell.

PLATE IV.—*PINUS*.

I. **Segmentation of ovum and formation of embryo,** *i.e.*, that part of the sporophyte concealed within the seed.

1-6. Segmentation (meroblastic) of ovum.

1*a*-3*a*. Ova as in 1 and 3, in relation with surrounding parts.

7. Section of ovule with four suspensors, a possible embryo at end of each.

8. Mature seed in longitudinal and transverse sections.

II. **Germination of seed.**

III. **Arrangement of leaves**—*a*. old wood; *b* 1. new wood, main axis; *b* 2, new wood, lateral branches; *s*. scale leaf; *b.s*. bifoliar spur; *l*. acicular leaf.

IV. 1. Male flower—*f*. axis of ♂ flower; *sp*. male sporophylls.

2. Male sporophyll, with two anthers (microsporangia) on under surface.

3, 4. Development of pollen (microspores) from mother cell.

5. Pollen grain, with *e*. extine and *i*. intine; *b*. bladders; *v*. vegetative cell (male prothallus), and *r*. reproductive cell.

6. Pollen grain, with reproductive cell elongated into pollen tube.

V. 1. Female flower—*sp.* female sporophylls.
   2. Female sporophyll—*ov.* two ovules on *p.* placenta, on upper surface of *l.* leaf.
   3. Longitudinal section of ♀ sporophyll and ovule.
   4-8. Development and fertilization of ovule.

In I., II., and V., *i.* = integument of ovule; *m.* micropyle; *n.* nucellus; *e.s.* embryo sac; *e.* endosperm; *em.* embryo; *s.* suspensor; *r.* radicle; *h.c.* hypocotyl; *c.* cotyledon; *p.* pollen.

PLATE V.—*ANGIOSPERMS.*

I. Embryogeny of typical Angiosperm. *Capsella.*

1-8. Development of the embryo--3 *a.* relation of embryo to ovule; *e.* embryo; *en.* endosperm; *pe.* perisperm; *s.* suspensor; *h.* hypophysis cell; *o.* octants; *pl.* plerome; *pe.* periblem; *d.* dermatogen; *c.* cotyledons; *a.* apex or plumule.
9. Exalbuminous seed.
10. Albuminous seed.

II. Scilla.

1. Bulb with adventitious roots, *r.*; bases of old leaves, *o.l.*; new leaves, *n.l.*; and racemose inflorescence.
2. Flower opened longitudinally.
3. Floral diagram.

III. Helianthus.

1. Diagrammatic section of capitulum—*t.* torus; *b.* bracts; *d.* disc florets; *r.* ray florets.
2. ♀ ray floret.
3. Disc floret in section.
4. Floral diagram.

IV. 1 ♂. Anther lobe—*e.* epidermis; *t.* Tapetan layer; *m.* mother cells.
   2 ♂, 3 ♂. Mother cell dividing into tetrads.

4 ♂. Young pollen grain.

5 ♂. Grain with intine and extine.

6 ♂. Germination of pollen—*v.* vegetative cell; *r.* reproductive organ, pollen tube.

1-7 ♂. Development of ovule and germination of embryo sac, *e.s.* ; *o.* ovum ; *s.* synergides ; *a.* antipodal cells ; *s.n.* secondary nucleus of embryo sac, dividing after fertilisation to form endosperm ; *m.* micropyle ; *f.* funiculus ; *t.* testa ; *h.* hilum ; *ch.* chalaza ; *p.* perisperm or nucellus.

PLATE VI.

Plate VI. gives a comparison of the life cycles of Bryophyta, Pteridophyta, and Spermaphyta. It will explain itself, all the figures except those of Equisetum and Selaginella having appeared in the previous plates. ♂ *p.* = male prothallus ; ♀ *p.* = female prothallus ; *an.* = antheridum ; *ar.* = archegonium ; *e.s.* = embryo sporophyte ; *s.p.* = sporangiferous spike ; *sl.* = sporophyll ; *s.* = sporangium ; *spo.* = spore ; *e.* = elater.

TURNBULL AND SPEARS, PRINTERS, EDINBURGH.

1.

Plate I.

W. E. Fothergill. del:

Plate II

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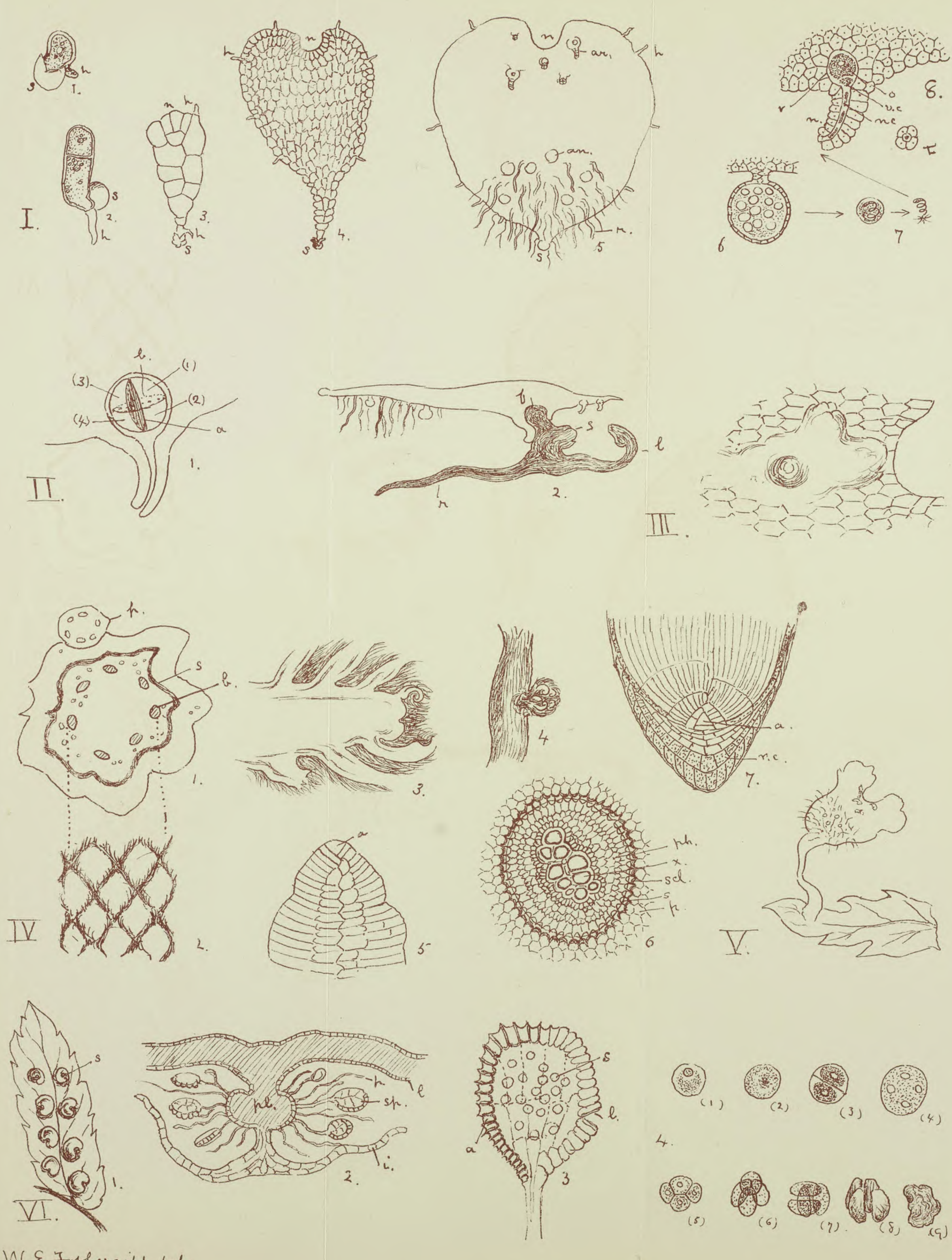
Plate III.



W. E. Fothergill. del:

Plate IV.

W. E. Fothergill. del.

Plate V.

Plate V.

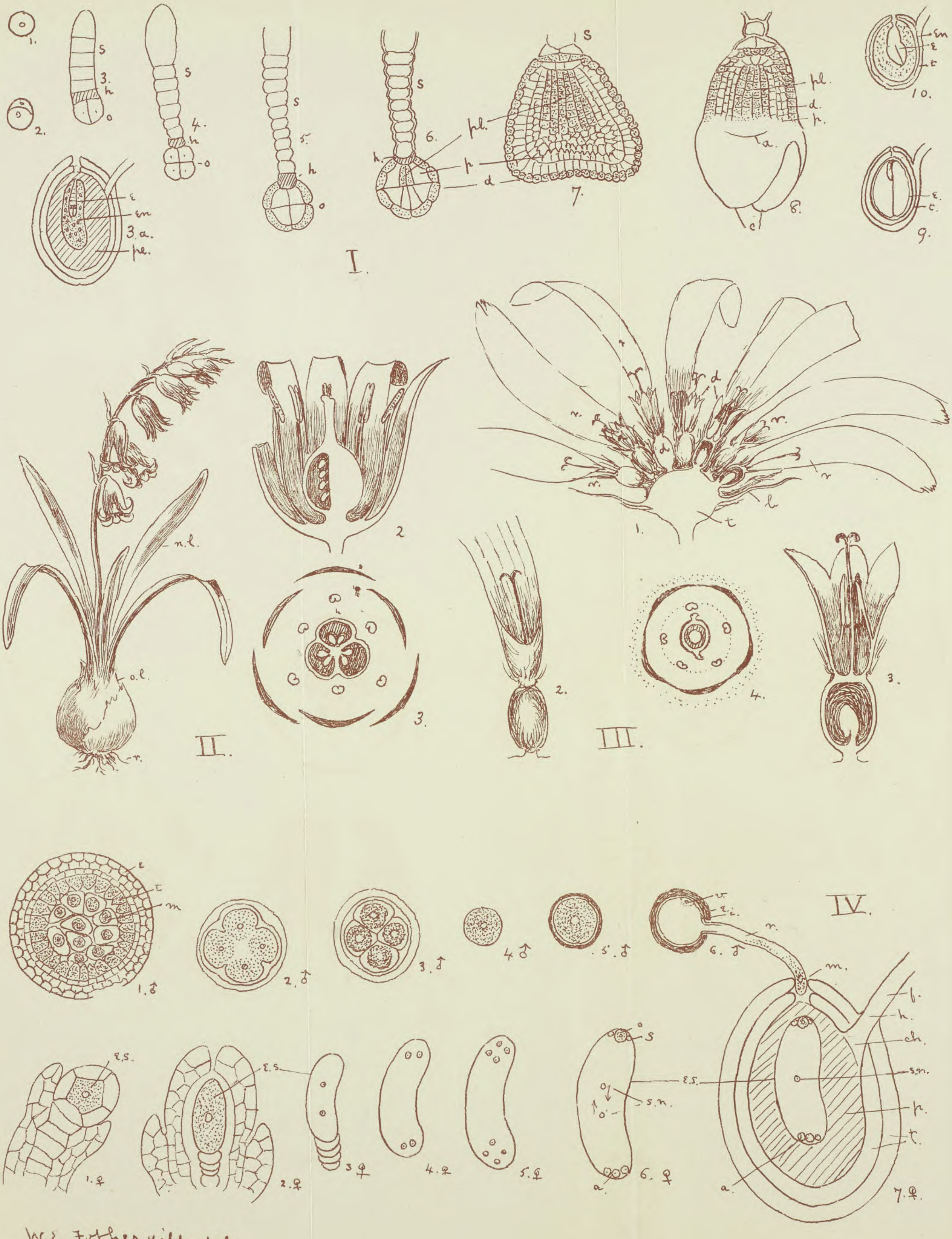


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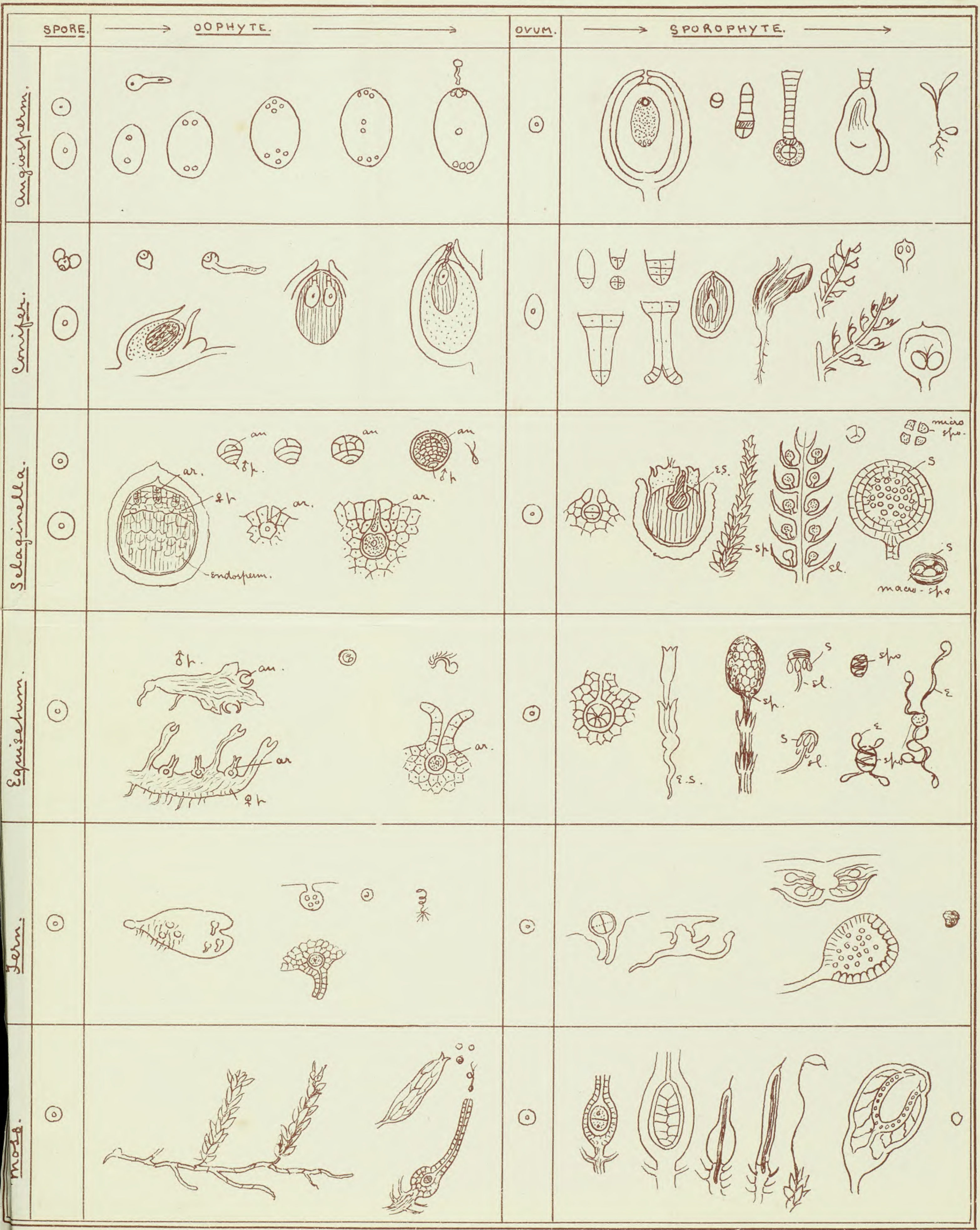
Plate VI.



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