THE BOTANICAL ATLAS

W. & A. K. JOHNSTON, EDINBURGH.

THE

BOTANICAL ATLAS

A GUIDE TO

THE PRACTICAL STUDY OF PLANTS

CONTAINING

REPRESENTATIVES OF THE LEADING FORMS OF PLANT LIFE

BY

D. M'ALPINE, F.C.S.

VOLUME II.

CRYPTOGAMS

W. & A. K. JOHNSTON, EDINBURGH

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PREFACE.

THE "BOTANICAL ATLAS" is carried out on the same plan as the "BIOLOGICAL" and "ZOOLOGICAL" ATLASES, which have been so favourably received. There are several improvements, however, introduced, which it is hoped the student will appreciate. The colour, for instance, is natural, so that every plant, or part of a plant, wears its appropriate garb. The Life Histories of organisms, too, have received full recognition, and the student of Animal Life will thus see that there is much in common between the two kingdoms.

The CRYPTOGAMS range from the simplest organisms which cause Disease or produce Alcohol, through Mushroom, Seaweed, Lichen, Moss, Fern, Horse-Tail, and Club-Moss, ending with those which foreshadow the higher Seed-bearing Plants. The microscope is here necessarily the principal instrument of research; and in delineating minute objects requiring the highest powers for their proper determination, I have been largely indebted to the labours of others. My thanks are specially due to Professor Dodel-Port, who allowed me free and full use of the beautiful Figures in his "Anatomical and Physiological Atlas of Botany," and even favoured me with other drawings to choose from, if necessary.

The PHANEROGAMS are represented in all their leading divisions, and the various reproductive processes are fully illustrated. Typical members are chosen from the principal Natural Orders, and the mode of examination pointed out. The Flower and its various parts passing into Fruit and Seed are mainly considered, and this forms the best introduction to a course of Practical Botany, since the eye and hand, trained to dissect and distinguish these comparatively conspicuous structures, can then more easily pass to the study of the minute structure of Root, Shoot, and Leaf, and their various modifications.

As the specimens chosen are of the commonest kind—from the road-side, the sea-shore, the ponds, the meadows, and the woods—and as full directions are given along with the drawing for their proper examination, this Atlas appeals to every one who takes an interest in the various forms of Plant Life; and as they are taken up in order, commencing with the simplest and most uniform, and ending with the most complex, that general view of the whole field is given which is the best preparation for dipping deeper into any department of it.

D. M'ALPINE.

April, 1883.

CONTENTS OF VOL. II.

CRYPTOGAMS.

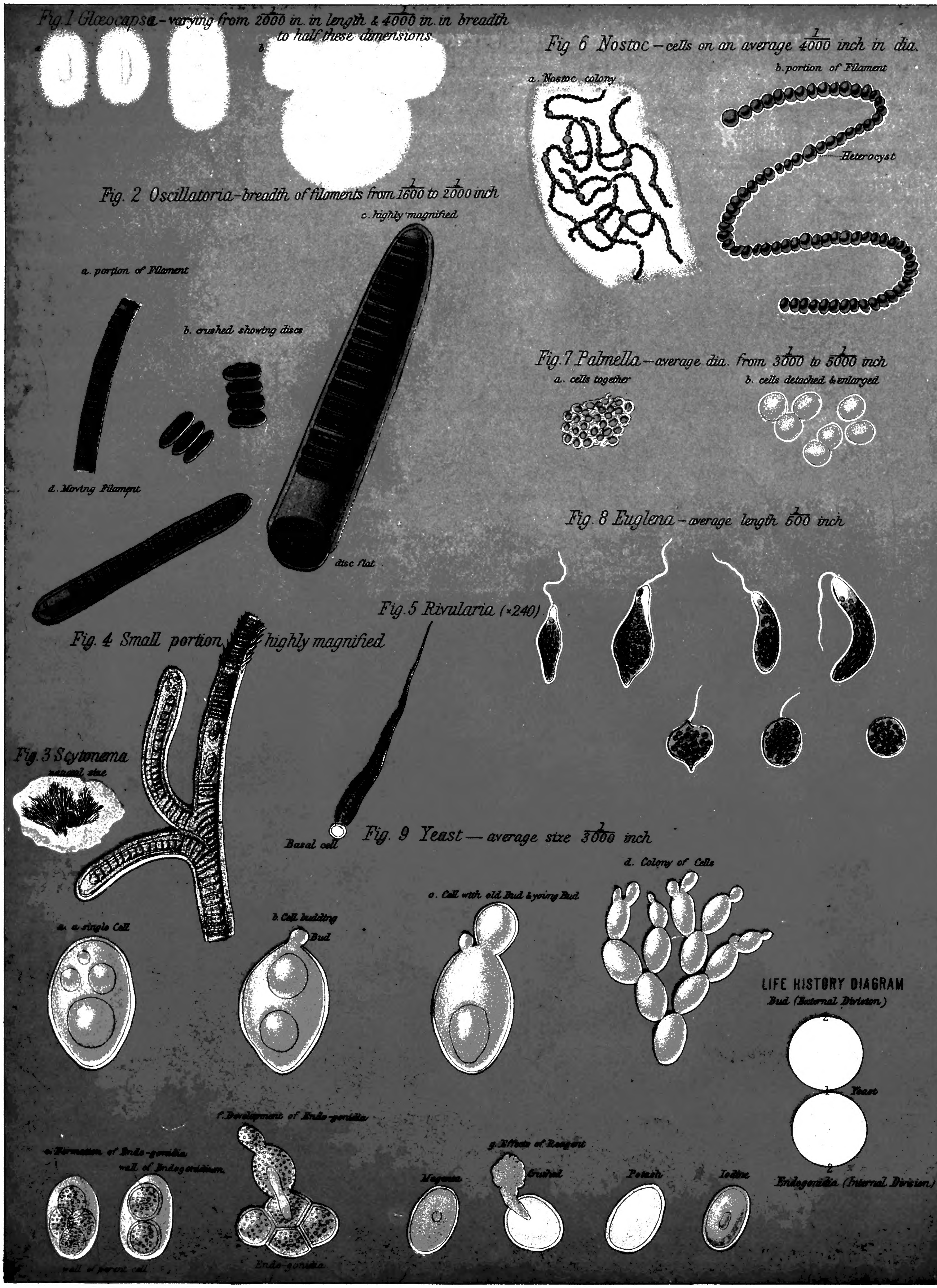

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PLATE I.—GLŒOCAPSA, OSCILLATORIA, SCYTONEMA, RIVULARIA, NOSTOC, PALMELLA, EUGLENA, and YEAST.

(Figs. 1b, 5, and 6a after Luerssen; Figs. 3 and 4 after Dr Welwitsch.)

Glœocapsa.

Glœocapsa (Gr. *glia*, glue; *capsa*, a case) occurs in damp places, and may be conveniently had for examination from the glass of damp green-houses, where it forms in gelatinous masses.

The single rounded cell consists of a small protoplasmic mass surrounded by a gelatinous cell-wall, and divides in all the directions of space till it forms a little colony. Division takes place within the parent envelope, and each daughter-cell forms for itself a new cell-wall. The original envelope, stretched in this way, absorbs more and more water until, towards the exterior, it gradually shades off into the surrounding liquid.

Fig. 1*a*. Examine under highest power: *1st*, as it naturally occurs; *2nd*, stained with magenta; and *3rd*, with iodine to bring out cell-wall distinctly.

The young cell stains deeply, showing the protoplasm to be dense; the next is undergoing division lengthways, and the third shows transverse division.

Fig. 1*b*. Showing different stages of division, ending in the formation of a colony.

Oscillatoria.

Oscillatoria (so named from its oscillating or pendulum-like movement) occurs in various situations, either in water or on damp earth; but it may be found at any season of the year by the roadside, where it forms those spreading green patches at the bottom of damp walls, etc.

Under the microscope it is seen to consist of long filaments, each with a distinct colourless sheath of cellulose, containing protoplasm coloured bottle-green. The protoplasmic contents are marked by transverse lines, with alternate lines only faintly indicated. The power of growth is equally distributed over the whole filament, and any one of the segments can divide into two new ones.

Under the influence of light these filaments exhibit movement. They have a slow, swinging movement from side to side, the stiff filament giving the idea of a pendulum in motion.

Fig. 2*a*. Mount a small quantity in a drop of water, and examine under highest power.

Long filaments, with their contents divided by numerous transverse lines.

Fig. 2*b*. Press upon cover-glass so as to crush the filaments.

The contents are seen to be little discs wrapped in a sheath of cellulose, which lies about ruptured.

Fig. 2*c*. The faint lines between the more decided transverse markings are the expression of the incipient division of each disc into two.

At the base a single disc is shown.

Fig. 2*d*. The moving filament swings from side to side, at the same time going forward.

Scytonema.

Scytonema (Gr. *skutos*, a whip; *nema*, a thread) occurs usually in dense tufts on moist rocks, sometimes in sufficient quantity to disguise the natural brownish or blackish colour of the rocks. This particular kind is of a shining black colour.

Instead of growth going on regularly throughout the filament, as in Oscillatoria, there are some points at which growth is more vigorous, and this bulging gives rise to side filaments or branches.

Fig. 3. Shows a small tuft in its natural size.

Fig. 4. Shows a small filament magnified. There is the common sheath wrapping round the discs, and branches going off at particular spots.

Rivularia.

Rivularia (Lat. *rivulus*, a rill) may be found in mountain streams, coating the surfaces of submerged stones or water-plants. It forms dark-green cushions, which are often incrusted with carbonate of lime, thus giving the whole a peculiar hardened look.

It departs from the uniform characters exhibited by the plants already considered in several respects. 1. Whereas, in Oscillatoria, the filaments of jointed protoplasm could evidently go on growing to any extent, here growth seems to die out at one end, giving rise to a tapering whip-lash filament. 2. Whereas, in Oscillatoria, the filaments were of equal diameter throughout, here not only is there a tapering at one end of the filament, but there is a globular development at the other end, in the form of a Basal-cell or Heterocyst, incapable of further sub-division. 3. Whereas each segment of Oscillatoria had the power of division, and a detached disc could give rise to a new plant, here certain cells, in the course of a filament, only possess that power. One of the cells becomes a basal-cell, and the cell immediately above that grows out into a new filament. As the whip ends of the filaments are all directed outwards, there is a radiating appearance presented, with a basal-cell at the bottom of each filament. 4. The large cell above the basal-cell may grow till it is fully ten times longer than broad, thus becoming capable of persisting during the winter when the rest of the plant has decayed, and producing a new Rivularia in the spring.

Fig. 5. A single filament with Basal-cell or Heterocyst (Gr. *heteros*, different) at one end, and pointed cell at the other.

The Common Nostoc.

The Commom Nostoc is to be looked for after rain, as it readily dries up. It occurs as dark, shapeless, jelly-like masses on garden walks or grass plots.

Under the microscope there is seen to be imbedded in the jelly long convoluted filaments, composed of little globular cells, forming a beautiful beaded neck-lace arrangement, with larger cells every here and there—the Heterocysts. The neck-lace is composed of distinct cells, and not mere discs of protoplasm embedded in a sheath, as in Oscillatoria. The embedding jelly is probably the cell-walls softened with excess of water and run together.

The mode of multiplication varies. The portion of the old colony, between two heterocysts, breaks away from the jelly, and in the water the cells stretch themselves transversely and divide repeatedly, *parallel* to the long axis of the chain. In this way a number of short filaments are formed, side by side, which afterwards arrange themselves end to end, and so form the long meandering chain. In rare cases spores are formed generally between two heterocysts, and persisting after the rest of the filament has decayed, they give rise to a new chain.

Fig. 6*a*. Examine small portion of the jelly under highest power, and observe the beautiful twistings of the chain, with larger cells occurring at intervals.

Fig. 6*b*. Stain with Iodine and Sulphuric acid to show the cellulose coat investing each cell.

Palmella Cruenta.

Palmella Cruenta (Gr. *palmos*, a shuddering; Lat. *cruentus*, bloody), or "Gory Dew," occurs towards the bottom of damp walls, and may frequently be observed even in the thoroughfares of towns. It is readily recognised by its bloody hue, and in cold water it yields a beautiful, pale pink colour.

The cells are embedded in gelatinous matter, and are sometimes angular from pressure.

Fig. 7*a*, *b*. Examine, under highest power, in a drop of water. It peels off the walls in flakes, and only a small clean speck from the surface need be mounted for examination.

Euglena.

Euglena (Gr. *eu*, great; *glene*, the eye-ball), unlike the preceding, is of a brilliant green hue, yet with a touch of red in it. It occurs commonly in the black water draining from manure heaps, which is known to be rich in Nitrogen.

Euglena is a motile organism, moving freely about by means of a long vibratile cilium, at least the length of the body. It is reckoned by some zoologists as an animal belonging to the Infusoria; but there are many points in its character which bear out its vegetable nature, so that, if an animal, it is a vegetating one.

It consists of a spindle-shaped body, tapering at both ends, but as it moves about the outline varies and assumes all possible shapes. There is a red spot, called the eye-spot, towards one end. The contents are distinctly granular and for the most part tinged with the green colouring matter chlorophyll. In the presence of sunlight, oxygen is evolved as a result of the decomposition of carbonic anhydride.

It multiplies by internal division. When about to do so, it gradually becomes still and rounded, drops its cilium, and encloses itself in a structureless case or cyst. The contents divide into numerous portions, each of which, on being set free by the rupture of the cyst, becomes a new Euglena.

Fig. 8. Dip a glass rod into the green scum, and leave the smallest possible portion on a slide, and examine under highest power. This shows the encysted or encysting stage.

Examine a drop of the blackish water for the fully developed forms.

They will be seen moving about leisurely and twisting themselves into all conceivable shapes. By the application of iodine, the cilium will be rendered apparent; and it is curious to note that Euglena is not propelled behind by its cilium but is actually dragged along by it.

In the same liquid there will be a variety of organisms, but the red eye-spot will mark out Euglena even when it is rounded and motionless.

Yeast (Saccharomyces—Lat. *saccharum*, sugar; Gr. *mukes*, a fungus).

Yeast may be obtained at any brewer's establishment.

Fig. 9*a*, *b*, *c*, **and** *d*. Take up a little yeast with a pipette, and drop on to slide, and examine under highest power.

In every position the granules appear round, hence they are not flat, like a coin, but globular.

Cell-wall.
Protoplasmic contents.
Vacuoles filled with cell-sap.
Buds produced, and this process may be repeated, as in *d*, until an aggregation is formed.

Fig. 9*e*, *f*. Starve some yeast by laying it out on a piece of plaster-of-Paris, and keep it moist with wet blotting-paper under a bell-jar. Under these circumstances the yeast is unable to throw off buds, so it breaks up internally in about a week into four portions, which have the power of reproducing the yeast under favourable conditions.

Fig. 9*g*. The vacuole is seen to be less stained than the rest.

In the larger cells the staining material may bring out a dark or denser spot, which is the Nucleus.

Life History.—The Yeast under ordinary circumstances multiplies by budding, and this may go on indefinitely as long as nourishment is supplied, but when nourishment fails, it can divide internally, and so prolong its existence by means of Endogonidia (Gr. *endon*, within; *gone*, seed).

NOTE.—The term *Gonidium* will be used to denote cells non-sexually produced, capable of reproducing the plant. On the other hand, the term *Spore* will be applied to such cells as result from sexual reproduction.

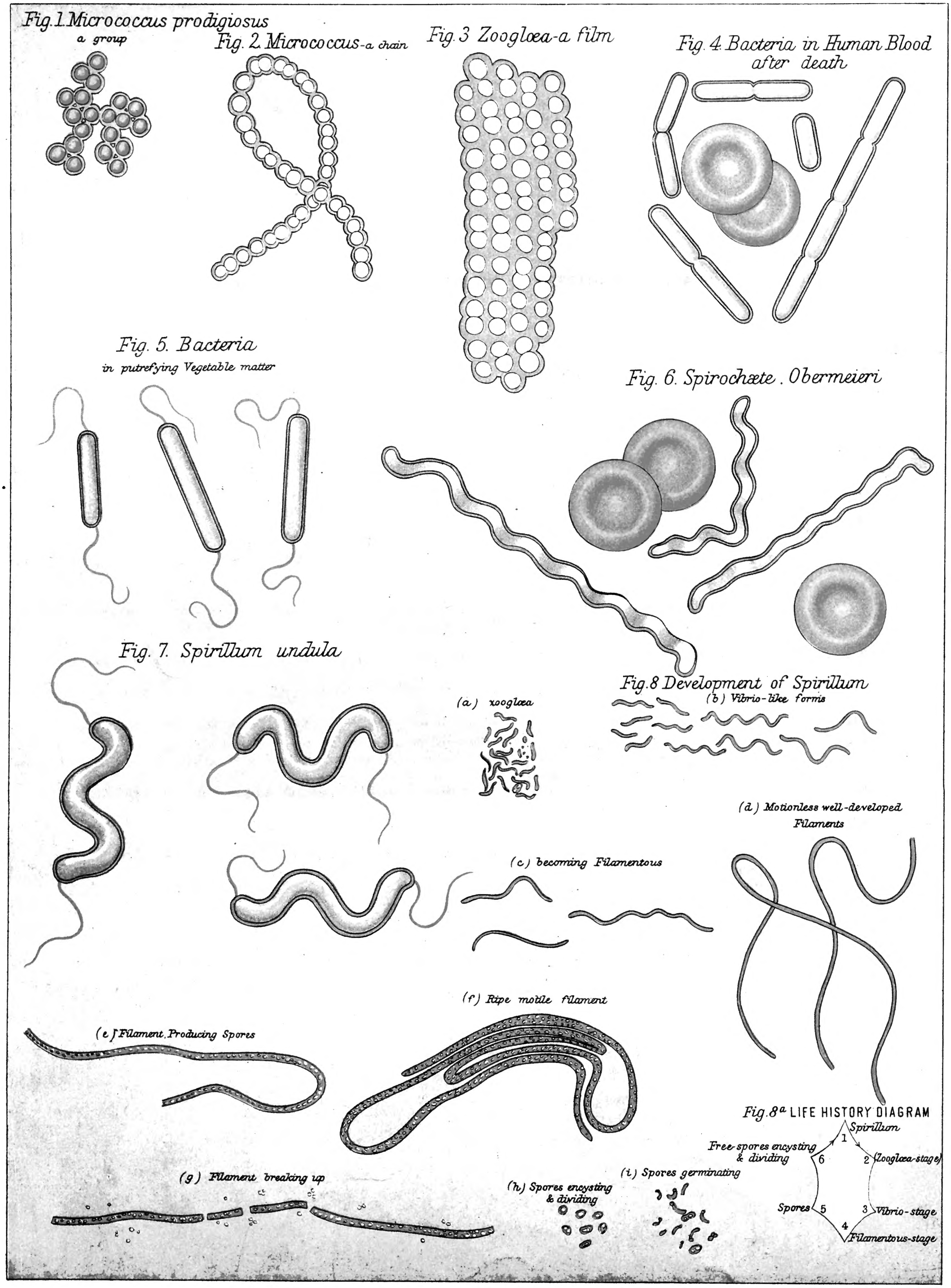

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PLATE II.—BACTERIA, or SCHIZOMYCETES (Gr. *schisis*, a splitting).

(*Fig. 8 is after Ewart, the rest after Dodel-Port, based on Dr Koch's photographs.*)

Bacteria are those organisms which produce the change in organic bodies known as Putrefaction. Hay Bacteria, developed in an infusion of hay, may be profitably examined first. Take some fresh hay, pour hot water upon it, and allow to stand. In the course of a day or two the liquid becomes turbid, due to the presence of Bacteria, and latterly it has the smell of decaying organic matter. If a drop of this liquid be examined under the highest power of the microscope, it will be found to contain Bacteria of simple form.

Figures X 3000, except Fig. 8.

Fig. 1. *Micrococci* (Gr. *mikros*, little; *kokkos*, a berry) are simply small, round, or oval cells, occurring free, or in chain-like rows, or united into a gelatinous mass. They are remarkable for the bright colouring matters with which they are tinged —red, blue, etc.

Micrococcus prodigiosus—the blood-red Micrococcus—is a spherical form, appearing as blood-red, slimy drops on stale potatoes, bread, damp wafers, and the like. From its sudden appearance (often arising in the course of a single night) it has often been superstitiously regarded as an evil omen, as stories of "bleeding bread" or "bleeding wafers" testify. The colouring matter is insoluble in water, but may be extracted by alcohol or ether.

Fig. 2. A chain of Micrococci found in putrefying blood.

This chain has probably originated from the repeated division of a single individual. The single cell lengthens as it grows, then forms a sort of figure of 8 preliminary to division, and this repeated again and again would give rise to the chain.

Fig. 3. A gelatinous film or Zooglœa.

This film or scum forms on the surface of putrefying fluids, and consists of a number of Micrococci embedded in rows in a gelatinous material. This arrangement in rows has probably been produced, as in Fig. 2, by repeated division, as some are found in that condition.

Fig. 4. *Bacteria* (Gr. *bakterion*, a staff), or Cylindrical Forms—the two red blood-corpuscles are merely represented to show relative size.

These forms are the first found in the body after death. They are short or long rods, multiplying by transverse division.

Fig. 5. Rods from putrefying vegetable matter, with a vibratile cilium at each end, by means of which they wriggle about.

Fig. 6. *Spirochæte* (Gr. *chaite*, hair), or Relapsing Fever Bacteria, occurring in the blood of fever patients.

The spiral filaments are flexible and exhibit wave-like movements, which is often revealed by the motion imparted to the blood-corpuscles in the neighbourhood.

Fig. 7. *Spirillum*—to be found in puddles in summer where there is decaying vegetable matter.

They form inflexible spiral filaments, of one or several turns, and have a vibratile cilium at each end.

Fig. 8. Development of Spirillum—*a* to *i*.

(*a.*) Zooglœa-stage—motionless forms embedded in gelatinous material.
(*b.*) Vibrio-stage—bow-shaped forms passing into spiral forms.
(*c.*) Filamentous-stage—the last elongated.
(*d.*) Filamentous-stage—further developed forms, in which the filament is long and motionless.
(*e.*) Filamentous-stage—Spore-producing filament.
(*f.*) Filamentous-stage—ripe and motile filament.
(*g.*) Filamentous-stage—filament breaking up.
(*h.*) Spores which encyst and divide to form sporules.
(*i.*) Spores germinating—little comma-shaped bodies which reproduce the original Spirillum.

Life History Diagram.—The stages are here given through which Spirillum passes in order to complete the cycle of its life.

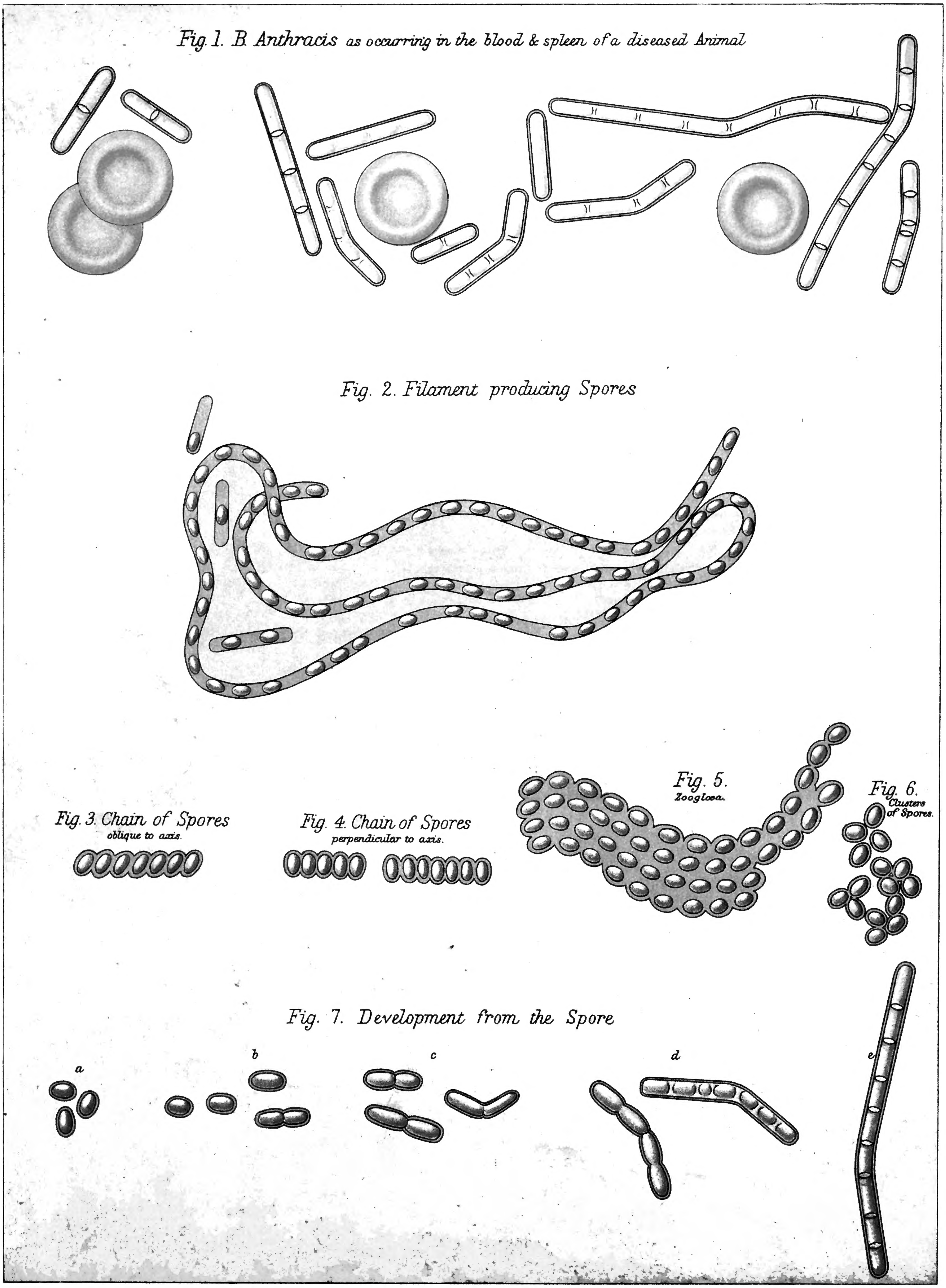

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PLATE III.—BACTERIUM ANTHRACIS, or BACILLUS ANTHRACIS, COHN.

(*After Dodel-Port.*)

Splenic Fever Bacterium, or Bacillus Anthracis (Lat. *bacillum*, a little staff; *anthrax*, *anthracis*, coal), may be taken as the type of those contagious disease germs which have been so destructive in their effects upon the human race, and which are only now being carefully studied. The principal facts made out concerning it may serve as a guide to other forms. It is interesting to note that it has been made to lose its infecting power by frequently changing it in a solution of extract of meat; and one of the triumphs of science at the present day has been to render this and such-like deadly organisms comparatively harmless, by appropriate treatment. The minute size and immense numbers of the spores readily explain the spread of the infection, and as it has been proved that they may retain their vitality for years, the disease may break out quite unexpectedly. It is also matter of experimental proof that the fever ensues when the germs are taken in with the air breathed in the form of a dry dust, and thus reach the blood in the Lungs; or they may reach the blood through scratches or other means.

Figures X 3000.

Fig. 1. Transparent rods, straight and bent, and of various lengths.
These rods are colourless and motionless. They divide transversely, and the joints adhere to form longer or shorter rods.

Fig. 2. Filament produced by the elongation of the rods.
These filaments may attain a length several hundred times that of the original rods, and when fully developed, their contents break up into numberless spores or endogonidia.

Figs. 3 and 4. Spores placed obliquely or perpendicular to the long axis of the filament.
The spores are oval or elliptical, with highly refractive contents and a dark outline.

Fig. 5. Gelatinous scum containing spores arranged in rows.
The gelatinous material gradually dissolves in the water, thus setting the spores free.

Fig. 6. Clusters of spores set free—either as above, or by the deliquescence of a gelatinous filament.

Fig. 7. Development.
(*a.*) Oval spore.
(*b.*) Oval spore, lengthening and dividing.
(*c.*) Short rod lengthening and dividing further.
(*d.*) Longer rods formed.
(*e.*) Long jointed rod, as in Fig. 1.

Life History.—The original short *rods* grow and lengthen in an appropriate medium, such as blood-serum or the aqueous humour of the eye. The *filaments*, thus produced, having attained their full development soon begin to show in their interior numerous bright spots, which latterly become the *spores*, and the rest of the filament passes into a jelly-like mass. Several of the filaments may lay themselves together and so produce a gelatinous scum with the spores embedded and arranged in rows. The spores are set free by the dissolution of this gelatinous material, and are then ready to begin anew their course of development.

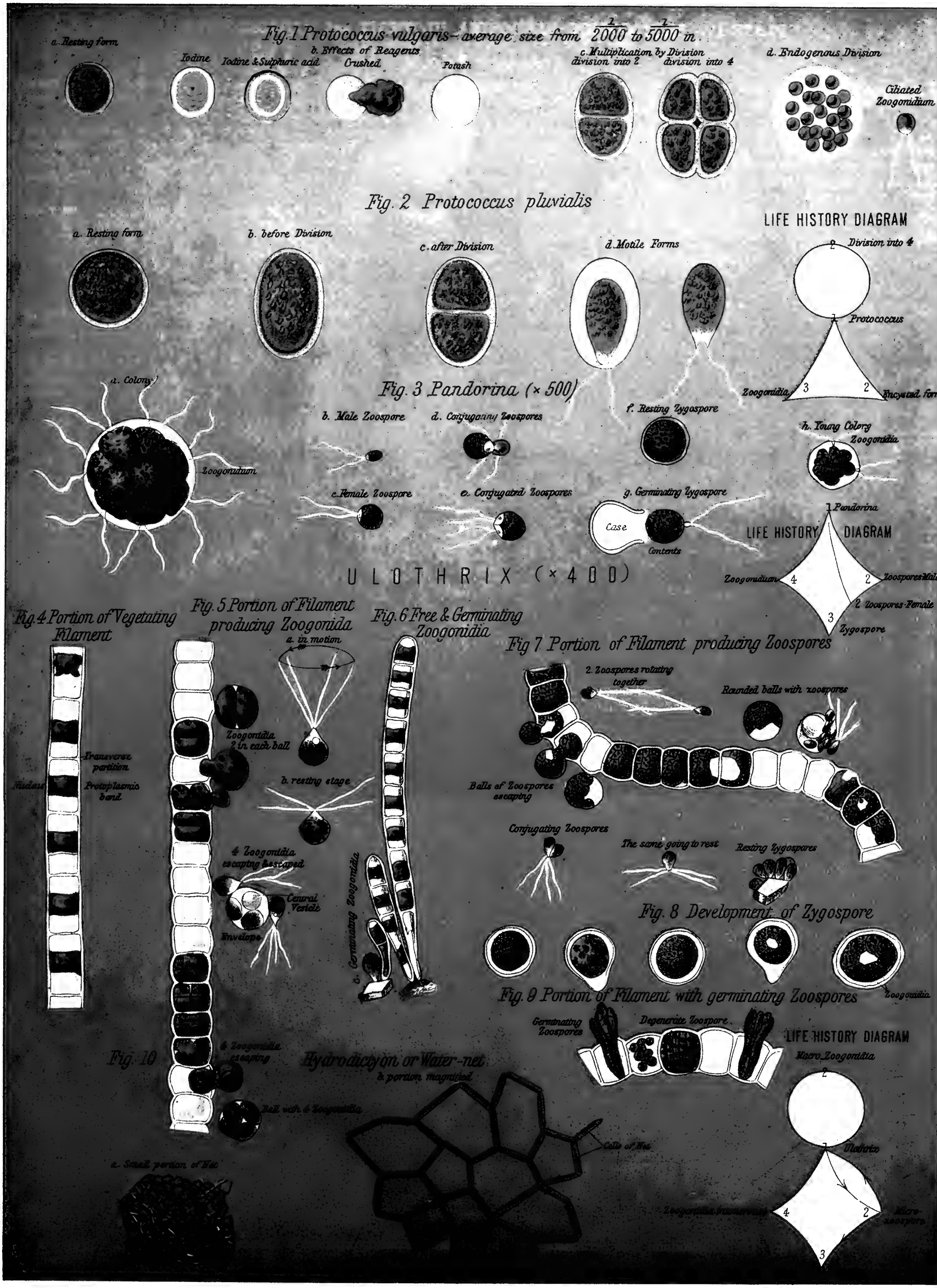

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PLATE IV.—PROTOCOCCUS, PANDORINA, ULOTHRIX and HYDRODICTYON.

Protococcus Vulgaris.

Protococcus Vulgaris (Gr. *protos*, first; *kokkos*, a berry), or Pleurococcus, is well known as the green scum on the bark of trees. It is so widely diffused that its means of multiplication must be very perfect. In fact it is like a continuous growing point, ever dividing and ever ready to divide.

Under the microscope it is seen to consist of rounded cells, usually having a nucleus. This nucleus is a denser portion of the protoplasm and stains more deeply than the rest. The cells are also seen to be divided into two, three, or four portions. But towards the end of autumn another process of division takes place. The contents of the cell break up into a great number of little masses which, on escaping by the rupture of the cell-wall, are seen to consist of naked bits of protoplasm, with two threads of it propelling them rapidly through the water. This naked moving protoplasm afterwards forms a cell-wall.

Fig. 1. Take a little bit of the bark of a tree, with this green scum upon it, and scrape off some of it into a drop of water on a slide. Examine under highest power.

(*a.*) Ordinary resting-form consisting of Cell-wall and green-coloured contents.

(*b.*) Iodine brings out Nucleus—seen as a small dark spot in the centre of the cell.
Iodine and Sulphuric acid together—the cell-wall becomes blue and the protoplasm coagulates.
Crushed—to distinguish clearly between the tough cell-wall and the semi-fluid protoplasm.
Potash—dissolving the protoplasm.

(*c.*) Multiplication by Division into four. The protoplasm first of all separates into two masses, and cell-wall forms in the partition between. Next, each half behaves like the original whole so that four divisions are formed. These divisions separate, become rounded, and each forms a new Protococcus.

(*d.*) Endogenous Division producing motile forms. The protoplasmic contents begin to divide in the same way as before, but instead of stopping at four, there is division into numerous segments of naked protoplasm. The particles become rounded and escape as *motile forms* through the rupture of the original case. The motile ciliated forms, non-sexually produced, are called Zoogonidia (Gr. *zoon*, an animal).

In the resting-forms it will be noticed, that they were clothed with a cell-wall *before* being set free, whereas the motile forms only assume a cellulose covering afterwards.

Life History.—Multiplication takes place either by simple division into four portions, or into numerous motile forms, which afterwards settle down and return to the ordinary resting-form.

Protococcus Pluvialis.

Protococcus Pluvialis (Lat. *pluvia*, rain) as the specific name denotes, occurs in places where rain-water collects.

Fig. 2. Take some of the muddy sediment from rain-water, mount with clean water and examine under highest power.
Observe motionless and motile forms. The motile forms may either be clothed with a wall or naked.

Pandorina.

Pandorina (Gr. *Pandora*, a beautiful woman) occurs in ponds and ditches, but it may be had for examination from certain Natural History dealers.

There are sixteen cells united into a free-swimming colony of globular shape by a gelatinous investment. Each of these sixteen cells may give rise to a new colony. The cilia are withdrawn, whereby the whole comes to rest, and each individual divides into sixteen portions like the parent. In other cases, however, a single cell does not reproduce the colony. Two cells from different individuals fuse together and the common mass ultimately forms a young colony. This process is called Conjugation, where the two uniting elements closely resemble each other, and the result of it may be traced in the Figures.

Fig. 3*a*. Colony or Cœnobium (Gr. *koine*, in common; *bios*, life) consisting of sixteen cells or Zoogonidia. Each Zoogonidium has a red eye-spot and two projecting cilia, by the collective and harmonious action of them all a rolling motion is imparted to the whole family.

(*b, c.*) Male and Female Zoospores. These reproductive cells are produced from different colonies, the smaller being reckoned the Male, and the larger the Female element.

(*d, e.*) In conjugation, the two elements first come into contact by their ciliated ends, then they gradually swing round side by side and fuse completely.

(*f, g.*) The single body resulting from conjugation is called a Zygospore (Gr. *zugos*, a yoke; *spora*, a seed). This zygospore bursts its case and begins to germinate.

(*h.*) The germinating Zygospore draws in its cilia, rounds itself off and divides into sixteen cells, forming a colony.

Life History.—Each Zoogonidium of the Pandorina-colony divides into sixteen portions—like the original—and then escapes through the gelatinous wall. This is the non-sexual mode of multiplication. The sexual reproduction consists in the production of cells which are called Zoospores, one colony forming sixteen small (male) Zoospores, another sixteen larger (female) Zoospores. Two unite to form a Zygospore, which germinates and produces a new colony.

Ulothrix Zonata.

(*After Dodel-Port*).

Ulothrix Zonata (Gr. *oulos*, woolly or curly; *thrix*, hair), or Curly-hair Alga, may be found in fresh waters, such as brooks, drinking fountains and the like. It occurs in green tufts attached to some fixed body.

It is a simple filamentous Alga, reproducing itself non-sexually during winter and sexually during summer, but if the sexually reproductive cells fail to conjugate, they may still grow into a new plant.

NON-SEXUAL STAGE—

Fig. 4. Portion of Filament in vegetating condition.
The cylindrical cells are placed end to end, and in each there is a green protoplasmic band about the middle containing a nucleus.

Fig. 5. Portion of Filament exclusively producing Zoogonidia.
A mother-cell may produce one, two, four, or eight zoogonidia. The inner wall of the cell passes out as an envelope surrounding them, and afterwards deliquesces to allow their escape.

Fig. 6. The Zoogonidium is pear-shaped, with four cilia and a red eye-spot and a contractile vacuole.

(*a.*) In motion, it rotates round its long axis by means of the four cilia.

(*b.*) On coming to rest, the cilia become stiff and fall off, and the zoogonidium fixes itself, by its tapering end, to some object.

(*c.*) The zoogonidium now germinates and, by repeated division, produces a filament, as in Fig. 4.

SEXUAL STAGE—

Fig. 7. Portion of Filament producing Zoospores, which are smaller and more numerous than the Zoogonidia, and only possess two cilia.

The Mother-cell, contains eight, sixteen, or more Zoospores.

In conjugation, two zoospores come together sideways and fusion takes place from the pointed end backwards. The united zoospores behave like a zoogonidium, lose their cilia and settle down. The result of conjugation is a Zygospore.

Fig. 8. The Zygospore germinates and divides into a greater or smaller number of Zoogonidia, which reproduce the plant as before.

NON-CONJUGATING STAGE—

Fig. 9. Portion of Filament with Zoospores that have not escaped, germinating directly.

When Zoospores do not meet in conjugation, they produce new plants directly, but they are weak and often perish.

Life History.—Ulothrix may give rise to Zoogonidia, which germinate and reproduce the plant; or it may give rise to Zoospores, which conjugate and produce a Zygospore, from which, by division, numerous Zoogonidia arise to go through the ordinary course; or the Zoospores directly produce a new plant.

With regard to the Conjugation of *U. zonata*, Professor Dodel-Port remarks: "The conjugation of *U. zonata* represents the simplest form of the sexual process. The conjugatory cells are *alike*, and are not distinguishable in their essential features from the non-sexual reproductive cells. If, for any reason, conjugation has not occurred, they behave just the same as the zoogonidia, incapable of conjugation, and develop non-sexually. The act of conjugation may be delayed without injuring their power of reproduction. Conjugation appears here merely as the result of a lucky accident, and we may therefore consider Ulothrix as a type of those lower forms which show us the first beginnings of the sexual process in plants."

Hydrodictyon.

Hydrodictyon (Gr. *hudor*, water; *diktuon*, a net-work), or Water-net, is met with in clear ponds or flowing streams. It often occurs in great masses and the meshes of the net may be distinguished by the naked eye.

The net is composed of cells containing green coloured protoplasm, and united so as to form a beautiful pattern. The contents of the cells may either break up into Zoogonidia or Zoospores.

The Zoogonidia may form in a single cell to the number of 20,000, and these minute particles have a swarming motion for a short time, then they arrange themselves into a netted pattern, by bringing their ends properly together. The mother-cell ruptures, setting free the delicately formed net perfect in all its details.

Fig. 10 *a.* A small portion of the old net—natural size.

(*b.*) A very small portion magnified, showing the individual cells forming each mesh.

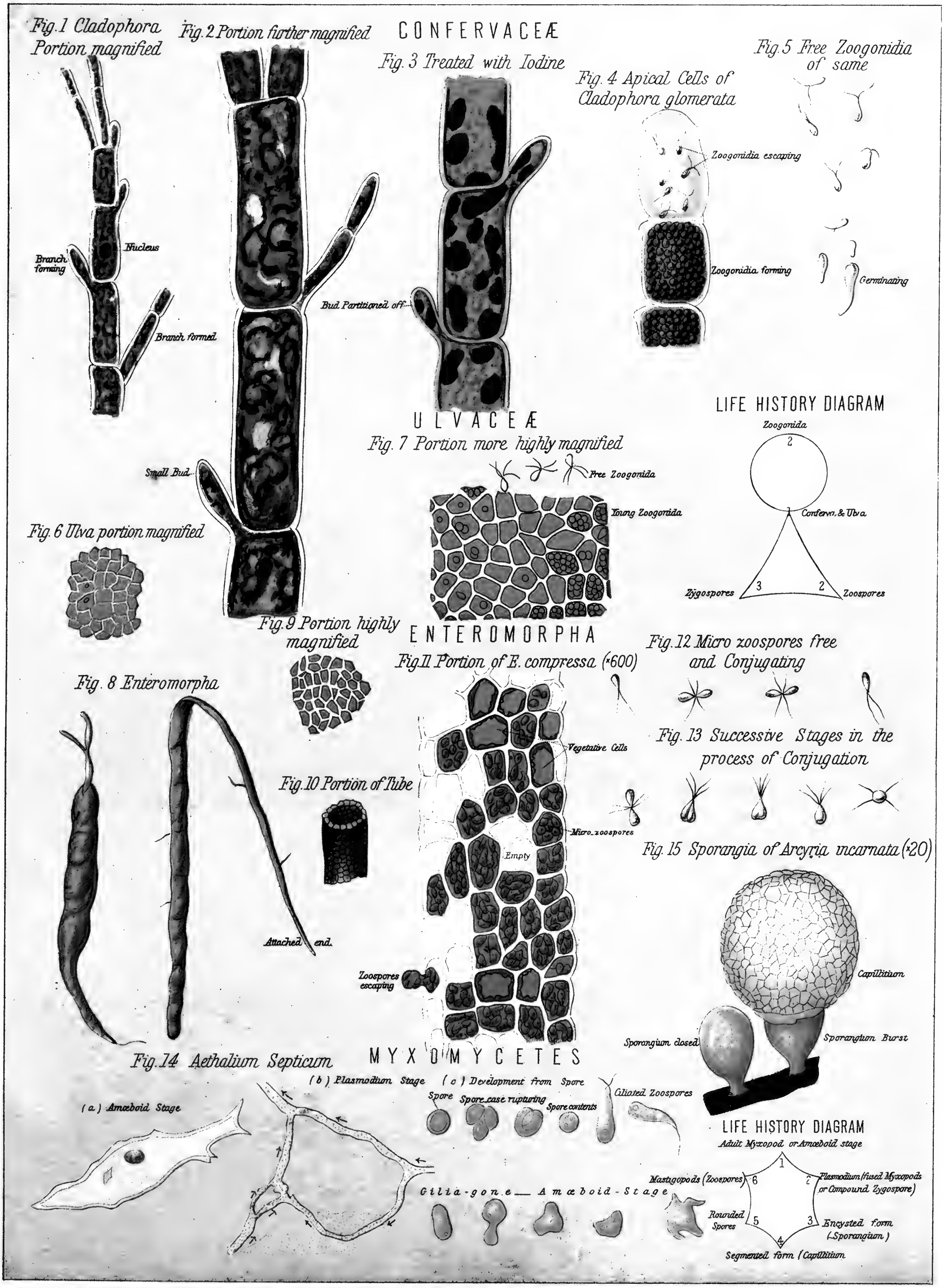

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PLATE V.—CONFERVACEÆ, ULVACEÆ, and MYXOMYCETES.

(Reproduction and Development principally after Oersted.)

CONFERVACEÆ (Lat. *confervere*, to unite) are filamentous Algæ, occurring plentifully in every stagnant water, usually in great abundance round the margin. The filaments grow in length by the individual cells dividing into two. Multiplication takes place by Zoogonidia, and Conjugation has been observed in Cladophora.

Figs. 1 and 2. Cladophora (Gr. *klados*, a branch; *phoreo*, I bear), so named from its being branched, is a very common form.

Examine a small portion in water.

Filament with alternate branches forming. The top of the cell puts forth a little pocket at one side, which grows and divides like the parent filament. Secondary branches may likewise be formed, thus giving rise to bushy tufts. One or more nuclei may be present in each cell.

Fig. 3. Treatment with Iodine, showing starch granules.

The contents are seen to be broken up into little ovoid masses called chlorophyll-corpuscles, and it is in these the starch is formed.

Yellowish brown colour indicates protoplasm.

The darker spots are in reality dark-blue, indicating their starchy nature.

The cellulose wall is clearly differentiated from the contents.

Fig. 4. Multiplication by Zoogonidia.

The contents of the cells break up into little masses, which round themselves off, acquire cilia, and escape by a break in the side of the wall.

Fig. 5. Zoogonidia germinating.

They lose their cilia, begin to elongate, and grow to a filament.

ULVACEÆ form flat expansions of cells, and are commonly met with on the seashore. The common green Laver (U. latissima) may be a foot square, and is so puckered and folded that it seems branched. Enteromorpha may be regarded as a tubular Ulva; and as Conjugation has been clearly observed in it, the process will be described in that connection.

Fig. 6. Mount a small piece in water and examine.

The cells are angular from pressure, and dark spots appear in each.

Fig. 7. Highly magnified portion.

A number of the cells contain Zoogonidia. The Zoogonidia escape by small openings on the surface, and move about in the water by means of cilia.

ENTEROMORPHA (Gr. *enteron*, intestine; *morphe*, shape), instead of being flat, like Ulva, forms a slender tube. It occurs plentifully on the seashore, attached to stones, rocks, or even seaweed, and also forms those slimy, green growths so common on the posts of piers, etc. In the autumn particularly the cells give rise to innumerable actively moving Zoospores. These come together in the water, and Conjugation takes place. The result is a Zygospore, which is believed to germinate in the ensuing spring and become a new Enteromorpha.

Fig. 8. It consists of a tapering attached end, giving off numerous small branches, then expanding till it reaches the apex, where a slender forked portion branches off a little to one side. The surface of this specimen is puckered, and here and there delicate branches are formed.

Figs. 9 and 10. Take a small portion and examine under microscope.

The tube is seen to consist of a single layer of cells, and when spread out, as in Fig. 9, quite resembles the frond of Ulva.

Fig. 11. Portion highly magnified.

Some of the cells are still in the vegetative condition, others are full of Zoospores, in some the contents have escaped, and on the left side the Zoospores are seen in the act of escaping, enveloped by the inner membrane of the cell.

Figs. 12 and 13. Micro-zoospores free and conjugating.

Two Zoospores meet by their pointed ends, then swing round side by side, blend, lose their cilia, and become a pear-shaped Zygospore.

Life History of Confervaceæ and Ulvaceæ.—The cells either produce Zoogonidia, which grow into a new plant, or Zoospores, which conjugate, thereby forming Zygospores to reproduce the plant.

MYXOMYCETES (Gr. *muxa*, slime; *mukēs*, a fungus), or Slime-fungi, as their name denotes, are slimy bodies found on rotten wood, decaying leaves, etc.; and the specimen chosen—Aethalium septicum, or "flowers of tan"—occurs on spent tan. It is of a creamy, yellow colour; and in nurseries, where spent tan is used for bottom heat, it may be found in the autumn overspreading large surfaces, and, forced by the heat, it has been known to make its way up the stems of plants. The limit of heat for this form is 40° C.

The Myxomycetes are peculiar in passing through an Amœboid stage, when they take in solid nutriment and feed like animals, so that in this stage of their existence at least they resemble animals rather than plants. Their life history too is quite comparable to that of some of the lower animals, as may be seen from the Figures.

Fig. 14. Aethalium septicum (Gr. *aithales*, splendid, from its appearance).

(*a.*) The Amœboid stage, or Myxopod of the animal series, possesses a nucleus.

(*b.*) The Plasmodium stage is the large, conspicuous, yellowish mass, made up of a protoplasmic network showing streaming of the contents as indicated by the arrows.

(*c.*) The Spore possesses a thick cell-wall, which bursts to allow the contents to escape. The rounded mass developes two cilia, which become reduced to one, and thus a body is formed like the Mastigopod of the animal series. Even this single cilium disappears, and the Amœboid stage is reached, as at the beginning.

Fig. 15. Sporangium of Arcyria—unopened and opened. The elasticity of the fibres composing the Capillitium (Lat. *capillus*, a hair) ultimately ruptures the case and jerks out the spores.

Life History.—In fixing the starting-point for the life history of the Myxomycetes I have been guided by its evident similarity to that of some of the Monera described by Haeckel, and so start with the Amœboid form as the first stage in the cycle. If the phases through which it passes are compared with those of Protomyxa—an undoubted animal found in the sea by Haeckel—it will be found that the agreement is striking.

The first, or Amœboid stage, has all the characters of an amœba, possessing a nucleus, throwing out processes in different directions, moving about, and taking in solid particles for food.

The second, or Plasmodium stage, consists of a number of amœboid masses run together to form one large spreading mass capable of a creeping motion, as already observed, along with internal motion of the contents. The nuclei of each originally independent mass remain distinct, so that there is coalescence of cells but not conjugation.

The third, or Encysted stage, is represented by the Sporangium. The irregularly-shaped Plasmodium assumes a more definite shape as its power of throwing out processes becomes weakened, and usually forms a rounded mass of protoplasm invested by a cellulose wall.

The fourth, or Segmented stage, is produced by the internal protoplasm, differentiating in such a way as to form a network of fibres, and the protoplasm still remaining in the meshes becomes the Spores. The hair-like structure, in the meshes of which the Spores are developed, is known as the Capillitium.

The fifth stage, or Rounded Spores. The contents of the liberated Spores escape and become—

The sixth stage, or Zoospores, which have two cilia, then one, and finally pass into the Amœboid form with which we started.

It will be evident from the above description that the Myxomycetes cannot retain their position among the conjugating forms of Fungi, and even when their animal nature is considered they do not fall into the lowest strata either of Plant or Animal society.

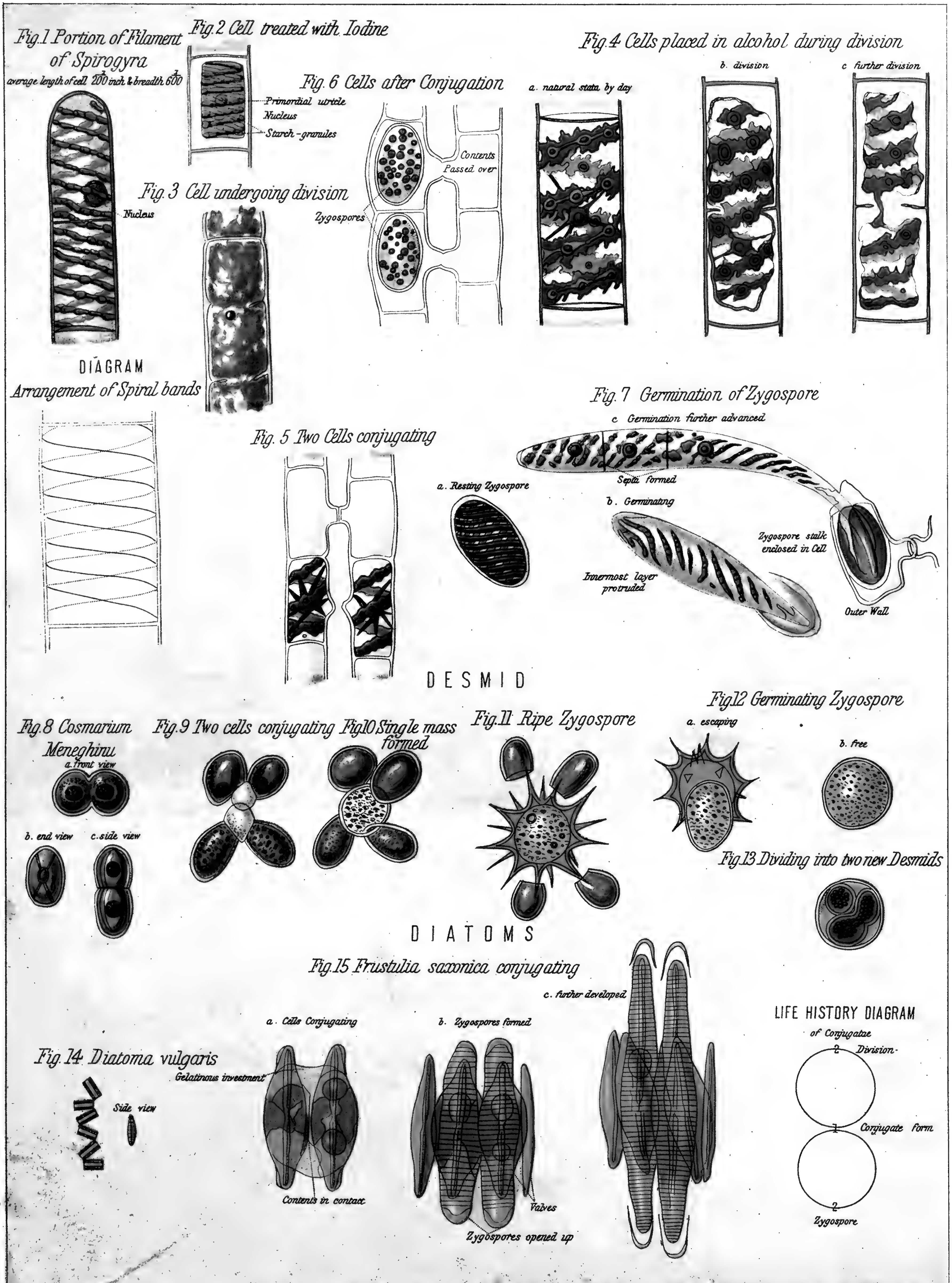

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PLATE VI.—SPIROGYRA, DESMIDS, and DIATOMS.

(Spirogyra chiefly after Sachs; Desmid and Diatom after Oersted.)

SPIROGYRA (Gr. *guros*, a ring) is readily recognised under the microscope from the spiral bands of green-coloured protoplasm. It floats in bright green masses near the surface of clear, fresh waters, such as ponds, and slips through the fingers on attempting to handle it.

The bands of coloured protoplasm are variable in their number and arrangement. They contain numerous starch-granules and oil-globules, and a nucleus is present in each cell. This condensed portion of the protoplasm is surrounded by a layer of protoplasm, which sends delicate threads towards the cell-wall, giving the nucleus a star-like appearance. There is also a layer of protoplasm lining the cell-wall, to which these threads are attached, and this lining is made very evident by the application of iodine, which causes the protoplasm to contract and withdraw itself from the wall. The protoplasm is broken up into shreds and bands, because, being unable to fill the cell, the cavities are filled with cell-sap, and these spreading and increasing finally leave the protoplasm in this scattered form. Protoplasm thus on the stretch, as it were, displays much of its intimate nature, which is concealed in the more uniform condition.

Multiplication of the cells takes place by Division, and Reproduction by Conjugation.

Fig. 1. Either take a small portion of the water in which odd pieces are floating, or a minute portion of the green mass, and examine under highest power.

Long filaments made up of cells, with distinct walls and green spiral bands, in which numerous granules are visible.

Diagram.—Showing arrangement of bands.

Careful focussing is necessary to make out the exact continuity of the bands, and this may be made out better after treatment with reagents than in natural specimens.

In this particular species the bands are arranged in two spirals, which intersect each other. In S. longata (Fig. 4) there is but a single spiral band.

Fig. 2. Stain with Iodine.

Iodine makes the nucleus prominent, turns the starch-granules blue, and causes the layer of protoplasm lining the cell-wall to contract about the spiral bands. This layer of protoplasm has received the name of "primordial utricle," but it is simply a portion of the protoplasm which lines the cell-wall.

Fig. 3. As division takes place during night, in order to get cells in the act of division place them in alcohol shortly after mid-night and examine with highest power.

The cellulose is seen to be extending inwards on each side.

Fig. 4*a*. Cell in the living state, with single nucleus and regularly-arranged bands.

b. Protoplasm contracted by the alcohol. Infolding of the protoplasm lining the wall, and cellulose formed in the notch. Two nuclei formed during division, one for each new cell.

c. Infolding further advanced, which would ultimately form a complete partition across.

Figs. 5 and 6. Conjugation.

Two filaments lay themselves alongside each other, and adjoining cells of each filament throw out pockets simultaneously towards each other, which eventually meet and form a connecting *tube* between the two cells. The contents of one cell pass over and fuse with that of the other, the nuclei also coalescing, thus producing a Zygospore, as in Fig. 6.

Fig. 7. Germination.

The outer wall of the Zygospore ruptures, and the innermost layer protrudes as a filament, gradually growing and forming transverse partitions until a proper filament is produced.

DESMIDS (Gr. *desmos*, a band) are beautiful, minute, green plants, found in fresh water, and consisting usually of a single cell. The cells are generally divided into two symmetrical halves, and the coloured protoplasm is arranged in bands.

Multiplication by Division is shown in next Plate. Sexual reproduction by Conjugation is shown here.

Fig. 8. Different views of Cosmarium, showing the two halves and the coloured bands.

Fig. 9. Two cells approach one another, the narrow waist ruptures, and the contents of each fuse.

Fig. 10. A single rounded mass is formed, with the empty halves of each Desmid still adhering to it.

Fig. 11. The Zygospore secretes a cellulose wall, which grows out into beautiful spines.

Fig. 12. The Zygospore escapes from its case and begins to germinate.

Fig. 13. Zygospore divides into two new Desmids, which lie across each other.

DIATOMS (Gr. *dia*, through; *temno*, I cut) are so named from the common genus Diatoma, in which the cell-walls, or Frustules (Lat. *frustum*, a fragment), remain connected in a zigzag fashion after each division, looking like a continuous structure cut up into a number of similar fragments. Various forms are sure to be met with while examining fresh-water Algæ, Euglena, and the like.

They are unicellular like the Desmids, but are yellowish in colour, have not the characteristic median constriction, and their cell-walls are silicious, exhibiting on their surface those beautiful markings which are a never-ending source of delight and interest to the micro-scopist. It is owing to this indestructible character of the cell-wall that Diatoms form geological deposits, and their beautiful structure has been preserved as finely as those living at the present day. The Diatom muds, of a pale straw colour, beneath peat-mosses, have acquired great importance recently from being used in the manufacture of dynamite, which is a combination of the silicious material with nitro-glycerine.

They exhibit slow movement from place to place, and exposed to light in considerable numbers they evolve oxygen.

Multiplication takes place by Division, Reproduction by Conjugation.

Fig. 14. Diatoma, a very common form. The cells formed by successive divisions remain slightly attached.

Fig. 15. Conjugation of Frustulia saxonica.

(*a.*) Two Diatoms beside each other surround themselves with a gelatinous mass, the valves then fall apart like an opened book, and the contents of each come together, but do not mix.

(*b.*) Next, the two contents clothe themselves with a delicate membrane, elongate, and form two Zygospores.

(*c.*) Each Zygospore now forms two valves, and becomes fully formed.

Fig. 1. Mature cell - front view

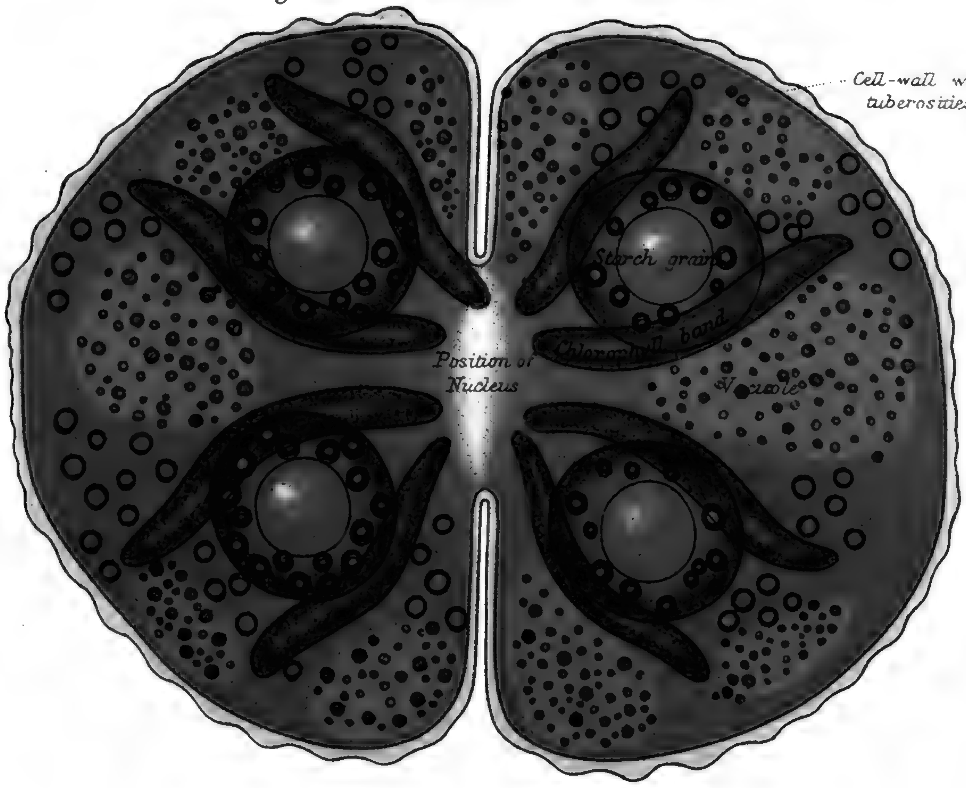

Fig. 2. Multiplication by division into two

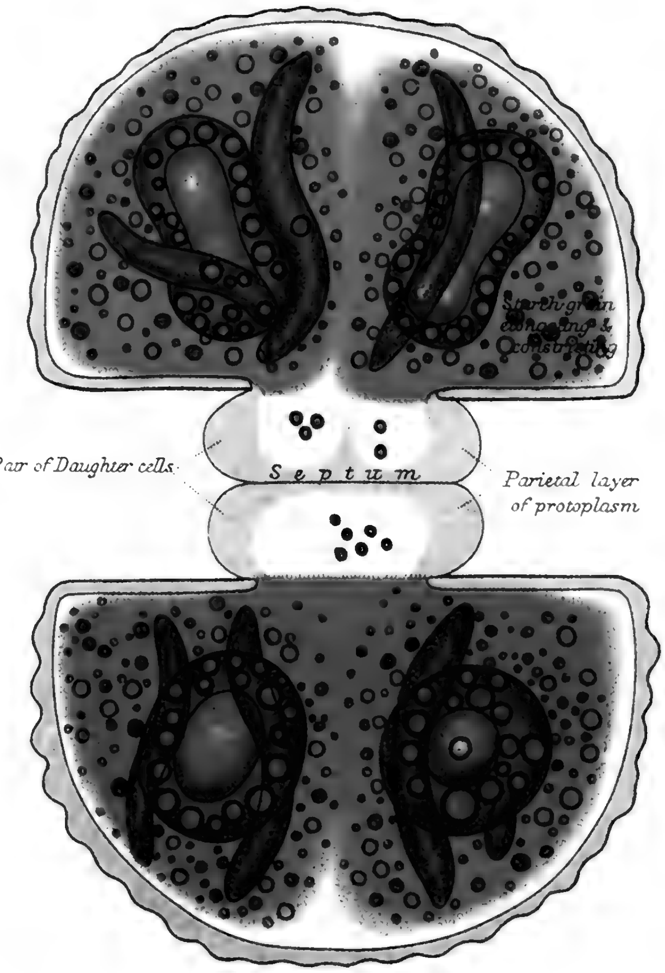

Fig. 4. The same an hour later than Fig. 3.

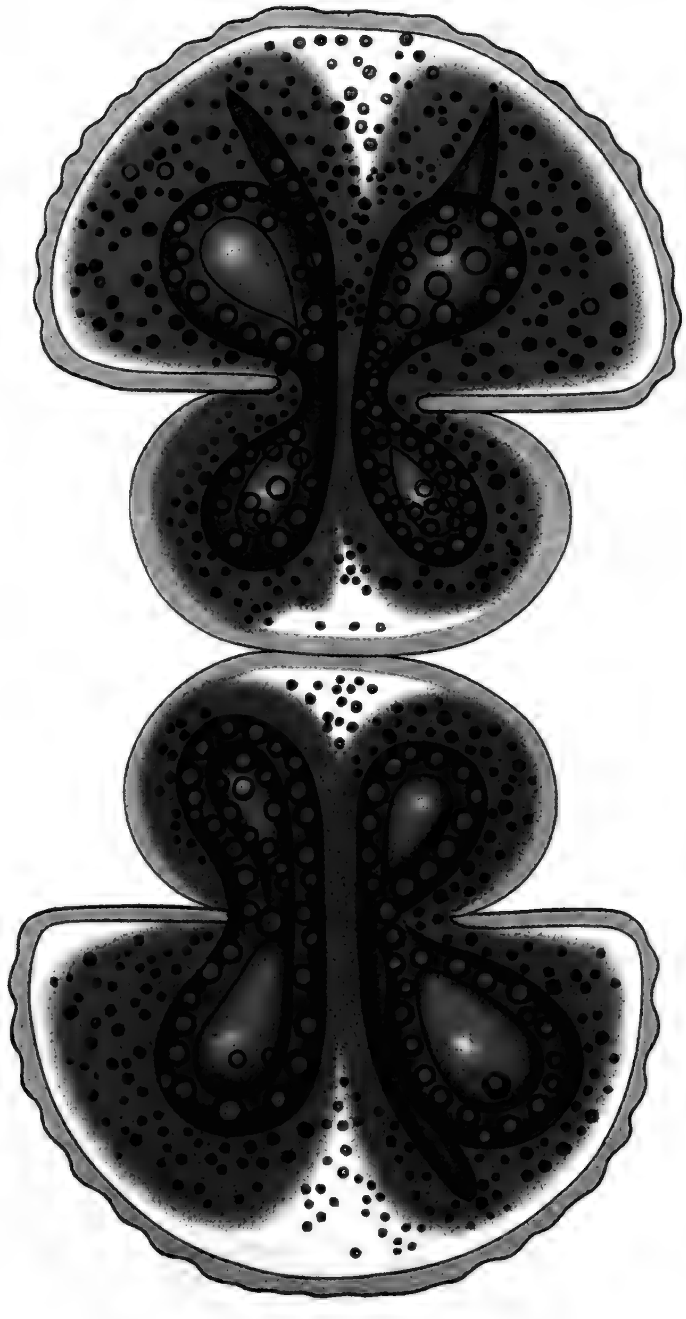

Fig. 3. The above half-an-hour later

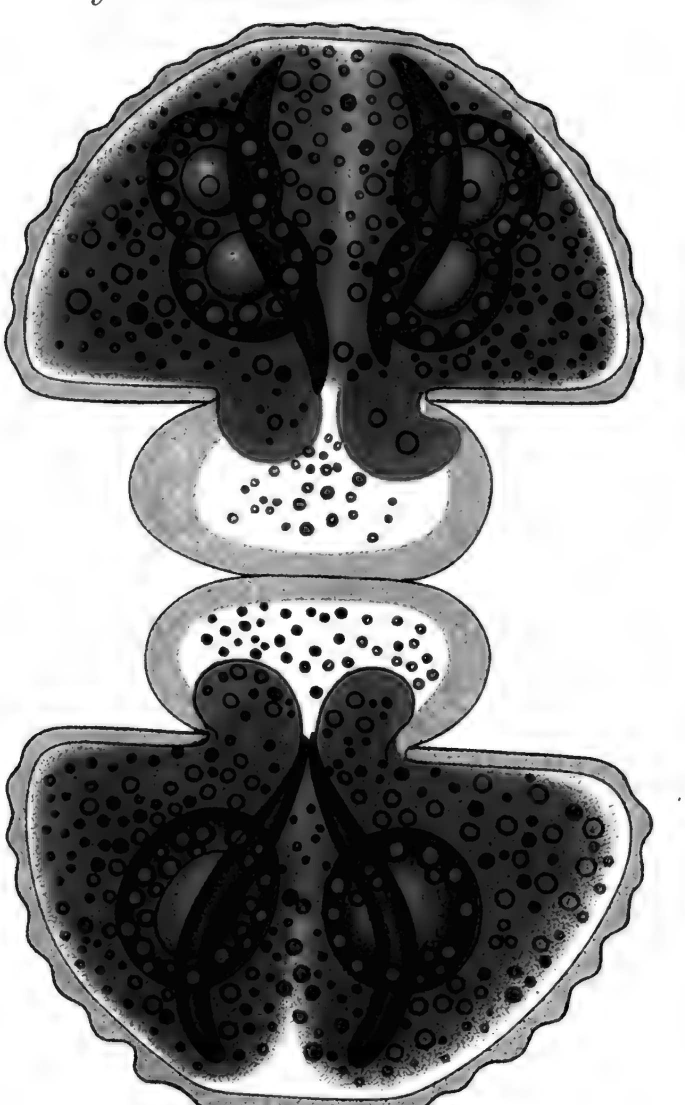

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PLATE VII.—COSMARIUM BOTRYTIS—a Desmid.

(After Dodel-Port and De Bary.)

Desmids (Gr. *desmos*, a bond) are unicellular Algae, of a green colour, found in fresh-waters. They are remarkable for their beauty and symmetry of form, exhibiting division into two symmetrical halves, with a bond or connection between the two—hence the name. They multiply either by *division* or *conjugation*. Multiplication by division is the most common, and is that here shown.

Figures X 1450.

Fig. 1. Adult form in front view.

The cell is divided by a deep constriction into two symmetrical halves. Each half looked at from the side is round, inclining to oval. The Cell-wall is marked by tuberosities scattered over it, giving it a remarkably elegant, sculptured appearance. Each half-cell contains protoplasm coloured green, two round starch grains, each with four chlorophyll-bands or green-coloured protoplasm lying over it, and several clear vacuoles containing a number of oscillating granules.

The Protoplasm generally is of a pale-green colour, only it becomes clear in the middle where the nucleus lies. The plates of protoplasm, the so-called "chlorophyll-bands," are of a dark-green colour, and only one-half the number are seen in this view.

The Starch-grains are symmetrically disposed, two being on each side of the principal axis.

The Vacuoles are filled with fluid, and lie between the starch-grains and the cell-wall. There are also a number of oil-drops scattered throughout the mass.

Figs. 2, 3, and 4. Multiplication by Division—

The central constricted portion lengthens, and a delicate partition forms, dividing the whole into two equal halves, as in Fig. 2.

Next, the daughter-cells thus formed increase in size, and the contents of each original portion begin to pass over, as in Fig. 3.

Finally, the newly-formed portions assume the dimensions of the old, as in Fig. 4, till, in about ten hours, two full-grown individuals appear.

MUCOR

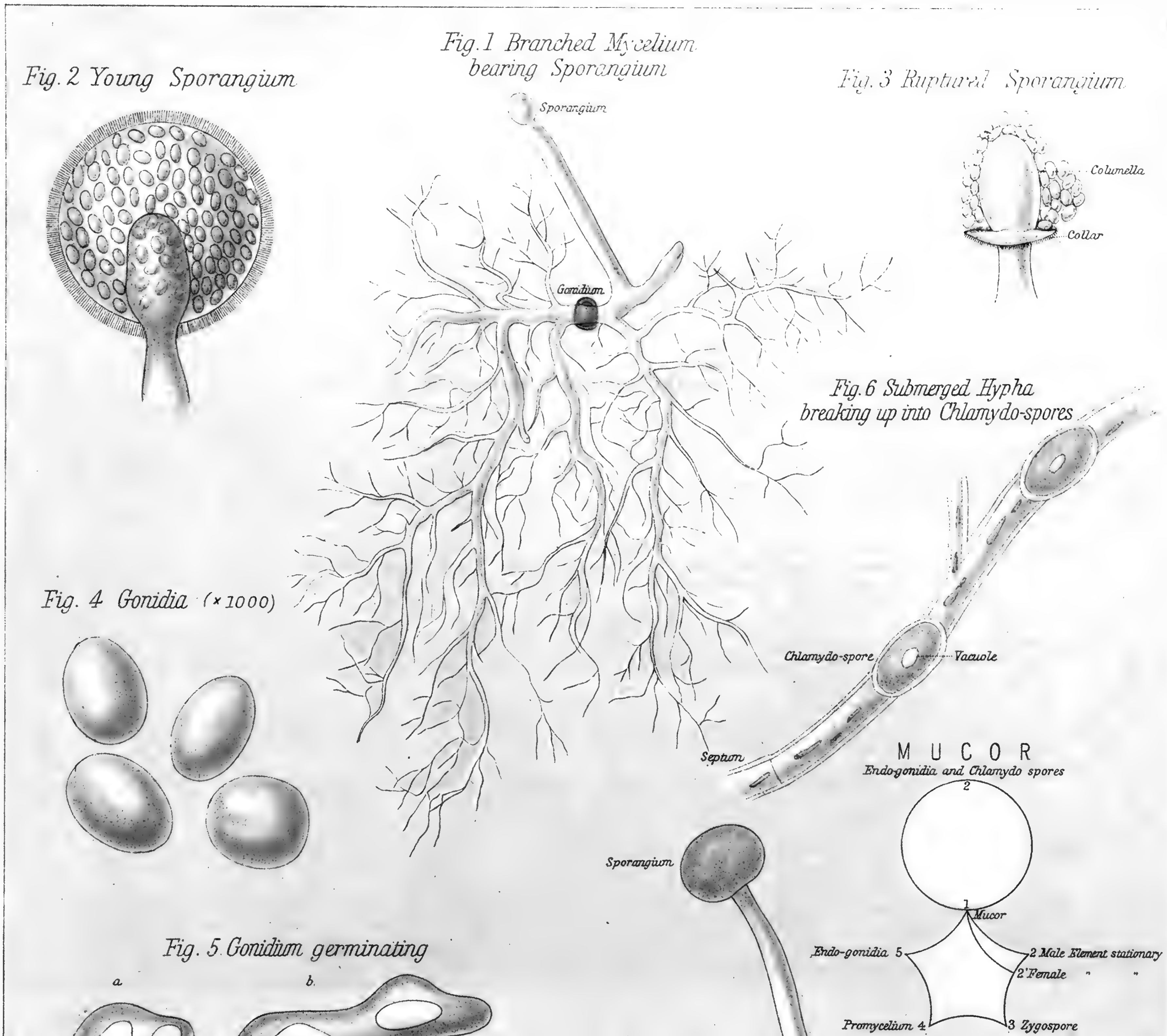

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PLATE VIII.—COMMON BROWN MOULD (Mucor mucedo).

(Conjugation after Brefeld.)

This Mould is to be found in damp, close places growing on a variety of substances. It may be obtained in a form suitable for examination either from bones, or from potatoes which have been pared and boiled. If the latter are allowed to stand for a few days in a covered dish, they produce a luxuriant crop. Mucor affords a good illustration of a simple form of the sexual process, in which two perfectly similar and stationary elements unite or *conjugate*, and produce a body capable of reproducing the plant.

Nuclei have been observed, although not shown in the drawings.

Fig. 1. Full-grown Mycelium developed from the gonidium.

The gonidium sends out various prolongations, which branch in all directions, so that the entire mycelium is formed, consisting of a tubular single cell. But at a further stage *septa* are formed in various parts, so that it becomes multi-cellular.

From a swelling an aerial branch arises, terminating in the young sporangium.

Fig. 2. Sporangium containing spores.

The swollen head of the aerïal hypha becomes divided off by a partition, and this bulging up into the interior constitutes the Columella.

The Sporangium-wall becomes coated with needle-like crystals of oxalate of lime.

The Endo-gonidia are formed from the protoplasm in the interior and become coated with a cellulose wall. The residue of the protoplasm forms an intermediate substance capable of swelling.

Fig. 3. Ruptured Sporangium.

The sporangium having imbibed moisture swells. The outermost layer is brittle but not distensible, so with the swelling of the innermost layer and the intermediate substance, it bursts, setting free the gonidia, and often leaving a remnant in the torn collar.

Figs. 4 and 5. Gonidia germinating.

The outer coat of the spore is inelastic, and the inner protrudes as a filament, growing and branching till it becomes full-grown, as in Fig. 1.

Fig. 6. Gonidia are not only produced by aerïal hyphæ, but not unfrequently from old *submerged* hyphæ. Septa arise close to one another, forming distinct joints, and these become rounded off, fall away, and are able, under favourable conditions, to germinate. These bodies are the so-called Mucor-yeast or Chlamydo-spores (Lat. *chlamys*, a cloak).

Fig. 7. The sexual process—Conjugation.

Branches from two adjacent filaments of the Mycelium, approach, the double wall between them is absorbed, and on each side of the central portion a partition is formed, thus marking off the Zygospore.

Fig. 8. Ripe Zygospore with thickened granulated outer wall.

Fig. 9. Zygospore germinating.

It produces a single hypha, which sends up an aerïal branch forming a Sporangium in which Endo-gonidia are produced in the ordinary way.

Life History of Mucor.—The mycelium of Mucor produces upright branches in the swollen ends of which gonidia are produced, giving rise, on germination, to a new Mucor, or submerged hyphæ produce gonidia with the same result. This mode of multiplication is non-sexual, but sexual reproduction also occurs. Two short branches unite end to end, forming a Zygospore. This Zygospore germinates, producing an upright branch with a sporangium at the end, and the gonidia give rise to the non-sexual generation as at first.

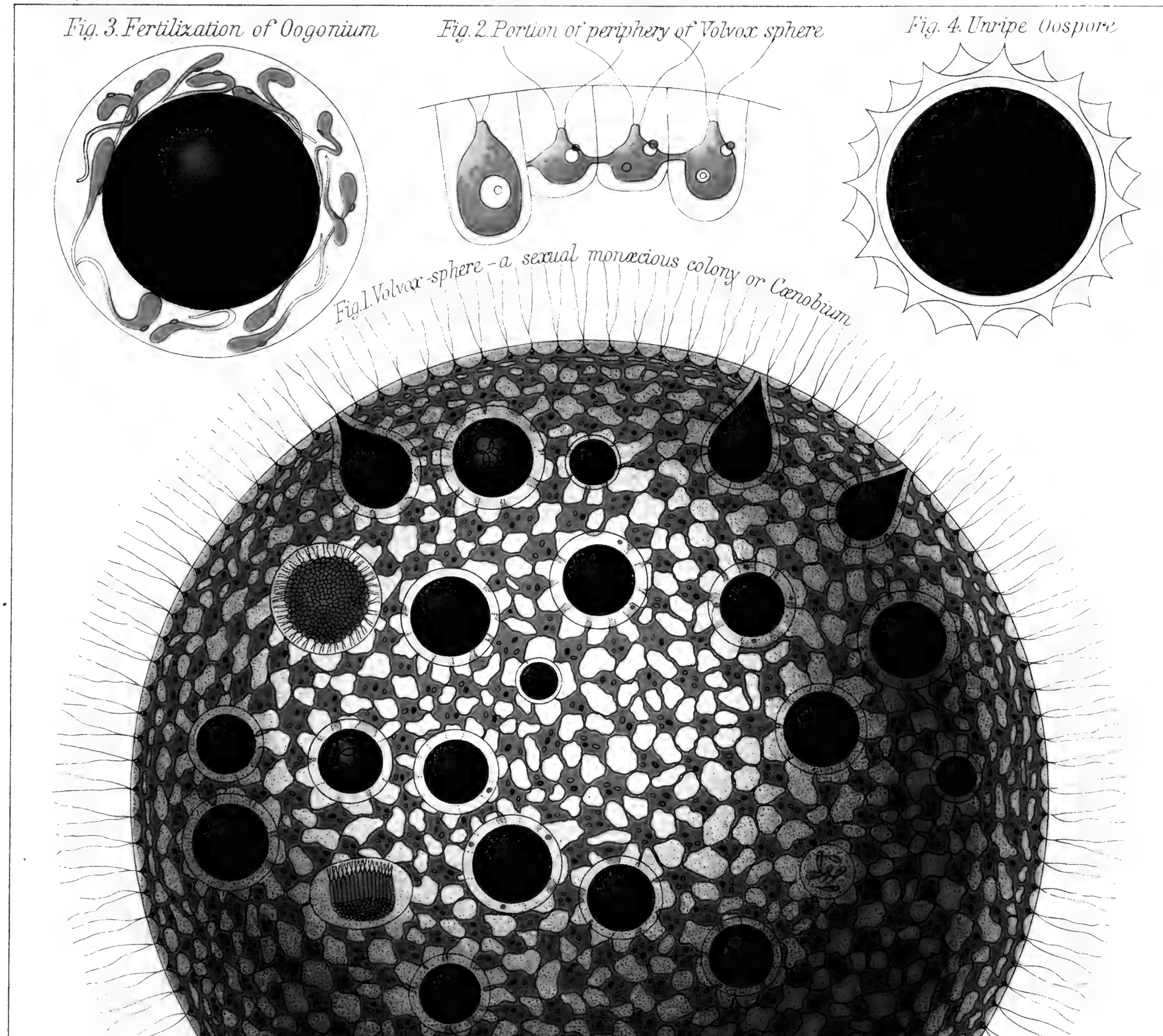

Fig. 1. Volvox-sphere – a sexual monœcious colony or Cœnobium

Fig. 2. Portion of periphery of Volvox sphere

Fig. 3. Fertilization of Oogonium

Fig. 4. Unripe Oospore

Fig. 5. Antheridium with its bundle of Antherozoids

Fig. 6. Antherozoids killed with iodine

Fig. 7. Escaped Antherozoids in active movement

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PLATE IX.—THE ROLLING SPHERE (Volvox globator).

(*From Dodel-Port.*)

Volvox, so named from its rolling motion, is found in fresh-water pools, and attains a size sufficient to be distinguished by the naked eye. It is a hollow sphere, and the entire periphery is formed of small cells, each furnished with two cilia. Its slow, stately, rolling motion is due to the harmonious action of these cilia. The sphere consists of vegetative cells and reproductive cells. It is so large that it would be a physical impossibility for every cell to undergo a process of division, and as the organization becomes more complex there arises a necessity for a division of labour. The work, which in a simpler form every portion of the organism was fitted to do, has now to be distributed and assigned to certain cells. Cells are thus set apart for the work of reproduction from a very early period, and are much larger than the vegetative cells. Not only so, but the male and female elements are decidedly different; in the one case being a tapering portion of protoplasm provided with cilia and motile, in the other a stationary rounded ball of protoplasm. Thus the two elements of reproduction are becoming more and more distinct. At first they were undistinguishable, as in Mucor; next distinguishable only in size, as in Pandorina; but now their form as well as their dimensions is different.

When Volvox is kept in a warm room, it has been observed in some cases that the protoplasm strays from the cells and creeps about in the water after the manner of an amœba. Here the green protoplasm of a plant behaves like the protoplasm of an animal, putting forth processes and progressing by reason of the contractility of the protoplasm. It shows that the fundamental difference between the lower plants and the lower animals consists in the one being free to move and the other not. Plants have their protoplasm inclosed in a rigid cell-wall, which curbs and restrains them, and under such conditions the protoplasm is forced to behave differently.

Fig. 1. Volvox-sphere in the sexual stage.

Reproductive cells.—Female Zoospores are flask-shaped at first, but finally become spherical. This stationary rounded mass of protoplasm is now called the Oosphere, and with its gelatinous cell-wall is called the Oogonium.

Antheridia, containing bundles of Antherozoids, or sperm-cells.

Fig. 2. Portion of periphery much magnified.

Reproductive cell relatively large, with nucleus and nucleolus. Vegetative cells smaller, often with red "eye-spot."

Fig. 3. The Antherozoids have bored through the gelatinous investment of the Oogonium, and now surround the Oosphere.

Fig. 4. The outer investment of the unripe Oospore is a firm and spinous Exosporium, while the inner is a gelatinous Endosporium.

Fig. 5. Antheridium, with its gelatinous investment containing the bundle of Antherozoids.

Fig. 6. Iodine kills the Antherozoids, and makes their cilia distinct.

The Antherozoids are of a whip-lash shape, with a pair of cilia towards the rounded end.

Fig. 7. The Antherozoids have a wriggling movement, caused by the expansion and contraction of their bodies, aided by the cilia.

VOLVOX MINOR

Fig.1. Oosphere with fertilizing Antherozoids

Fig.2. Ripe Oospore

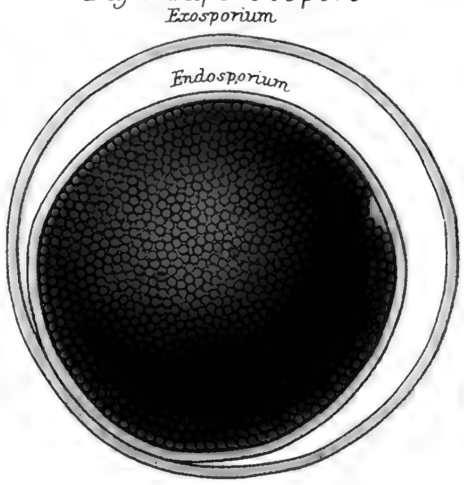


Fig.3. Exosporium ruptured

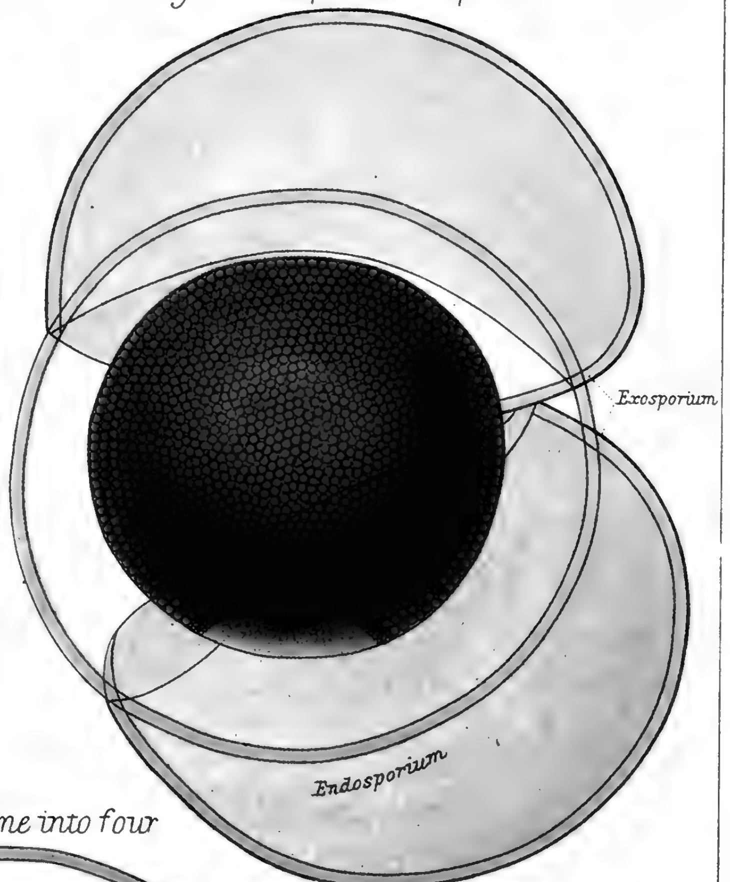


Fig.4 Contents of Oospore divided into two

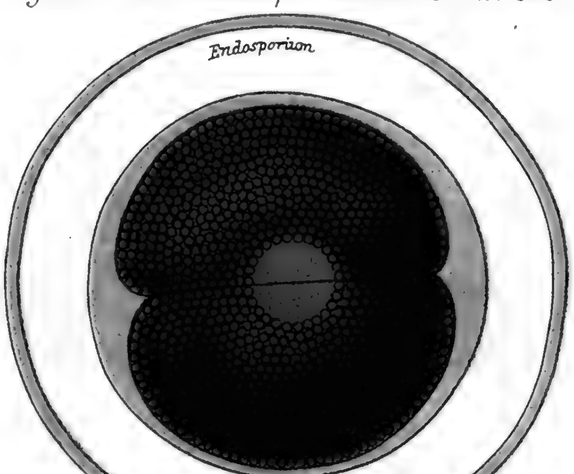
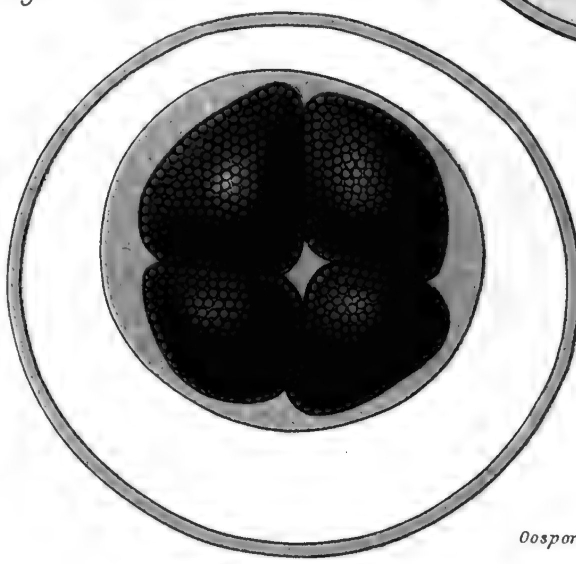


Fig.5. Division of same into four



LIFE HISTORY DIAGRAM

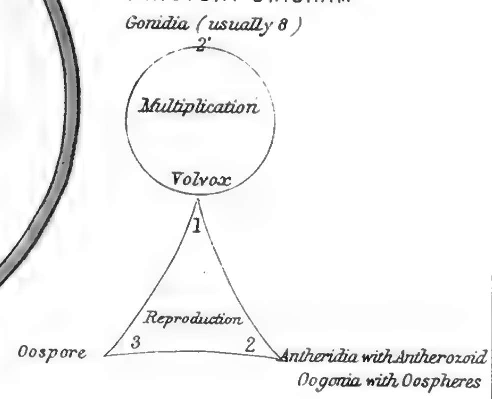


Fig. 6. Division into sixteen masses

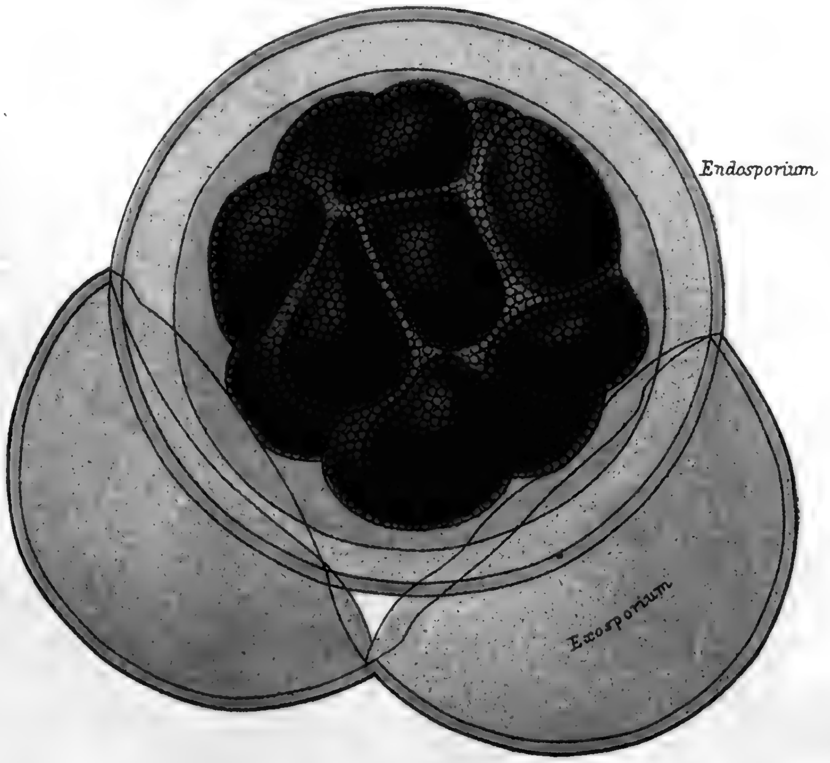


Fig.7. Young Volvox

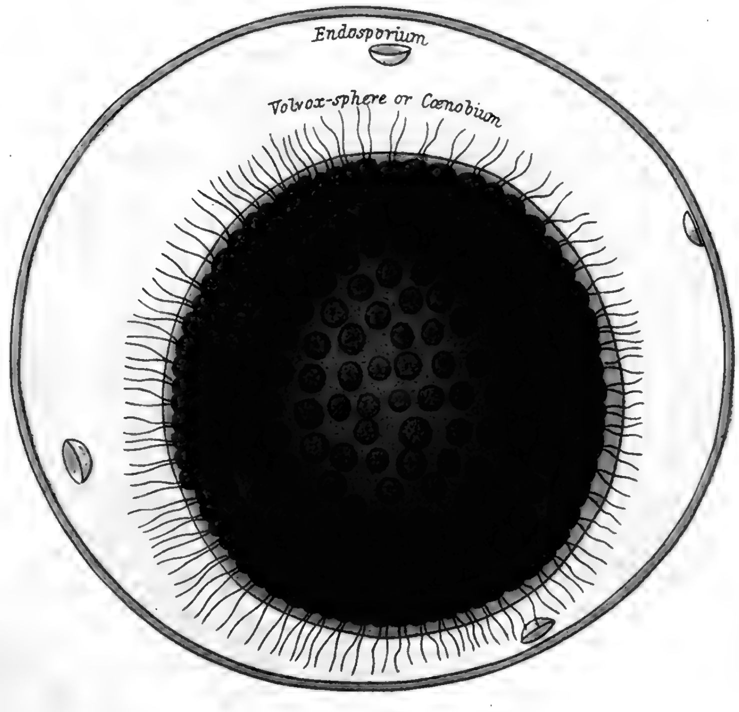


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PLATE X.—VOLVOX MINOR.

(From Dodel-Port, after Dr Kirchner.)

Volvox minor produces both male and female cells in the same colony, but they are ready at different times—the female first, the male afterwards. The germinating Oospore is shown in this Plate, and it is only within the last few years that the process has been traced. The preliminary act in this life drama is shown in the blending of the Antherozoids with the Oosphere. This sets agoing that activity in the cell which finally issues in the formation of a young Volvox-sphere.

Figures X 880.

Fig. 1. Oosphere and Antherozoids in contact.
The floating Antherozoids find their way to an Oosphere, and readily blend with it. This is the process of Fertilisation—and the result is an Oospore.

Fig. 2. Ripe Oospore invested by two coats—an outer (Exosporium) and an inner (Endosporium). The investment is unlike that of *V. globator* in being smooth.

Fig. 3. Exosporium ruptured.
The swelling contents cause the rupture of the outer coat, and the Oospore is now free to undergo division.

Fig. 4. First division into two.

Fig. 5. Division at right angles to the first, forming four daughter-cells.

Fig. 6. After division into eight comes division into sixteen.
The Exosporium in this instance has remained attached.

Fig. 7. Young Volvox formed, green and motile, after about nine divisions altogether in geometrical progression.

Life History of Volvox.—Volvox multiplies *non-sexually*, a single cell repeatedly dividing and producing a new colony, or there is *sexual reproduction* by Antheridia and Oogonia. The Antheridia or male cells are larger than the vegetative cells, and their contents break up into Antherozoids. The Oogonia or female cells are at first flask-shaped, but latterly become spherical, each containing a rounded mass of protoplasm—the Oosphere. The Antherozoids floating in the water ultimately come into contact with a liberated Oogonium, bore through its gelatinous wall, and being merely protoplasm destitute of any investment, they blend with the Oosphere, and so produce a body ready to germinate, now called the Oospore. The future history of the Oospore is indicated in this Plate, where it is seen by repeated divisions to form a young Volvox.

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PLATE XI.—VAUCHERIA and ŒDOGONIUM.

Vaucheria.

Vaucheria, named in honour of the Swiss botanist Vaucher, occurs usually on damp soils as a green film, but may readily be obtained from the surface earth of flower-pots kept in green-houses. It is a long filamentous green Alga, consisting of a single tubular cell which branches, and also forms root-like structures.

Fig. 1. Take a small portion of the green film, tease it out in a drop of water, and examine under microscope.
Filament showing the granular protoplasm lining interior of tube.

MULTIPLICATION—

Fig. 2. End of branches forming Zoogonidia.
These are formed during night, by the protoplasm, towards the end of a tube, collecting itself into an oval mass and becoming separate from the rest by a partition. The end of the tube gives way, allowing this oval mass to escape into the surrounding moisture, where it revolves and progresses by means of delicate cilia with which the whole surface is covered. The cilia, however, soon disappear, and the motionless mass then sinks to the bottom.

Fig. 3*a, b, c*. Germinating Zoogonidium.
It gives rise to filaments at two or even three points, which branch and grow to the size of the parent. Delicate transparent branches are also formed (as in *c*) which serve to fix the plant to solid bodies, and thus partly serve the purpose of rootlets.

REPRODUCTION—

Figs. 4 and 5. Male and Female Organs—Antheridia and Oogonia.
Both organs arise as branches, sometimes as in Fig. 4, or as in Fig. 5, where a branch ends in a hooked Antheridium, with an Oogonium on each side below it.
The contents of the Antheridium break up into minute particles of protoplasm, each furnished with two cilia and motile—called Antherozoids.
The Oogonium forms a single body in its interior—the Oosphere—which is a portion of the protoplasm marked off from the rest by a partition. It is relatively large and motionless, and the antherozoids find access to it through a rupture in the cell-wall, thus converting it into an Oospore.

Fig. 6. Germinating Oospore.
The Oospore is surrounded by a three-layered membrane and, after resting for a few months, the contents protrude to form a branching tube.

Life History.—Vaucheria either multiplies by Zoogonidia, or reproduces itself by means of Antherozoids and Oospheres. The naked protoplasm of the Antherozoids blends with the naked protoplasm of the Oosphere, and the result is a body capable of germination—an Oospore. This surrounds itself with a membrane, becomes detached along with the Oogonium, and is finally set free by the dissolution of the Oogonium. After a period of rest it germinates and gives rise to the original branched structure.

Œdogonium.

(After Juranyi.)

Œdogonium (Gr. *oideo*, to swell; *gone*, seed) derives its name from the fact that the joints of the filament swell out to form the female organs. It may be looked for in waters where Conferva and such organisms are found, and occurs as patches of green filaments, composed of cells attached end to end.

Fig. 7. Young Filament, consisting of a row of cells.
The green-coloured protoplasm is arranged in stars and stripes, and each cell has a distinct nucleus.

MULTIPLICATION—

Fig. 8. Zoogonidia produced in the cells.
The protoplasmic contents of each cell form a single rounded mass—the Zoogonidium, which escapes by a fissure in the wall, and revolves and progresses by means of the band of cilia.

Fig. 9. Germination of Zoogonidium.
The zoogonidium loses its cilia and settles down, producing from the colourless ciliated end a root-like structure for fixing the plant, while the opposite end divides and forms a row of cells.

REPRODUCTION—

Fig. 10. Male Filament.
The contents of certain cells become orange-yellow and produce the Antherozoids, which resemble the Zoogonidia in form and motion, differing mainly in the colour. In some cases, however, zoogonidia are formed in the cells, which become rudimentary plants, and the sole object of these *Dwarf-males*, as they are called, is to produce Antherozoids. They attach themselves to the Oogonium, as in Fig. 12, and the upper portion separates like a lid to allow the antherozoids to escape.

Figs. 11 and 12. Female Filaments.
The joints here and there are swollen, forming the Oogonia, which contain the Oospheres. The ripe Oosphere consists of a coloured and a small colourless portion, which protrudes through a small opening.

Fig. 13. Process of Fertilisation.
An Antherozoid blends with an Oosphere, and the result is an Oospore.

Fig. 14. Ripe Oospore.
It becomes surrounded with a membrane, and assumes an orange-red colour. The swelling of the Oospore finally ruptures the Oogonium, and the oospore escapes as a naked mass of protoplasm.

Figs. 15, 16, and 17. Germinating Oospores.
The germinating Oospore does not grow in the usual way, but surrounds itself with a new membrane, and the contents divide into four portions generally. The Zoospores thus formed are set free by the dissolution of the membrane, and produce a young plant, as in Fig. 17.

Life History.—Œdogonium multiplies by Zoogonidia, or is reproduced by Antherozoids and Oospheres. An Antherozoid, produced either directly from the joint of a filament or through the intermediate agency of Dwarf-males, blends with the Oosphere and produces an orange-red Oospore. This Oospore does not directly produce the plant, but divides into usually four Zoospores, like the zoogonidia, except in the matter of colour, and each germinates and grows into a filament, as in Fig. 17.

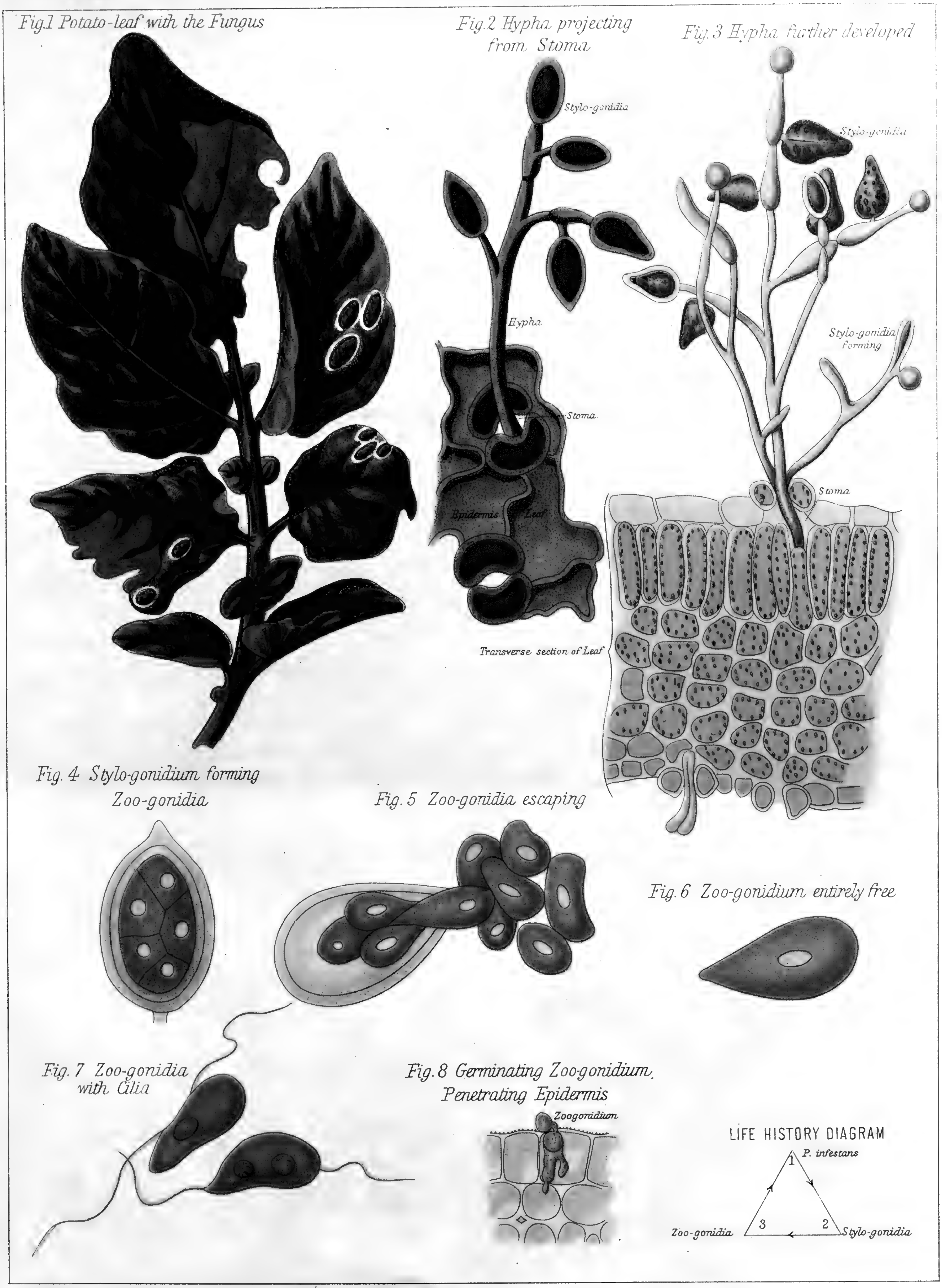

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PLATE XII.—POTATO-DISEASE FUNGUS (Phytophthora infestans).

(Principally after De Bary.)

The Potato-disease Fungus was formerly known as *Peronospora*, but the fuller investigation of its history has caused it to be placed in the genus *Phytophthora*. Although its life-history has been traced to a certain extent, yet, as in the case of Rust of Wheat and other parasitic fungi, a satisfactory mode of dealing with the disease has not yet been found.

It is but fair to add that some consider this fungus-growth as a consequence and not as a cause of the disease. They maintain that a fungus cannot establish itself upon a living plant, until that plant has become enfeebled; and further, that before any appearance of the disease in the potato could be detected by the eye or microscope, it was possible to reveal it by a simple chemical test. This was done by using a minute borer and taking a thread of the potato bored out and placing it in a flask with milk in a warm closet. If the milk curdled in a very short time, the potato was found to be diseased; and if healthy, no curdling took place. The diseased potato soon showed signs of decay and of premature germination, and so the actual disease is supposed to be antecedent to the appearance of the fungus.

Fig. 1. Diseased Leaf of Potato.
The infected parts of the leaf turn black.

Figs. 2 and 3. Hypha bearing Stylo-gonidia.
The filament bores its way through the tissues of the plant, absorbs and appropriates their nutriment, and gradually traverses the whole plant. Eventually it puts forth hyphæ through the stomata of the leaf, which branch and bear capsules styled *Stylo-gonidia*.

Figs. 4, 5, and 6. The contents of the Stylo-gonidium break up into separate portions (usually six), which escape by rupturing the wall.

Fig. 7. Each Zoogonidium possess a pair of cilia, and through the medium of rain or dew may find their way from one plant to another and thus infect a whole field.

Fig. 8. Zoogonidium germinating.
The inner membrane protrudes as a filament, penetrating the epidermis, and begins to ramify through the underlying tissue.

Life History.—The fungus traversing the potato-plant bears aerial hyphæ with Stylo-gonidia, the contents of which break up into Zoogonidia. These motile Zoogonidia, on reaching the epidermis of a potato-plant, germinate to form a uncellular filament which branches among the tissues and becomes like the parent-form. This is the non-sexual mode of multiplication, but a sexual process has not yet been observed.

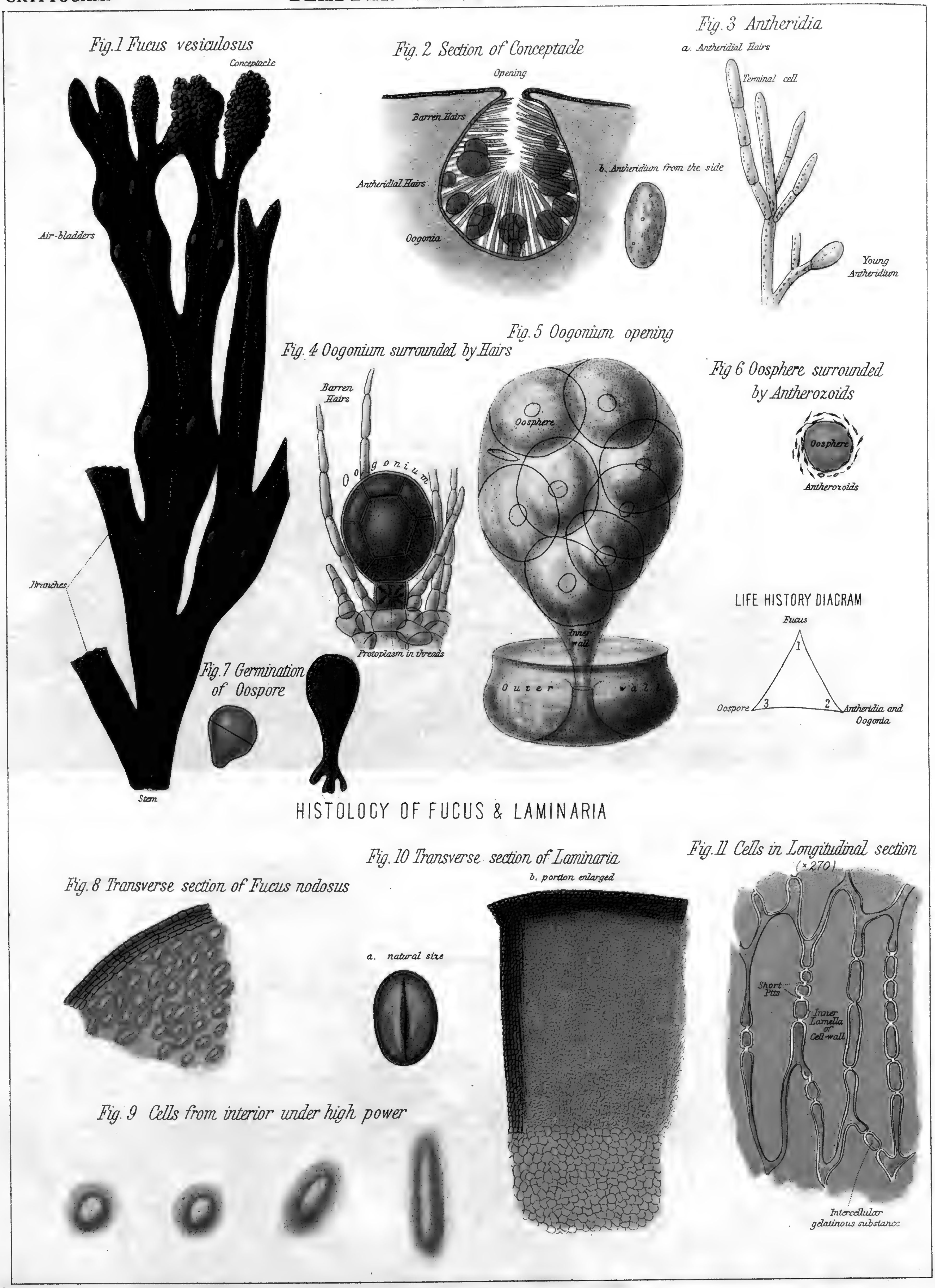

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PLATE XIII.—COMMON BLADDER WRACK (Fucus vesiculosus) and TANGLE (Laminaria digitata).

Fucus (Gr. *phukos*, sea-weed) and Laminaria (Lat. *lamina*, a thin plate) may be taken as representatives of the brown-coloured sea-weeds. They are common objects of the shore wherever rocks abound.

In *Fucus*, the flat expansion or Thallus is dichotomously branched, and attached to the rocks by suckers, so that there is a superficial resemblance to stem, roots, and leaves. But it is only superficial, since the whole plant is bathed with sea-water from which, and not from the soil or air, every part withdraws its appropriate nourishment. The root-like portion consists of delicate hair-like branches with thin cell-walls. It acts like a boy's sucker; it can be pressed very close to the rock, and the pressure of the water, just like the air in the previous case, keeps the two together.

The stem-like narrow portion, as well as the more expanded upper portion, is slimy all over, and this is due to the cell-walls of the outer cells becoming mucilaginous.

The air-bladders serving the purpose of floats contain various gases.

The reproductive organs are borne by the swollen ends of branches and developed in little cavities known as Conceptacles. These are seen by the naked eye as little elevations with openings, and have been formed by a pushing-in or indentation of the exterior. Each dimple or Conceptacle contains Antheridia with Antherozoids or male organs, and Oogonia with Oospheres or female organs.

The most common species are *F. vesiculosus* (Lat. *vesicula*, a little bladder) with a midrib running along each part of the thallus, and air-bladders arranged in a double row; *F. nodosus*, with air-bladders arranged singly and no midrib; and *F. serratus* (Lat. *serra*, a saw) destitute of air-bladders and margins toothed.

Laminaria digitata (Lat. *digitus*, the finger) is so named because the expanded portion is split up like the fingers of the hand. It has a root-like portion consisting of numerous branching stalks expanded at their attached end; a stem-like portion which is perennial, and increases in thickness by concentric layers added year after year; and the split-up leaf-like portion which is renewed every year.

Multiplication takes place by Zoogonidia developed from the expanded portion. Sexual reproduction is as yet unknown.

Fig. 1. Portion of plant, natural size.
Thallus branching in a forked manner or dichotomously, with a well-marked midrib.
Air-bladders occurring in a double series.
Fertile branches swollen and studded over with little papillæ.

Fig. 2. Make a transverse section of a fertile branch, so as to get one of these little papillæ in section which are called Conceptacles. There is a confused mass of hairs, amongst which may be seen the male and female organs. The close-set cells of the exterior are continued right round the Conceptacle, thus suggesting an infolding of the exterior and not an interior cavity afterwards opening externally.
Antheridia, branching hairs.
Oogonia, swollen hairs.

Figs. 3 and 4. Take some of the yellow colouring matter from Conceptacle and mix with salt-water to see Antheridial hairs and Oogonia clearly.

Antheridial hairs repeatedly branched, the ends of the branches swollen and filled with yellow granular matter. When ripe the contents of these cells consist of Antherozoids each provided with two cilia whereby they move rapidly about in the water.

Oogonia are globular bodies, derived from a single cell and producing eight Oospheres. The protoplasm of the surrounding hairs and stalk is broken up into threads, because of the numerous vacuoles formed, owing to the cells getting too large for their contents, as in Spirogyra.

Fig. 5. Oogonium discharging its contents.

The wall of the Oogonium consists of two layers—an outer, inelastic, which splits, and an inner, extensible, which stretches a deal before giving way. The Oospheres are discharged into the conceptacle, then into the surrounding water.

Fig. 6. The liberated Oospheres meet with Antherozoids which surround them, blend with them, and convert them into Oospores, ready to germinate.

Fig. 7. Germination of an Oospore.

It first becomes pear-shaped, then divides into two, and the tapering end soon develops organs of attachment. The upper end divides further and further in all the dimensions of space until the adult form is attained.

Life History.—Fucus reproduces itself sexually by Antheridia and Oogonia, either produced together or on separate plants. The Antherozoids of the Antheridia fertilise the Oospheres of the Oogonia after being set free, and each Oospore thus produced may develop a new plant.

Histology.

Fig. 8. Make a transverse section of the narrow stem-like portion, and examine in alcohol or glycerine under low power.
Cells close-set towards exterior, but arranged loosely in interior.

Fig. 9. Stain transverse section with magenta, and examine under high power.
Cells are round, oval, or elongated, and cell-walls very gelatinous.

Fig. 10. Cut across Tangle and examine—*first*, with naked eye; *second*, a transverse section under low power.
(*a.*) Outer yellowish-brown portion, and inner colourless portion.
(*b.*) Outer coloured portion, small and close-set cells. In old specimens there is a ring of oval slime-cavities pretty near one another. Inner almost colourless portion of larger cells.

Fig. 11. Make a longitudinal section, and examine interior cells as in Fucus.

The elongated cells are bounded by a firm inner membrane, and between this membrane, of two adjoining cells, there is a gelatinous intercellular substance often arranged in layers. Short Pits occur here and there in the membrane.

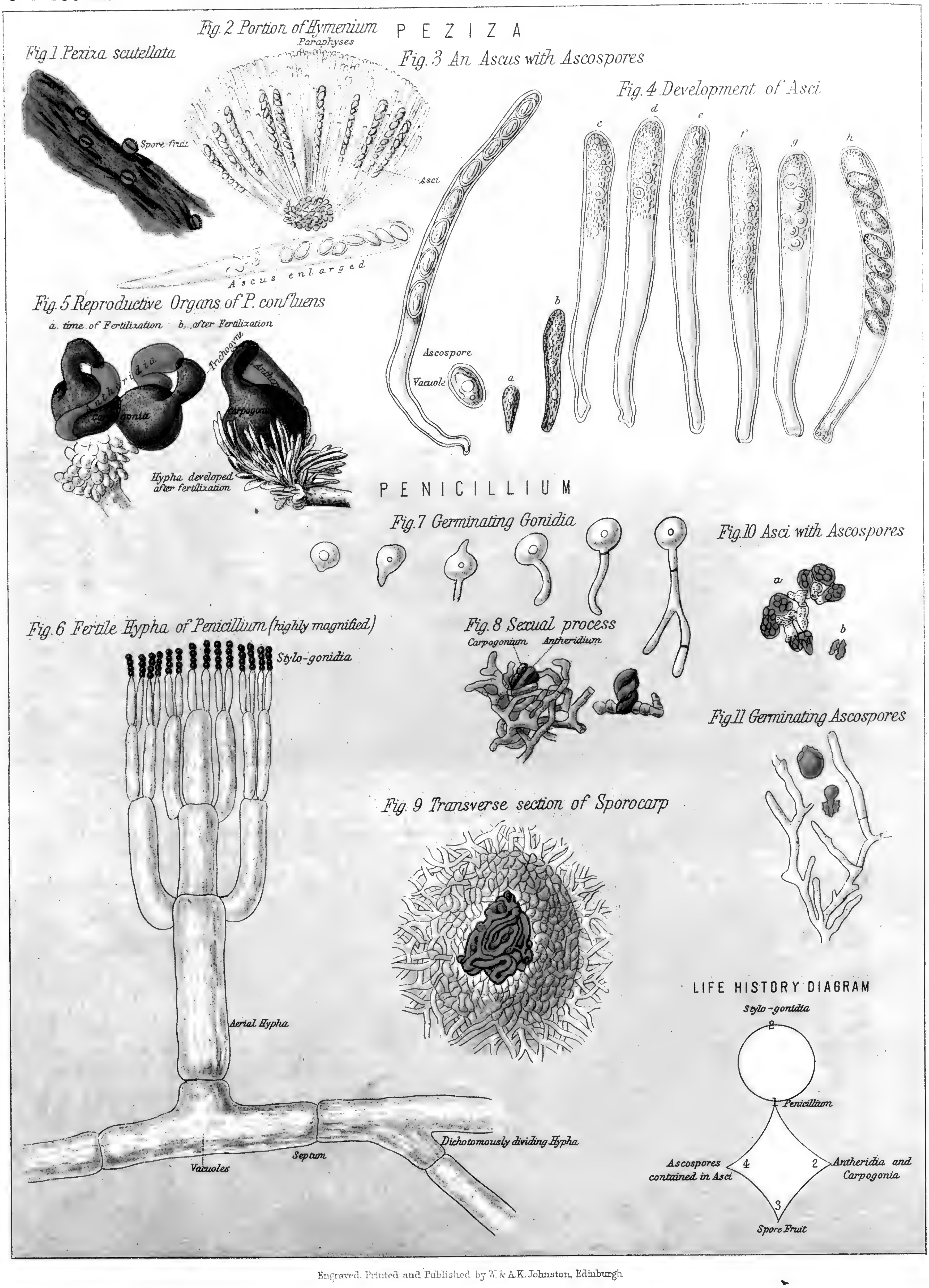

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PLATE XIV.—PEZIZA AND PENICILLIUM.

Peziza.

The Pezizæ are usually found on decaying vegetable matter, such as rotten wood, old cow-dung, dunghills, and the like. They also grow among moss, and may occur on growing plants. The Spore-fruit, which results from Fertilisation, is disc-like or cup-shaped, stalked or sessile, and may be black or white, red or yellow, etc. The mycelium ramifies through the substance on which it grows; for instance, the bright green colour often staining as it were decayed wood, is due to these mycelial threads.

Fig. 1. Piece of rotten wood with Spore-fruits of Peziza upon it.

This specimen is pretty common in such situations, and has a brightly coloured spore-fruit with stiff hairs on its margin.

Fig. 2. Scrape off with a needle a little of the surface of the spore-fruit, tease out in water, and examine with high power.

A number of radiating filaments will be seen, many slender, fewer swollen. The slender filaments are barren, while the swollen filaments contain spores to the number of eight. The barren filaments are called Paraphyses, and the spore-bearing filaments Asci (Gr. *Askos*, a bag), hence the spores are Ascospores.

Fig. 3. Ascus and Ascospore detached.

The eight Spores are usually arranged obliquely, following one another, and in the centre of each is a Nucleus.

Fig. 4. Formation of Spores in the Asci of *P. confluens*.

In the early stage (*a*) the small sac is filled with granular protoplasm and a few vacuoles, but no nucleus. Next, a nucleus appears with a nucleolus (*b*). By repeated division this original nucleus becomes divided into two, four, and finally eight nuclei (*f*). The protoplasm now begins to aggregate around each as a preliminary operation in the formation of the spores, until finally the ripe spores are produced (*h*). Each spore is now surrounded by a firm membrane, the nucleus disappears, and a small oil-globule appears at each end.

Fig. 5. Reproduction of *P. confluens*. (The Male and Female organs are coloured artificially—male, red; female, blue.)

Adjoining branches of the mycelium form respectively the slender Male organ or Antheridium, and the swollen Female organ or Carpogonium. The free end of the Antheridium comes into contact with the hooked end of the Carpogonium (*a*), and, as a result of Fertilisation, a Spore-fruit is formed with innumerable spores. This Spore-fruit consists not only of the fertilised Carpogonium, but of an investment of delicate hyphæ (*b*) which grow and branch till they finally form the coloured cup on the surface of which the Asci lies.

Penicillium.

Common Green Mould or Penicillium (Lat. *penicillum*, a painter's brush) is so named from the brush-like form of the fertile hyphæ, bearing innumerable gonidia which give the familiar greyish-green hue to the mould. These minute gonidia on reaching a suitable medium are able to germinate, hence it is that the mould spreads with such wonderful rapidity and appears so constantly where the conditions are favourable. But even under unfavourable conditions, the mould can still survive and reproduce itself. If the supply of Oxygen is checked, so that the ordinary course of life cannot be run, then it resorts to a sexual process, just as a plant might throw itself into flower when food-supplies are limited.

Fig. 6. Remove a small piece of the crust with its green covering and tease out in water. Fertile hyphæ may be met with.

Hypha branching, contents granular with vacuoles, divided here and there by *septa*.

Fertile hypha branching regularly, the terminal branches breaking up into gonidia. The end portion of this small branch rounds itself off and becomes detachable, the new end repeats the same process, and so on till a row is formed.

Fig. 7. Sow some of the gonidia in a clear fluid, such as Pasteur's, to observe germination.

The Gonidium at first is spherical, but when germination begins, one or more protuberances appear which grow in length, divide, and form *septa*. Continued growth produces a mycelium bearing fertile hyphæ, and so the life-history repeats itself.

Fig. 8. The Sexual process has only been lately discovered, and occurs under peculiar conditions, as yet attained only by artificial means. The Male and Female organs are formed by short branches—the Antheridium being simple and the Carpogonium coiled like a cork-screw. These two come together and produce a Spore-fruit which is about the size of a pin-head.

Fig. 9. The Spore-fruit is naturally of a yellowish colour, and consists of a mass of Spore-bearing hyphæ, enclosed by sterile hyphæ.

Fig. 10. Portion of Spore-bearing tissue removed from Spore-fruit.

(*a*) Asci, containing the Ascospores.

(*b*) Ascospore, separate.

Fig. 11. Germinating Ascospore producing a mycelium like the Gonidium.

Life History of Penicillium.—Upright hyphæ give off numerous small branches, which become rounded off at their ends to form gonidia. These gonidia germinate and give rise to a new plant. This is non-sexual multiplication, but sexual reproduction has recently been discovered by Brefeld.

When the plant is deprived of air and light, the development of gonidia is interfered with, and sexual organs appear. Two short hyphæ lay themselves together—Antheridium and Carpogonium—and the result of their union is a Spore-fruit, in which Spores are afterwards formed, contained in bags or Asci. Each Ascospore may germinate and produce a mycelium bearing aerial hyphæ as before.

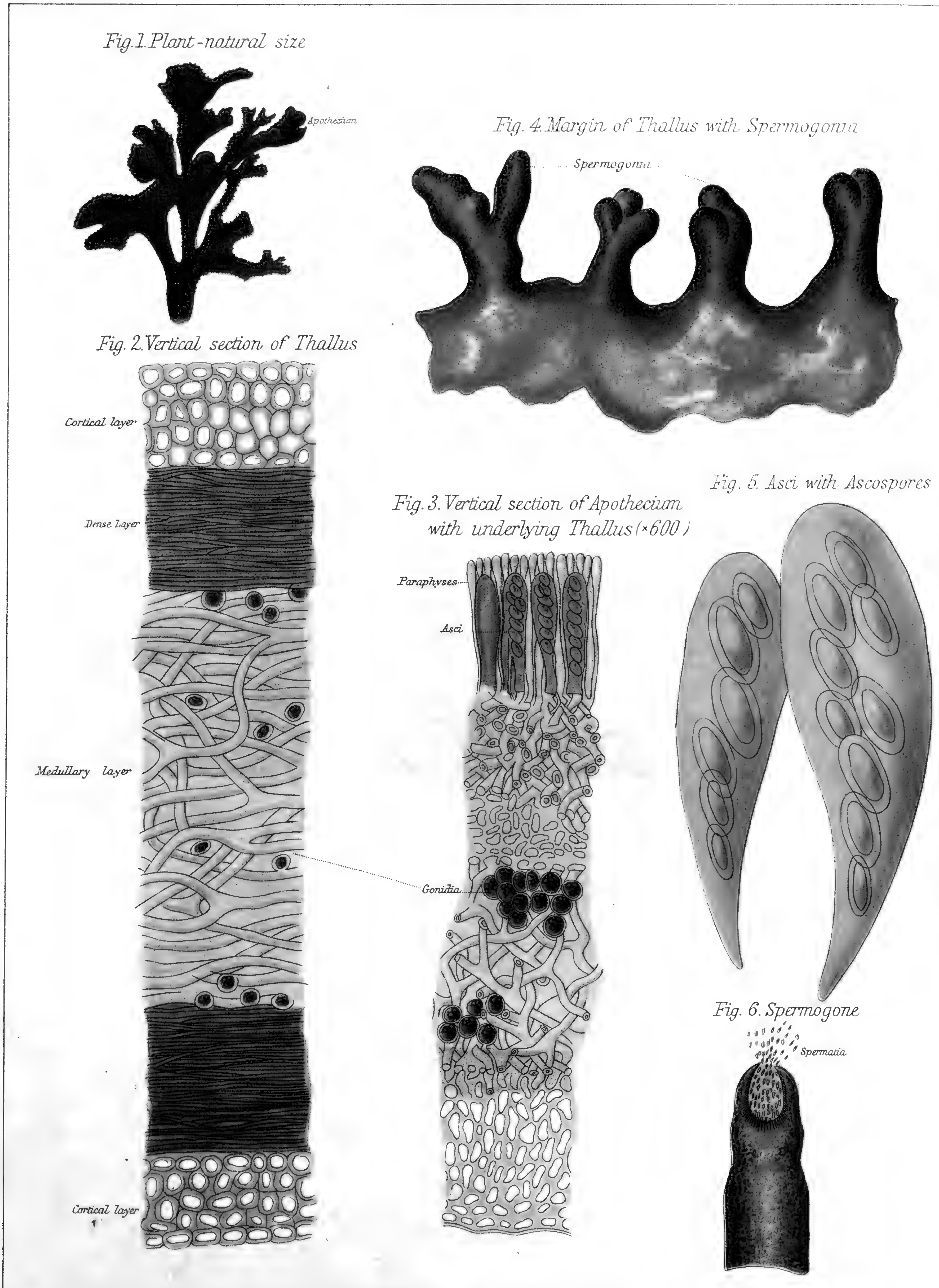

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PLATE XV.—ICELAND MOSS (Cetraria islandica).

The *Lichen-thallus* is regarded, according to the most recent investigations, as forming not one individual organism but a kind of composite structure. It is a *commensal* organism, formed by the partnership of different individuals preying upon, and at the same time mutually accommodating, each other. The *hyphae* form one of the plants which is an Ascomycetous Fungus, and the gonidia or green cells form another plant which belongs to the Palmellaceous Algae, in this instance, viz.—*Cystococcus humicola*. These Algae living among the mycelial filaments of the Fungus supply them with nutriment, and receive in return that amount of moisture and protection, which enables them to grow and multiply. The hyphae in fact are parasites upon the gonidia, abstracting from them the materials they manufacture as green plants. But the gonidia, though thus kept in check are not exterminated, and the survivors go on growing and multiplying, so that there is always an excess over and above the wants of the lichen. As the gonidia multiply so do the hyphae, and the scale on which the business is carried on necessarily becomes larger. It is a combination for the supply of continually increasing wants, which almost suggests forethought in its striking adaptation.

Fig. 1. The so-called Iceland Moss is a *Lichen*, growing on the ground with its thallus erect. It may be procured in the dry state from the chemist, as it is used medicinally.

The lobes of the thallus are numerous and tufted, and the edges are fringed with short teeth. The so-called "fructification" is rare, and is called an Apothecium, because the surface of the receptacle is very slightly concave (when the receptacle is excessively concave, it is called a Perithecium).

Fig. 2. The Thallus or flat expansion of the Lichen shows in vertical section several distinct layers:—

Cortical or superficial layer of closely applied thick-walled cells.

Gonidial layer, a looser layer of intermingled hyphae in the meshes of which are entangled green rounded cells—the "gonidia."

Medullary layer of thread-like cells forming the bulk of the thallus.

Cortical layer as above.

Fig. 3. Vertical section of the "Fructification" and underlying Thallus.

Asci containing Ascospores originating from the colourless filaments here called the Sub-hymenial layer.

Paraphyses are barren filaments.

Figs. 4 and 5. The Asci are club-shaped and the Ascospores are elliptical.

Fig. 6. Spermogonia occur on the margin of the thallus and produce Spermatia.

Life History.—The Sub-hymenial layer of the Thallus produces numerous Asci, each containing several Ascospores. The Asci absorb moisture as they ripen, causing their membranes to swell, until finally the tension is so great, at the top of the tube, that it gives way and the sudden collapse jerks out the spores. The moist spores are accompanied by hymenial gonidia, and put forth several embryo-tubes, some of which lay hold of the substratum, and the others embrace the gonidia and ramify to form the thallus of the Lichen.

The Spermogonia are considered to be Male Organs; and as they appear before the fructification is formed, it is very probable that a Female Organ lies imbedded in the thallus, to which the Spermatia are conveyed by water. In this case the fructification would be developed as a result of fertilisation.

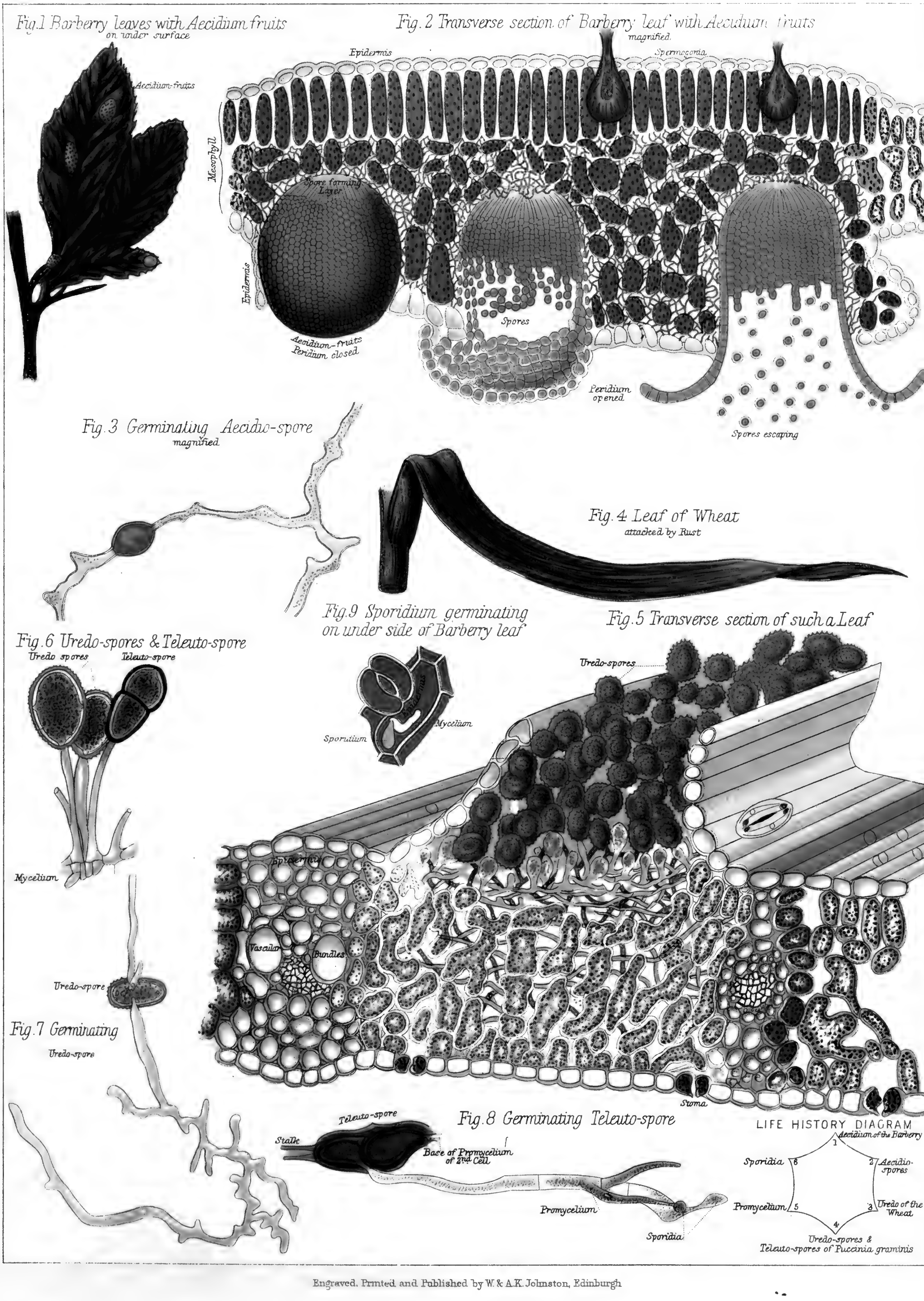

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PLATE XVI.—RUST OF WHEAT.

(After Dodel-Port, De Bary, and Tulasne.)

The Rust of Wheat is interesting on various grounds, for the varied forms it assumes, and the change of quarters it delights in, as well as for the effects produced by it. It has a curious history, owing to the fact that its connection with the Barberry was recognised by farmers in practice long before scientific men had traced or even dreamt of the connection. It was found out that in going its various rounds in order to complete its life history, there existed the same relation between Rust and Barberry as between Lodger and Boarder. Although so well investigated, no remedy has yet been found for its ravages.

Fig. 1. Leaves of Barberry bearing yellow or orange patches on stalk and blade—the Aecidium-fruit.
Towards the end of summer these patches appear, called Barberry rust.

Fig. 2. Transverse section of such a leaf.
The mycelium of the fungus has penetrated through the tissue of the leaf, extracting nourishment and draining the leaf by the way. It has also produced a fructification of two kinds; one on the upper side, the other on the under side of the leaf.
The Spermogonia are flask-shaped bodies on the upper surface, producing numerous filaments called Spermatia.
The Aecidium-fruit on the under surface is a globular body surrounded by a wall or peridium, which on opening allows the spores to escape.

Fig. 3. Aecidio-spore germinating.
It sends out two filaments, which branch and form the Mycelium of the Rust.

Fig. 4. Streaks of a rusty colour appear on the surface of the leaf owing to the Uredo-spores bursting through.

Fig. 5. Transverse section of leaf.
The mycelium ramifies through the tissues of the leaf; and towards the surface, branches produce the Uredo-spores. These cause a swelling, and the epidermis ruptures, when the spores are easily blown about by the wind.

Fig. 6. Uredo-spores produced late in the summer along with Teleuto-spores. The double coat of the Uredo-spore is relatively thin, and covered with minute projections, while that of the Teleuto-spore is thick and brown.

Fig. 7. Uredo-spore germinating, and giving rise to a branched mycelium in the leaf, which again reproduces Uredo-spores, and so on.

Fig. 8. Teleuto-spore germinating.
This spore is two-celled, and was formerly supposed to belong to a different fungus, which was named Puccinia graminis.
It forms a branching pro-mycelium of several cells, from the branches of which Sporidia arise.

Fig. 9. A Sporidium falling on the Barberry, when it is to be found in hedge-rows adjoining corn-fields, germinates on the under surface of the leaf, and produces the form in Fig. 1.

Life History.—The Cluster-cups, or Aecidium-fruits on the Barberry, produce numerous Aecidio-spores, which germinate on the damp leaves of Wheat. There a mycelium is formed, the Uredo, which gives rise to Uredo-spores, forming the rusty powder on the surface of the leaf. The Uredo-spores, or Summer-spores, may in turn germinate on a leaf of Wheat, produce a mycelium giving rise to Spores, and this course may be repeated over and over again, spreading the Rust till the harvest season. Then Teleuto-spores, or Winter-spores, are produced, which germinate next spring, and develope Sporidia at the end of branches of a short filament, which can form the Aecidium-fruits on the young Barberry leaf, as in Fig. 1.

The Rust of Wheat may appear even before the appearance of Barberry leaves, owing to the Uredo-spores persisting during the winter and directly germinating on the young Wheat.

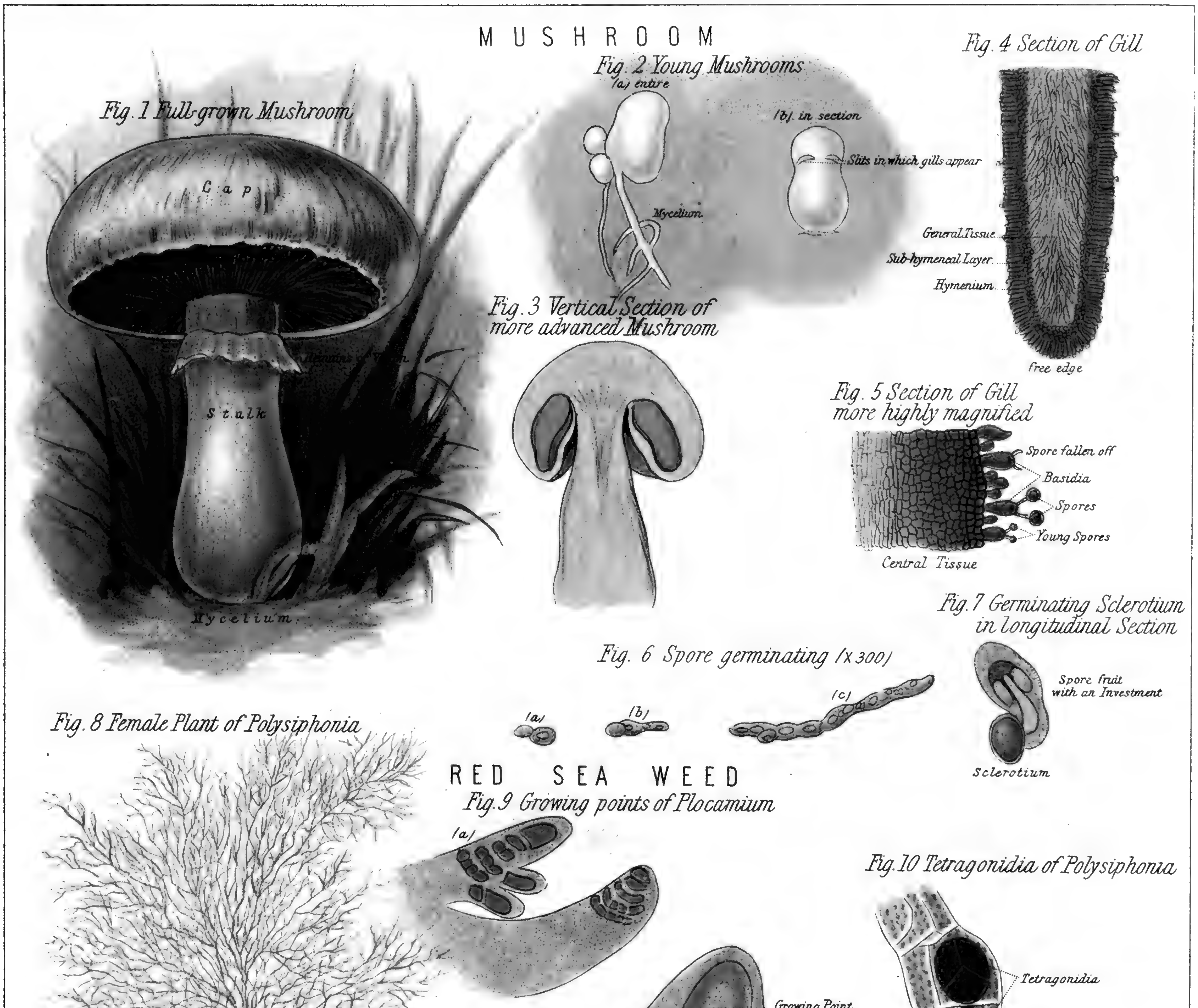

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PLATE XVII.—COMMON MUSHROOM (Agaricus campestris) and RED SEA-WEED (Polysiphonia).

Mushroom.

The Pezizæ are distinguished by producing their spores in the *interior* of cells called Asci, and the Mushroom produces its spores on the *exterior* of enlarged cells called Basidia, hence the name applied to the group—*Basidiomycetes.* The common Mushroom may be found towards the end of summer in open pastures, but it can be raised from spawn at any season of the year. Mushroom spawn simply consists of the mycelium mixed up with decaying organic matter, and under proper treatment, as to moisture and temperature, mushrooms may be produced.

Although the mushroom belongs to the most highly organised group of *Fungi*, just as the Red Sea-weed belongs to the highest group of *Algæ*, yet no sexual stage has yet been discovered.

Fig. 1. Mushroom, full grown.

The mycelium consists of interlacing threads spread out in the mould, and what is called the Mushroom is really the Spore-fruit arising from this mycelium.

Spore-fruit composed of—Stalk with a remnant surrounding it near the top, of what once extended to the margin of the Cap.

Cap spread out like an umbrella, and bearing on its under surface the radiating plate-like Gills.

Fig. 2. Young Mushroom, entire and in section.

The cap and stalk are already roughly indicated.

The section shows the commencement of the gill-chamber, which is really a hollow ring in which the gills are formed.

Fig. 3. Mushroom more advanced—in section.

Velum (Lat. *a veil*), forming a floor to the gill-chamber from the roof of which the gills are developed.

Fig. 4. Remove a gill, embed it in paraffin, and make a section of it.

The centre is occupied by mycelial filaments closely packed and adhering side by side, and towards each surface this tissue becomes denser on the outside, giving rise to the Basidia.

Fig. 5. Section under high power.

Towards the surface the cells get rounded, and the superficial layer of cells is enlarged to form Basidia. The Basidium has four slender processes (two only shown), at the ends of which the spores are developed and easily detached.

Fig. 6. Germination of Spore of Coprinus.—The spores may be readily obtained by laying the Spore-fruit upon a sheet of paper, then by placing over the spores a glass slide moistened by the breath, they may be lifted up and examined.

The spore placed in a drop of an appropriate fluid on a slide begins to germinate in a few hours by putting forth a delicate filament. This grows, becomes divided by transverse partitions and branches, thus forming a mycelium. In the course of from nine to twelve days the Spore-fruit arises directly from the older mycelial filaments.

Fig. 7. In some cases, however, a Sclerotium is formed first.—This consists originally of an aerial branch, which divides and branches on all sides till it forms a small ball of closely packed and interosculating filaments. One of the surface-cells grows out and becomes the young spore-fruit, which, in this instance, is entirely invested by the velum.

Life History.—It is very tempting to suppose that the Spore-fruit is the result of a sexual process, but as experiments specially directed to that point have failed to show any trace of it, it is now generally believed that in the whole of the Basidiomycetes the Spore-fruit arises directly from the mycelium or indirectly from a Sclerotium.

The stages through which they pass would be briefly as follows:—the Mycelium (or Spawn) produces a Spore-fruit directly, which bears the numerous spores from which the mycelium is again produced, and so on; or, in some cases, the Spore-fruit is preceded by a Sclerotium.

Red Sea-Weed.

Polysiphonia (Gr. *polus*, many; *siphon*, a tube) is one of the Red Sea-weeds—plants usually of a graceful form and beautiful colour, so that they attract attention. This form is found about low-water mark, attached to rocks, the stalks of the Tangle, etc., and although so finely divided, it may be removed from the water without collapsing. These divisions might be regarded as of the nature of leaves, just as in the next form considered (Chara). There are three distinct forms of this plant, all agreeing in general appearance, but differing in their reproductive habit—the Non-sexual, the Male and the Female; and it is the first of these which will be considered now.

Fig. 8. Plant much divided.

Fig. 9. Plocamium is one of the feathery red sea-weeds, and when simply spread out in water under the microscope, it shows clearly the single growing cell—cells a little further back dividing longitudinally to produce breadth, and a single cell growing laterally and dividing to form one of the numerous branches. The cell-walls are gelatinous.

Fig. 10. Portion of Non-sexual plant showing Tetragonidia.

They appear as little round balls, but under a high power division is seen. The four gonidia do not lie in one plane, but are arranged like a tetrahedron; hence, either one or three divisions may be seen.

The gonidia escape by a parting between the peripheral cells.

Fig. 11. Germination.—The Gonidium elongates, divides transversely, one of the divisions serving for attachment, the other growing and dividing longitudinally and transversely, and branching, till it becomes a parent plant.

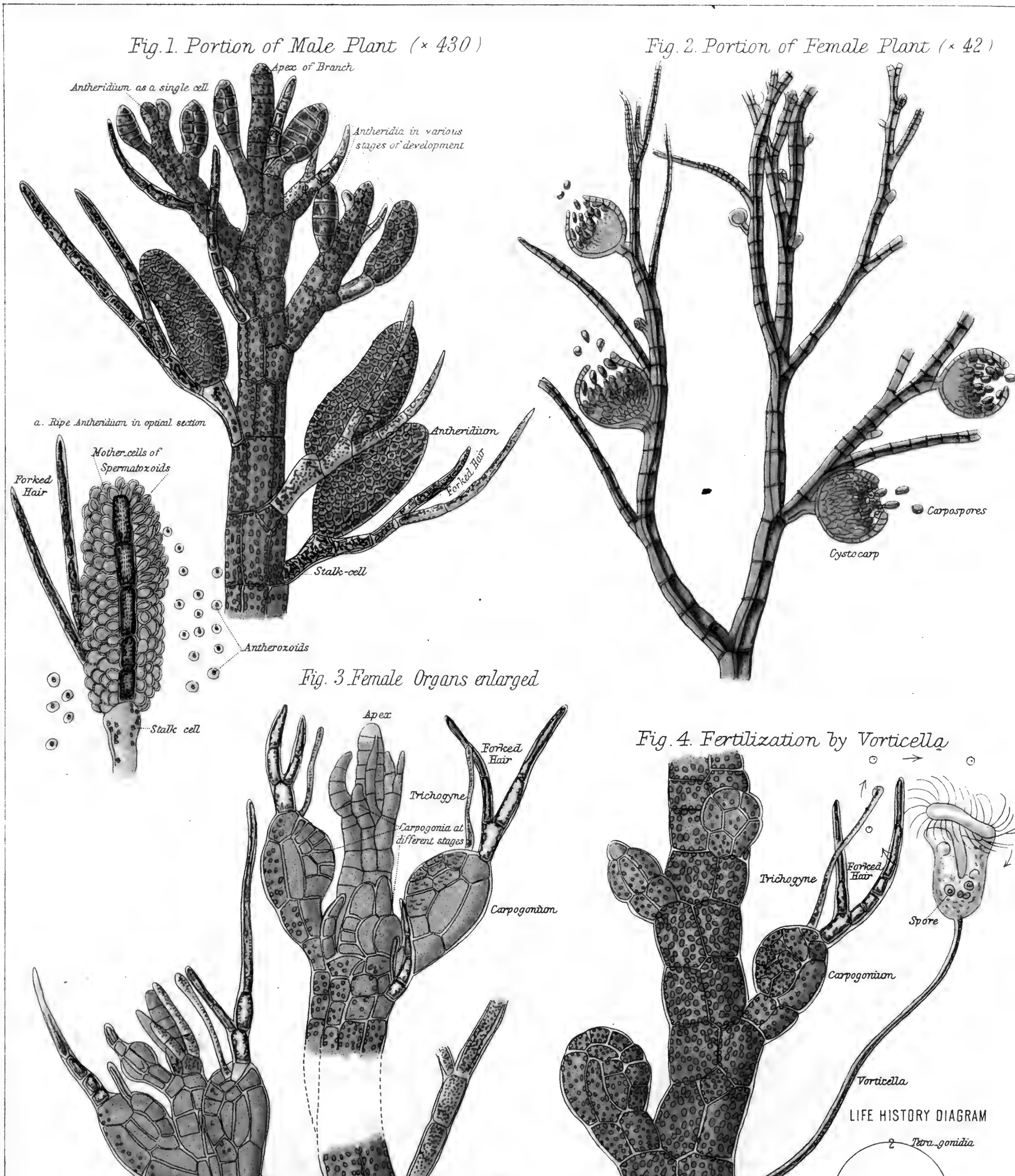

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PLATE XVIII.—RED SEA-WEED (Polysiphonia Subulata)—*continued.*

Fig. 1. Male Plant.

Antheridia, or male sexual organs, are cone-like, supported by a short stalk.

Forked hair on the outside of each, protecting it.

Fig. 1*a*. Ripe Antheridium in optical section (×430).

There is a basal-cell forming the Stalk, a row of cells in the centre forming an Axis, and the mother-cells of the Antherozoids are grouped around this Axis. The Antherozoids are spherical motionless masses of protoplasm, discharged into the surrounding water by the bursting of the ripe mother-cell.

Figs. 2 and 3. Female Plant.

Carpogonia, or female sexual organs, are obovate, when ready for fertilisation, and consist of three principal parts—

1. Foot or attachment.
2. Fertile spore-forming part. This is the swollen portion, and consists of a central cell surrounded by a number of peripheral cells.
3. Hair apparatus, consisting of the forked hair and the Trichogyne (Gr. *trichos*, hair; *gone*, seed).

Fig. 4. The process of Fertilisation is extremely interesting, because of the part that Infusoria have recently been found to play in it. The antherozoids, discharged into the surrounding sea-water by the bursting of the ripe antheridia, are passively floated about by the waves, since they are motionless in themselves, and they may accidentally come into contact with the trichogyne of a female plant; but their chances are greatly increased by the action of unconscious agents, such as Infusoria, which create currents in the water in the neighbourhood of the female organs.

Vorticella, or the Bell Animalcule, is a stalked Infusorian, attached to this red sea-weed. The stalk may either be lengthened out, as in the drawing, or shortened by being coiled into a spiral. The bell is surmounted by a crown of cilia which move in a definite order, so as to cause currents which will sweep particles of food down the gullet. The Vorticella is at first a free-swimming unstalked bell, but with the stalk it becomes fixed, and it naturally settles down where there is likely to be an abundance of food. The currents set up necessarily send antherozoids down the gullet, but some come in contact with the apex of the trichogyne, and are retained there. The forked hair, too, will serve to break the force of the current, and form a sort of eddy, so that the antherozoids may the more readily settle down where wanted. The antherozoid thus blends with the trichogyne, and its substance passes down the canal of the trichogyne, till it reaches the central cell, and thus fertilisation is effected. The forked hair and trichogyne both disappear after fertilisation, having served their purpose.

Life History.—The Red Sea-weeds multiply by a simple non-sexual process, or are reproduced sexually in a somewhat complicated manner.

The contents of certain cells break up into four portions, which escape by rupturing the cell-wall, and germinating reproduce the parent plant. These are the Tetragonidia produced non-sexually.

In some red sea-weeds the male and female organs are on different parts of the same plant, but in Polysiphonia they are on different plants. The Male plant produces Antheridia, which begin as a single-celled branch, then become a row of cells, and finally a cone-like mass of cells. The forked hair arises from the stalk-cell, and the other cells produce the rounded Antherozoids. The Female plant produces Oogonia, but as they become spore-fruits after fertilisation, they are called Carpogonia. These arise, like the Antheridia, from a single cell, which eventually becomes a basal portion or Foot, consisting of a ring of four cells, and one in the centre; a middle or Fertile portion, consisting of a large central cell, surrounded by a number of cells; and a top portion, consisting of a long cell or Trichogyne, with a forked hair. An Antherozoid reaching the apex of the trichogyne, in the way already described, is retained there, and strange to say, the fertilising effect is produced at some distance in the central cell and surrounding cells of the Carpogonium. The surrounding cells grow and divide till they form a fruit-like cover, while the central cell forms a number of close-set branches, at the ends of which the Carpospores are developed. There is thus a Spore-fruit formed, which discharges its so-called Carpospores or Endogonidia by a hole at the top; these on germination give rise to young plants.

CHARA

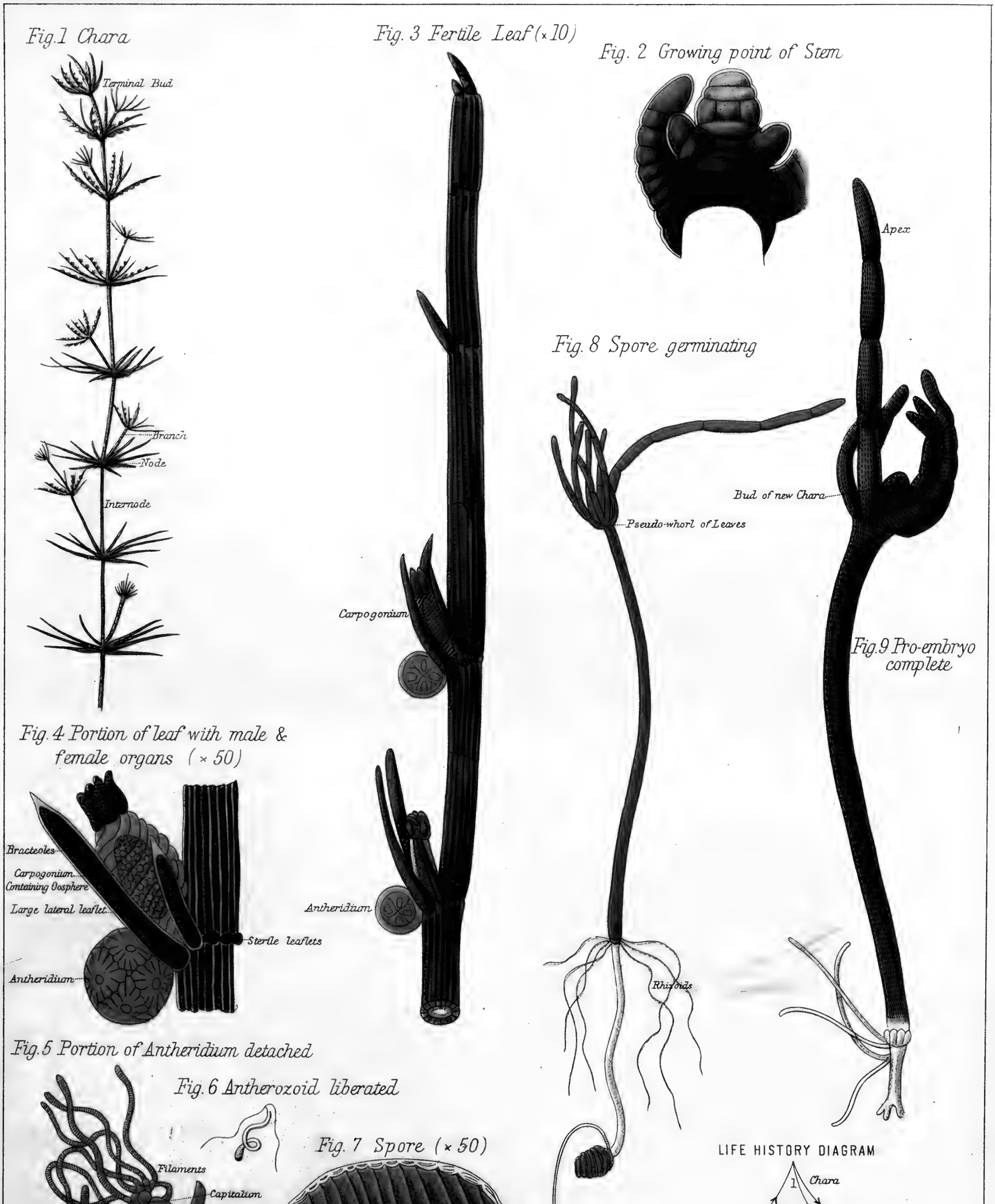

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PLATE XIX.—STONEWORT (Chara).

(Development after Pringsheim).

Chara may be found growing in ponds and streams, varying in height from a few inches to several feet. It is entirely submerged and the stem is often encrusted with calcareous matter derived from the water, which makes it exceedingly brittle. In bog-pools, however, where the water is soft they may be found free from this, and so more useful for purposes of study.

This plant differs from those hitherto considered in possessing an Axis and Appendages. The Axis grows in the direction of its length and is furnished with an apical cell, by the division of which growth is continued. Certain cells of the stem have also different functions assigned to them. The Lateral Appendages arise from one kind of cell while another kind is much longer and form the main part of the axis.

Fig. 1. Portion of Chara in Fruit.

It is composed of a long thread-like stem, giving off at intervals appendages arranged in whorls, and ending in a terminal bud. The place where each whorl of appendages comes off is called a Node, and the space between two nodes is called an Internode. An internode and node with its appendages forms a Segment, and the whole axis is thus a repetition of similar segments. Branches or secondary axes repeating the structure of the primary axis, arise from the angle between the leaves and the stem.

Fig. 2. Harden specimens in a weak solution of chromic acid, which also dissolves any limy incrustation; then get as small a portion as possible of the terminal bud and press it out, without destroying it, in glycerine.

The apical cell or growing point is a nucleated hemispherical cell. It is hemispherical, for its free rounded surface is not influenced by pressure, while the under surface is flat, being pressed against its neighbour. Below the second cell, which is flat on both surfaces, comes three cells formed from a single cell by vertical divisions. Next is an undivided cell, followed by a divided cell.

Fig. 3. Fertile leaf detached.

Antheridia or Male Organs, globular.

Carpogonia or Female Organs, more elongated.

Fig. 4. Portion of same enlarged.

The Antheridia and Carpogonia arise from a node, and the leaflets or bracteoles protect them.

Fig. 5. Tease out a ripe Antheridium and examine portions under highest power of microscope.

The essential parts are the filaments divided into numerous cells, each containing an Antherozoid.

Fig. 6. The liberated antherozoid is seen to have two long cilia at the tapering end and granular contents at the blunt end.

Figs. 7, 8, and 9. The spores on germination gives rise to a Primary Rootlet and a Pro-embryo, one of the cells of which buds forth and produces a Chara.

Life History of Chara.—Chara produces Antheridia with Antherozoids and Carpogonia with their central cells. The antherozoids fertilise the central cell of the Carpogonium thus converting it into an Oospore. This germinates and produces a Pro-embryo, from a bud of which Chara is developed.

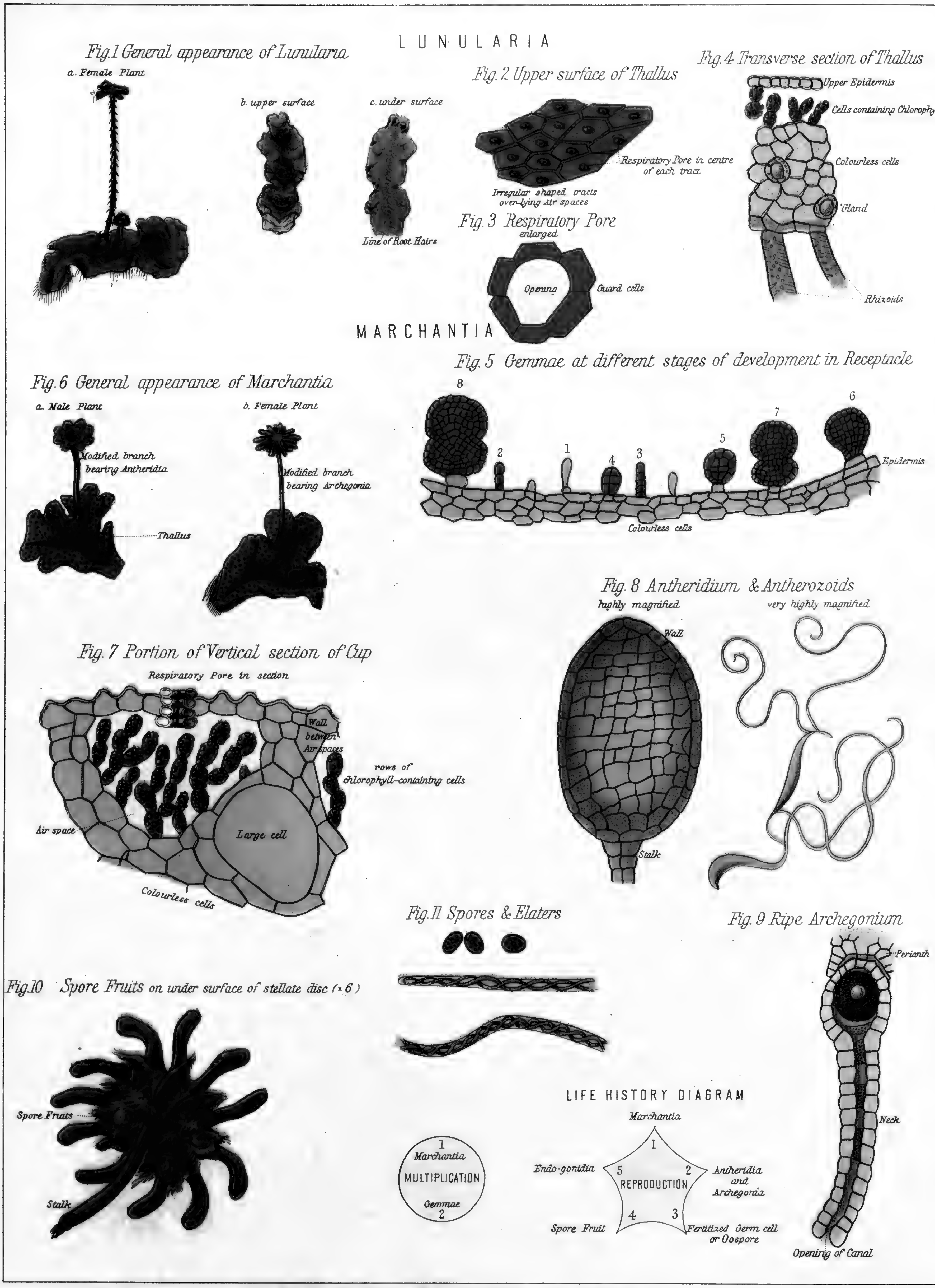

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PLATE XX.—MOONWORT (Lunularia vulgaris) and VARIABLE LIVERWORT (Marchantia polymorpha).

Lunularia.

Lunularia, so named from its crescent-shaped receptacles, is found on neglected flower-pots left in a damp and shady place, and such like. It only produces buds in this country and is very convenient for seeing the Gemmæ at different stages, while the Marchantia may serve for tracing the sexual process. It forms a small, bright-green bifurcating Thallus.

Fig. 1*a*. Female plant with fertile branch, forming a cross-shaped apex bearing Archegonia.

Fig. 1*b* and *c*. The gemmæ-bearing plant, with a forked growing apex, and withering away behind. The upper surface has gemmæ-cups and the under surface a tangled line of root-hairs.

Fig. 2. Upper surface of *Thallus* under simple microscope shows irregularly shaped tracts with Respiratory-pore in centre of each.

Fig. 3. Peel off a very thin slice of epidermis and examine under high power.
Opening of Respiratory-pore (seen in section, in Fig. 7).

Fig. 4. Embed small portion of Thallus in paraffin and make tranverse section.
Upper Epidermis of close-fitting cells.
Respiratory-cavity containing green cell .
Colourless cells.
Lower Epidermis, giving rise to Root-hairs, each composed of a single cell and with walls, strengthened by incomplete spiral thickenings.

Fig. 5. Embed a young Receptacle in paraffin and make transverse section.
The Gemmæ are seen at all stages of development, from little pear-shaped bodies (1) till they reach maturity (8), ready to be detached and shed.

Marchantia.

Marchantia is very common in moist or damp places, spreading over damp rocks or soil, or on the mould of flower-pots. It is a leathery flat expansion and grows by repeated bifurcation at one end, so that it gradually forms a fan-shaped mass. The upper surface is dark-green, while the under surface, in contact with the soil or rock, is pale in colour. There are not only root-hairs on the under surface to fasten it, but a double row of membranous appendages which are apparently comparable to leaves.

Fig. 6*a*. Male plant with fertile branch spread out at the top in umbrella fashion. The upper surface of this fertile branch is studded with little openings which are the mouths of sacs containing Antheridia.

Fig. 6*b*. Female plant with fertile branch expanded at the top into a star-like disc bearing Archegonia on its under surface.
The cup-shaped receptacle with toothed margin contains gemmæ.

Fig. 7. Embed piece of cup in paraffin and make section—or a piece of the Thallus may be used.
On the inner surface of cup (lower surface in drawing) the cells are relatively large and colourless, and the outer surface has its epidermal cells close together. Beneath the epidermis there are Respiratory cavities containing branched rows of chlorophyll-containing cells, to which air has admission through the little openings seen on the surface of the Thallus (Fig. 2) called Respiratory-pores.
The object of this arrangement is only to admit the air where most wanted. The general arrangement of the tissues is impermeable to air, and the plant does not readily dry up, from its tough and leathery texture; but by means of these little lung-like chambers the air plays freely among the spread-out green cells and enables them to decompose carbonic acid in the presence of sunlight.

Fig. 8. Embed portion of male plant containing Antheridia and make sections. Examine first under low power, then add a drop of spirit, afterwards glycerine, and examine under high power.
Antheridium with stalk, an outer wall, and inner mass of cells developing antherozoids.
The ripe antheridium bursts irregularly on one side to discharge its contents. The cell-walls swell up with water and burst, then the gelatinous contents poured out are gradually dissolved by the water, and the freed antherozoids may be seen moving about with two cilia.

Fig. 9. Ripe Archegonium, showing the margins of the lobes of the disc growing down to form a sort of investment or perianth.

Fig. 10. Sporogonia or Spore-fruits on under surface of disc, consisting of rounded bodies.
The interior mass of cellular tissue is converted into alternating rows of spores and spiral filaments. As water is absorbed the spore-capsule bursts and, under the same influence, the spiral filaments, coiled up like a spring, spread out and scatter the accompanying spores with considerable force.

Fig. 11. Spores and Elaters.
The Elaters are doubly coiled filaments enclosed by a wall.

Life History of Marchantia.—Marchantia multiplies by asexual buds or Gemmæ, which are little green bodies enclosed in cup-shaped receptacles, and on becoming detached, may develop into new individuals.

Marchantia also reproduces itself sexually. The male organs (or Antheridia) and the female organs (or Archegonia) are borne by different individuals. The Antherozoids fertilise the central cell of the Archegonium, converting it into an Oospore which swells up and grows into a Sporogonium full of spores. The spore germinates, producing the green, flat expansion, as at the beginning.

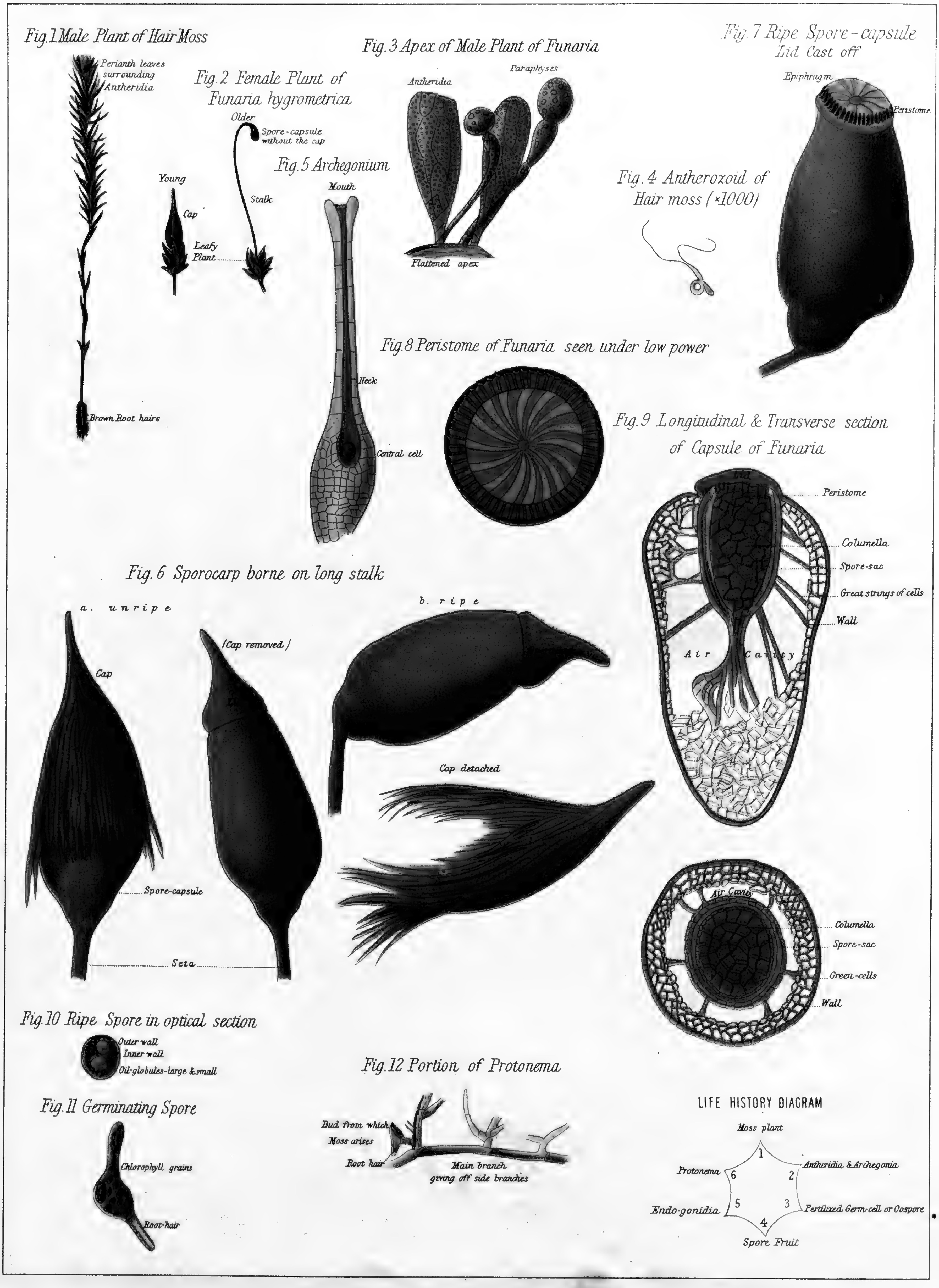

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PLATE XXI.—COMMON HAIR-MOSS (Polytrichum) and FUNARIA HYGROMETRICA.

Mosses are common everywhere, on wall-tops, roofs, and trees, decking the banks with a mantle of green, or carpeting the forests with their luxuriance. Mosses, however, like other plants, have also their favourite haunts and their favourite seasons, but Funaria has this advantage, that it may be found in fruit at almost any season of the year.

The Hair-Moss (*Polytrichum*) is common on waste-ground and heaths where it forms tufted masses. The male and female organs are borne by distinct plants, and the hairy cap of the moss-fruit may be readily recognised. The stem may be several inches in height.

Funaria occurs on walls, roofs, and waste-places pretty common. The leafy plant is small, but the stalk bearing the pear-shaped capsule is an inch or two in length. This stalk has the peculiarity of contracting to a spiral on drying after being moistened.

Fig. 1. Male Plant of Polytrichum, with numerous brown root-hairs and slender stem.
The apex of the stem forms a leafy expansion bearing the male organs.

Fig. 2. Female plant of Funaria.
In the young condition the Capsule is sessile, but it is borne on a long stalk later.
The Leafy plant has a very short stem, with bright green leaves overlapping each other.

Fig. 3. The flattened apex is bounded by leaves, and bears stalked bodies of considerable size intermixed with barren filaments.
The stalked bodies are the male organs or Antheridia, consisting of a wall formed of a single layer of cells, and the interior cells developing Antherozoids.
Tease out portions of the apex, and examine under high power for Antheridia with Antherozoids, and Archegonia.

Fig. 4. Antherozoid, a coiled body with two cilia.
Stain with iodine to kill them and make cilia visible.

Fig. 5. Archegonium, a flask-shaped body with long neck and a lower swollen portion containing the central cell.

Fig. 6. Sporocarp of Polytrichum.
The unripe Capsule is still green and covered by its brown hairy cap.
The lid beneath the cap is peaked.
The ripe Capsule is of a brownish-yellow and the cap yellowish.

Fig. 7. Ripe Spore-capsule of Polytrichum (June).
The lid is cast off and the spores escape.
The mouth of the capsule is surrounded by sixty-four teeth forming the Peristome.
The Epiphragm is the expanded end of the Columella.

Fig. 8. Peristome of Funaria consisting of sixteen teeth converging to a centre.

Fig. 9. Embed Capsules of Funaria in paraffin, and make longitudinal and transverse sections.
Outer wall or peripheral layer of cells.
Columella or central cylinder of colourless cells.
Spore-sac surrounding columella.
Air-cavity with strings of green cells permeating through it.

Fig. 10. Ripe spore consisting of inner and outer wall, protoplasm and oil-globules.

Fig. 11. Sow spores on blotting-paper kept moist under a glass shade.

Fig. 12. The germinating spore gives rise to a thread-like branching body—the Protonema, and a bud forms which grows up into the leafy Moss.

Life History of a Moss.—The leafy Moss-plant forms at its apex either Antheridia producing Antherozoids or Archegonia with their Central-cells. The antherozoids fertilise the central cell, converting it into an Oospore. This oospore divides and produces directly the Sporogonium with its contained Spores. The top of the ripe capsule detaches itself, and the spores come out: and on a suitable situation begin to germinate. The thick outer coat is ruptured, and the inner coat protrudes as a filament which grows, divides and branches, till a mass of branched filaments is formed called the Protonema. The Protonema gives rise to a bud by the bulging out of a side branch, and this produces the leafy Moss as at the beginning.

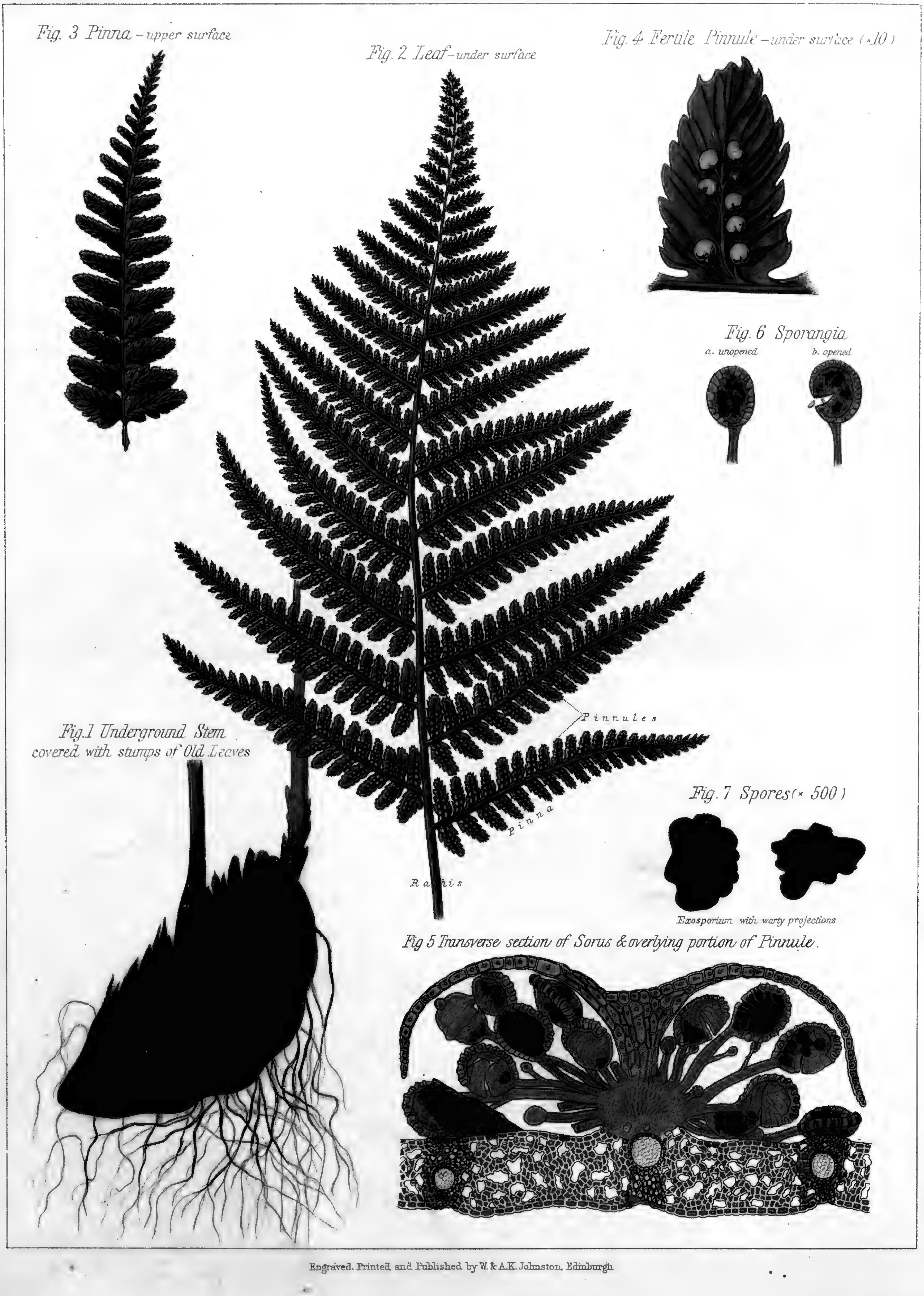

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PLATE XXII.—MALE SHIELD FERN (Aspidium filix-mas).

Ferns have always attracted notice from their graceful outlines and their varied forms, still it is only comparatively recently that the complete course of their life history has been made out. The frond of the Fern is the most conspicuous, the underground portion being generally overlooked. Having so much leaf about them, they generally inhabit moist and shady situations. Their prevailing colour is green, but towards the autumn a brown hue appears on the under surface of the frond, in streaks or patches, and this is due to the formation of spore-cases containing the spores.

The Male Shield Fern is so named by way of contrast to an allied form—the Lady Fern, with its graceful habit, its elegant form, and its delicate hue. It bears its fronds in tufts, arranged in shuttle-cock fashion, and rising to a height of two or three feet. The young fronds are rolled up like a shepherd's crook, and gradually unfold themselves. The veining of the leaflets is distinctly seen, and that constant forking of the veins so characteristic of Ferns. The spore-cases are arranged in patches, each patch being indicated by its kidney-shaped cover. The amount of spores produced is enormous, and readily accounts for its extensive distribution. Professor Dodel-Port has reckoned the number of spores scattered by a single fern, in a single summer, to be no less than one thousand millions.

Fig. 1. Underground Stem ascends obliquely, and is completely covered with the stumps of leaves, from the base of which the numerous roots arise.

Fig. 2. Fertile leaf or frond bearing Sporangia on under surface.

The leaf is bi-pinnate; the pinnæ are long, narrow, tapering, and the pinnules are obtuse.

On the under surface of the leaf, usually at the forking of two veins, kidney-shaped structures appear called Indusia. Each Indusium covers a cluster of stalked capsules, such a cluster being called a Sorus, and each stalked capsule a Sporangium.

Fig. 3. Pinna or leaflet on upper surface.

The pinnules towards the top run into each other

The forked Venation is evident.

Fig. 4. Pinnule from base of Pinna.

The Indusium may be found *closed* over the cluster of Sporangia, or *raised* on one side to allow the ripe spores to escape, or in some cases *burst*.

Fig. 5. Section of Pinnule through Ripe Sorus in Fig. 4.

Indusium arising from central swelling of vascular bundle, arching completely over clusters of Sporangia, and consisting of a single layer of nucleated cells in its expanded portions.

Sporangia in different stages of development, opened and unopened, full and empty of Spores. Some have longer or shorter stalks, with a stalked gland which is peculiar to the species, and there are several hair-like undeveloped Sporangia known as Paraphyses.

Fig. 6. The Sporangia may be rubbed off on a slide and examined in water. They can afterwards be burst by pressure on the cover-glass.

The Sporangium is an oval body borne by a short stalk. There is a ring of thick projecting cells extending from the cleft overhead, and backwards to the top of the stalk. The cells forming the slightly convex wall on either side are thin and easily ruptured.

Fig. 7. Spores.

The Spore has a thick, outer brown coat or Exosporium with irregular markings, and a thin, inner delicate coat or Endosporium.

Fig. 1. Development of Spore

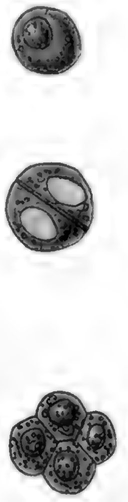

Fig 2. Germination of Spore

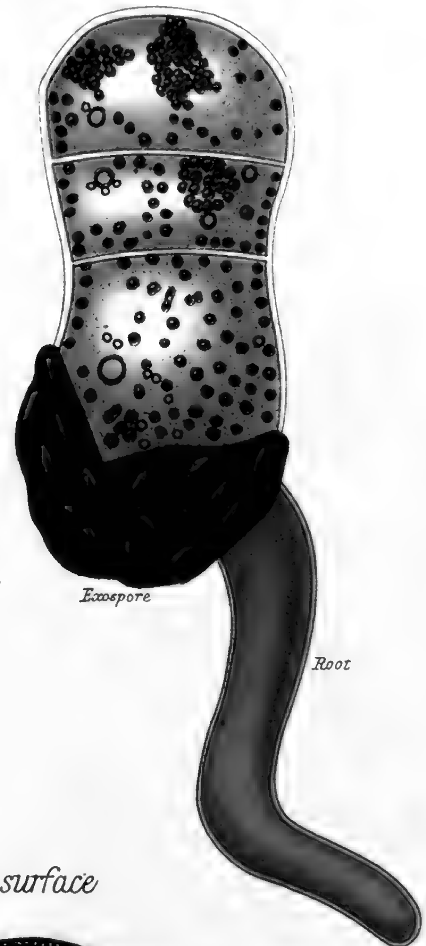

Fig. 7. Archegonium in Sectional Elevation & Plan

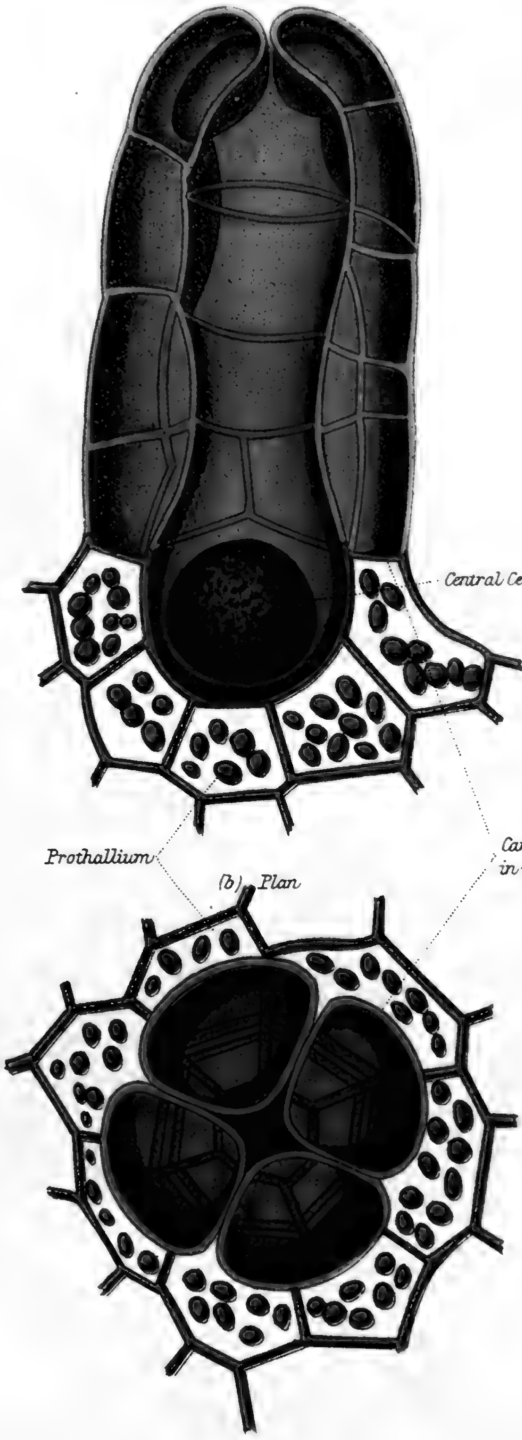

Fig. 3. Prothallium-under surface

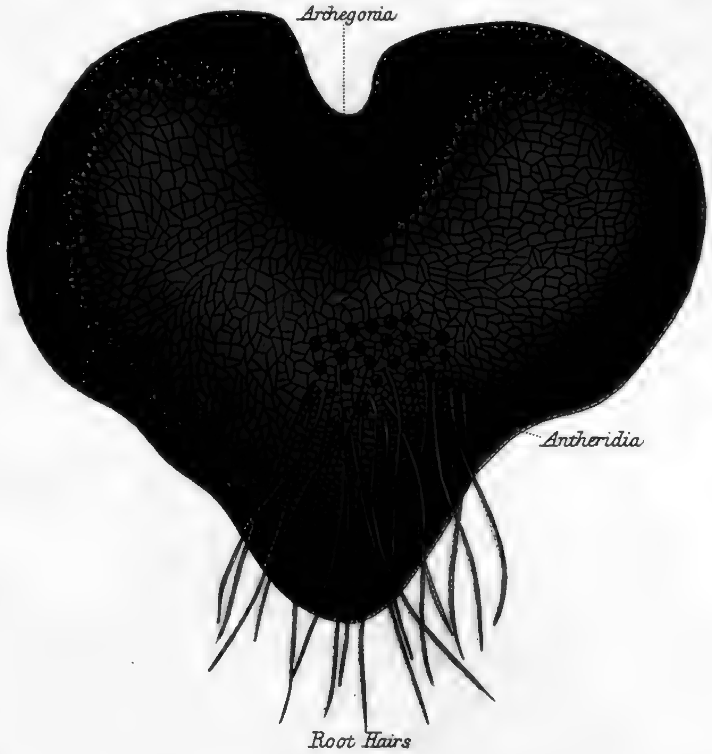

Fig. 6. Antherozoid

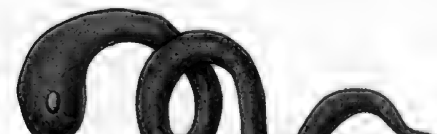

Fig. 4. Antheridium

Fig. 5. Mother-cell with Antherozoid

LIFE HISTORY DIAGRAM

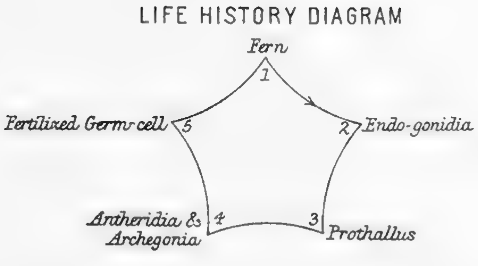

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PLATE XXIII.—MALE SHIELD FERN—*continued.*

Fig. 1. Development of Spores.

In each Sporangium a single central cell gives rise to sixteen mother-cells by successive division into 2, 4, 8, and 16.

Each mother-cell divides into four Spores, as shown. The cell-wall of each spore is differentiated into an inner and outer coat, as seen in Fig. 2, and chlorophyll is developed in the contents.

Fig. 2. Spore germinating.

With moisture the Spore swells, and the outer, firm Exosporium ruptures, while the inner, delicate Endosporium protrudes. As this grows a transverse septum is formed, and about the same time the lower cell gives forth the first rootlet.

Fig. 3. Prothallium.

The germinating Spore first produces a row of cells, then, by oblique division, a surface of cells, and finally the flat expansion of the Prothallium.

Male and female reproductive organs next arise on the under surface of the Prothallus.

Antheridia, or male organs, arise among the bases of the root-hairs, and Archegonia, or female organs, near to the notch.

Fig. 4. Antheridium.

The Antheridia are rounded projections, the contents of which break up into mother-cells, in each of which an Antherozoid is developed.

Fig. 5. The coiled-up Antherozoid is seen in the mother-cell.

Fig. 6. Antherozoid free.

Fig. 7. Archegonium.

The central or germ cell is the point which the Antherozoids must reach in order to produce fertilization. For this purpose there is a central canal open at the top, and bounded by four longitudinal rows of cells.

Life History Diagram.—The conspicuous Fern (1) developes Spores or Gonidia (2) on its under surface; and one of these germinating produces a Prothallium (3), afterwards producing male and female organs—Antheridia and Archegonia (4)—on its under surface; the central cell of the Archegonium becomes fertilized by the access of Antherozoids, and the Fertilized Germ-cell (5) developes into the Fern (1).

CLASSIFICATION.

Sub-kingdom.—Vascular Cryptogams.
True Roots.
Fibro-vascular bundles.
Prothallus bearing reproductive organs comparatively inconspicuous.

Class.—Filicinæ.
Stem usually unbranched.
Leaves large and compound.
Sporangia in clusters, and each sporangium developed from a single epidermal cell.
Spores of one or two kinds.

Order.—Filices.
Leaves without stipules.
Spores of one kind.
Prothallus independent and monœcious.

Genus.—Aspidium.

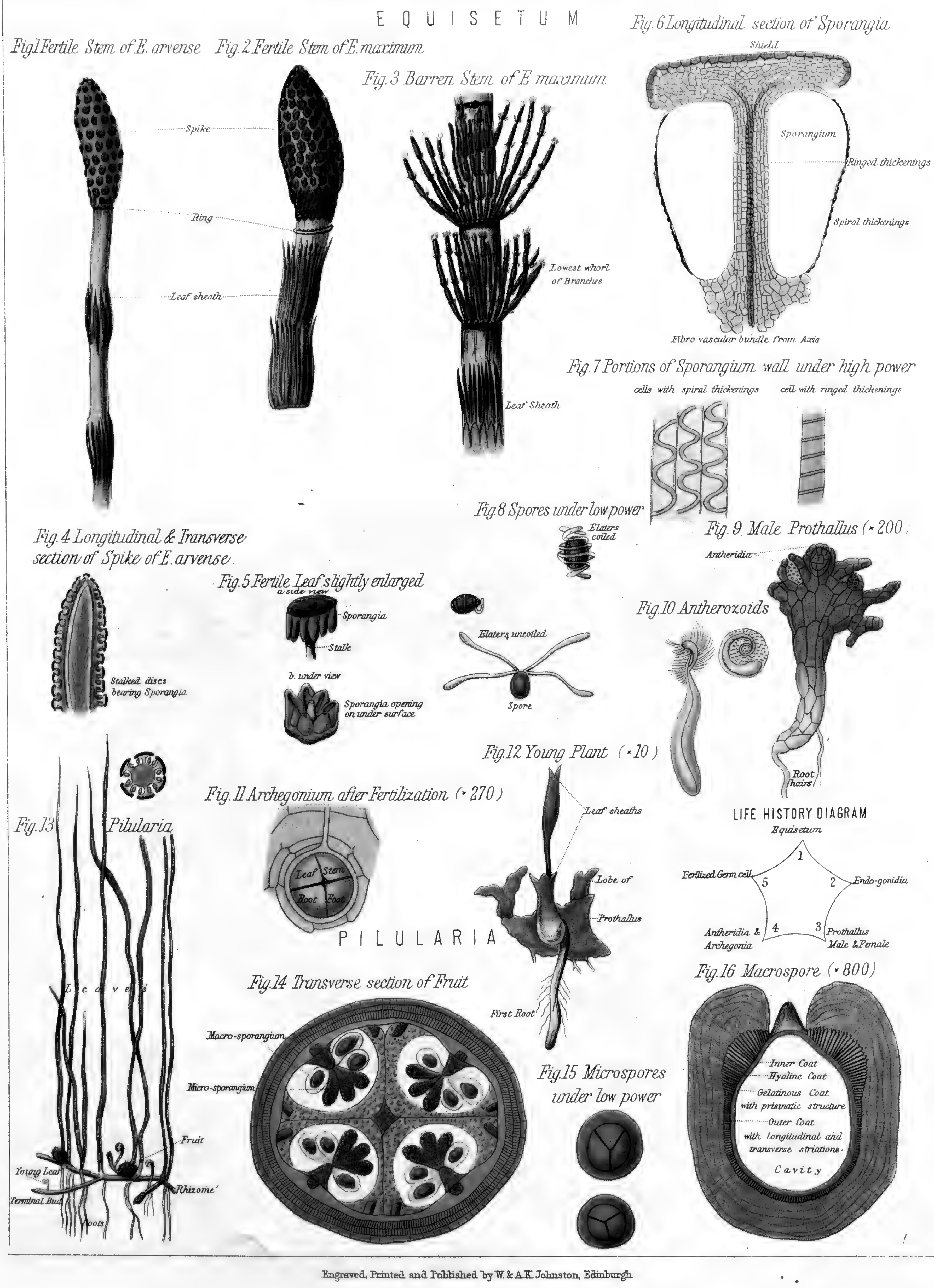

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PLATE XXIV.—COMMON HORSE-TAIL (Equisetum arvense), GREAT HORSE-TAIL (E. maximum) and PILLWORT (Pilularia globulifera).

Horse-tails belong to the smallest natural order among Vascular Cryptogams, there being but a single living genus and representative—*Equisetum.* They all inhabit marshy and damp places.

Gigantic forms existed during the Carboniferous period, such as the Calamites.

The Vegetative structures which these plants produce are extremely dissimilar—according as they are fertile or barren. The fertile shoots are formed in the spring, bear spores, have no chlorophyll, and usually do not branch. The barren shoots, on the other hand, which are relatively large, are formed later in the year, have abundance of chlorophyll, and branch freely, the numerous whorls of branches giving that peculiar appearance suggestive of a horse's tail. The business of the barren shoot is to nourish the plant; so during summer it manufactures and stores up nutriment in the underground stem, to enable it to send up a fertile shoot early next year.

The Underground Stem or Rhizome develops Roots at each of the nodes, and produces Buds which give rise to upright shoots. These buds are sometimes curiously shaped and swollen, being distended, particularly with starch, for the rapid early growth of the young shoot.

The Upright Shoot is a hollow cylinder, interrupted at the regularly recurring nodes by a transverse plate. This is a form of great mechanical strength, combined with lightness and economy of material. The outer surface is usually marked with ridges and furrows; and this roughness, along with the silica contained in the stem, sometimes renders them available for polishing purposes. The presence of silica may easily be shown by fusing a piece of the stem in the hottest part of the gas flame, when little beads of glass are produced.

The Branches are slender green filaments, given off at the nodes, and arranged in whorls. They repeat the structure of the stem in being jointed and possessing leaf-sheaths. They have this peculiarity, that although formed in the axils of leaves just like ordinary buds, yet instead of growing up between the leaf and the stem they burst through the base of the leaf-sheath.

The Leaves are the funnel-shaped sheaths investing the stem, inconspicuous in the barren shoot, more prominent and swollen in the fertile one. They are produced into longer or shorter teeth; the teeth of successive whorls not being placed above one another, but alternating.

The Modified Leaves of the fertile shoot form the shield-like structures of the spike. These little shield-like leaves are *homologous* with the leaf-sheaths, each appearing as a ring of tissue round the axis; the margins, in the one case, growing out into teeth or points, in the other, expanding into plates or shields.

Figs. 1 and 2. The Fertile shoot is clothed at regular intervals with leaf-sheaths, and at the apex is expanded into a club-shaped head covered with little stalked discs, arranged in whorls. Immediately beneath the spike is a wavy ring, representing a rudimentary leaf-sheath, just like bracts or modified leaves in the neighbourhood of a flower.

Fig. 3. The Barren shoot is seen to have leaf-sheaths closely embracing the stem, and whorls of branches bursting through their base.

Fig. 4. Make a longitudinal and transverse section of the Spike.

The modified fertile leaves of the spike are placed at right angles to it and arranged in whorls, each whorl supposed to correspond to a leaf-sheath, but instead of growing applied to the stem it grows at right angles to it. Successive whorls of leaves are closely pressed against each other, so that the discs assume a polygonal outline.

Fig. 5. Fertile leaf detached and examined.

It has a short stalk bearing its shield, from the under or inner surface of which sporangia containing spores are produced. The sporangia open towards the stalk by a longitudinal slit, and the greenish powdery spores readily escape.

Fig. 6. Embed young spike in paraffin, and cut transverse sections. Mount in glycerine, and examine under low power.

Each stalk contains a fibro-vascular bundle, which passes from the axis of the spike, and in the shield branches towards the insertion of each sporangium.

Sporangium wall formed of a single layer of cells.

Fig. 7. Examine portion of wall under high power.

Cells next to stalk with ring-like thickenings. These ringed cells burst longitudinally when the spores are ripe. Other cells of sporangium with spiral thickenings.

Fig. 8. Shake out some of the green spores on a slide and gently breathe upon them.

The Spores are round or somewhat egg-shaped bodies, averaging $\frac{1}{100}$ to $\frac{1}{500}$ inch in diameter, with bright green contents and spirally coiled Elaters.

Each spore is furnished with three membranes instead of two, and the outer membrane, as the spore ripens, splits up into ribbon-like strips which are the Elaters.

These Elaters uncoil as the moisture of the breath evaporates; and, by drying and moistening in this way, a perpetual motion can be kept up, which is so lively and jerky that it looks more like vital than purely physical action.

Fig. 9. The germinating spore produces a Prothallus, which may either bear Antheridia or Archegonia.

The Prothallus is irregularly lobed, and bears the Antheridia at the end of these lobes; while in the female Prothallus, the Archegonia are developed between the lobes.

Fig. 10. The Antherozoids are not much coiled, but very stout, and have a brush of cilia at the tapering end. They are the largest in the whole vegetable kingdom.

Fig. 11. Early development of the Embryo.

There is first division into two cells, the upper half representing the primary axis, the lower half representing the root portion. Each half is again divided into two cells, the upper two representing stem and leaf, the lower two forming root and foot. This foot is functionally the root of the young embryo, and is temporary, while the root proper is for the growing plant.

Fig. 12. Vertical section of lobe of Prothallus, with young plant. The young plant at this stage has its first root formed, and its leaf-bearing axis developing leaf-sheaths.

Life History Diagram.—The fertile branch of *Equisetum* produces its spike with the sporangia containing the spores. The spores, carried by their outspread elaters to a damp and shady spot, begin to germinate, producing either a Male Prothallus with Antheridia, or a Female Prothallus with Archegonia. The Antherozoids set free, fertilise the central cell of the Archegonium, thus producing an Embryo which grows up into the mature plant.

CLASSIFICATION OF EQUISETUM.

Sub-kingdom.—Vascular Cryptogams.
Order.—Equisetaceæ.
Upright stems, hollow and jointed.
Leaves, small, forming sheaths.
Fertile leaves, in whorls, forming a spike and bearing sporangia on inner surface.
Spores, of one kind, and furnished with Elaters.
Prothallus generally diœcious.

Genus.—Equisetum—the only genus.
Species.—Arvense—Leaf-sheaths of fertile stem, loose and distant.
Maximum—Leaf-sheaths of fertile stem, large, loose, and close together.
Difference from Ferns.—In Ferns, the fertile leaves bearing the sporangia are not usually confined to any particular part, and they act both as ordinary green leaves and as spore-carriers. In Equisetum, different stems are produced at different seasons of the year for these two purposes. The Barren stems are green, and their sole work is to store up nutriment in the underground stem. The Fertile stems do nothing towards their own support, but use up the accumulated nourishment, in order to produce the spores.

The majority of Ferns, too, produce Antheridia and Archegonia on the same prothallus; whereas in Equisetum the two are kept separate, the male prothallus being smaller than the female.

Pilularia—Fructification.

Pillwort occurs by the margins of lakes or ponds, or in badly drained places. It has a wiry, creeping rhizome, which gives off roots on the under surface, narrow stiff leaves on the upper surface, and terminates in a growing bud. Little pill-like bodies occur towards the autumn, at the base of several of the leaves, either at or beneath the surface, and these are the Fruits. These fruits contain spores of two kinds—Micro-spores or Male spores, and Macro-spores or Female spores. No male prothallus is formed, and only a small female prothallus with a single Archegonium.

Fig. 13. Rhizome, slender and creeping, ending in a terminal bud.
Roots, from under surface.
Leaves, in two rows, youngest always nearest the growing point.
Fruits, at the base of the leaves.

Fig. 14. Embed Fruit in paraffin and make sections.

Fruit consisting of four segments, supposed to be modified leaves joined edge to edge, the midrib represented by central fibro-vascular bundle in each.

Each segment with three fibro-vascular bundles, the middle one forming the core of a projecting cushion on which the spore-cases are produced.

Sporangia borne on the inner surface of modified leaves arranged in a whorl, containing Microspores and Macrospores.

Fig. 15. Microspores examined under low power—average size about $\frac{1}{800}$ inch in diameter.

The Microspore forms no male prothallus, but its contents break up directly into Antherozoids. The tri-radiate markings show the lines along which the spore splits to allow the escape of the Antherozoids.

Fig. 16. Macrospore examined under high power.

Contents.—Cavity filled with nutritious substances, such as starch and oil globules.
Investments.—Four coats of varying quality, formed in succession from within outwards.
Inner coat, compact, the first formed coat.
Hyaline coat, forming papilla at apex.
Third coat, with radiating structure.
Outer gelatinous coat, with concentric and radiating structure. This outer coat swells up with water.

LYCOPOD AND SELAGINELLA

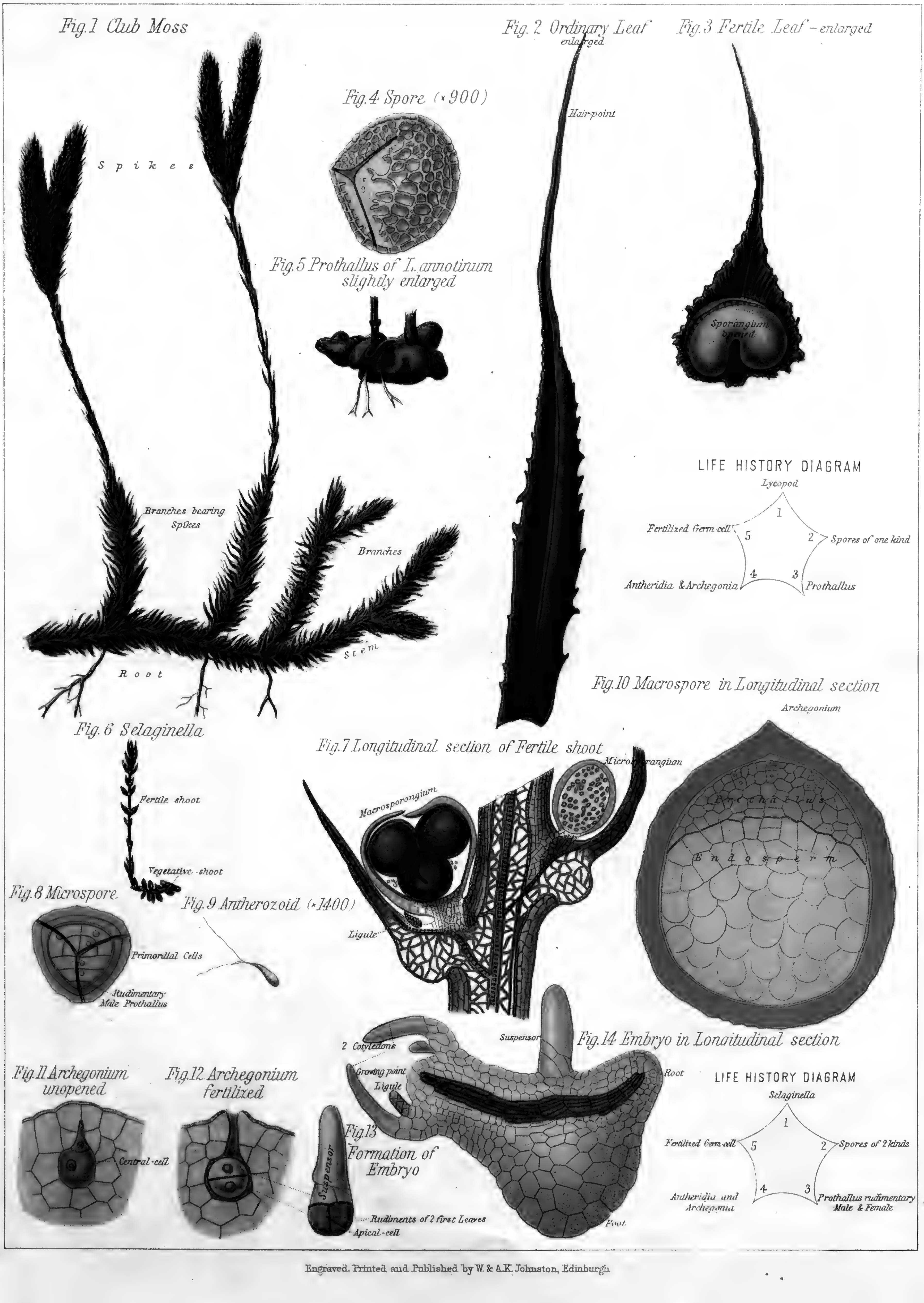

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PLATE XXV.—COMMON CLUB-MOSS (Lycopodium clavatum) and Selaginella.

(*Chiefly from Luerssen's "Medicinisch-Pharmaceutische Botanik."*)

Lycopodium.

Club-mosses, as the common name denotes, are moss-like plants, having slender herbaceous stems, clothed with delicate small leaves, and found in mountainous situations or stony, wet places.

The fossil forms of the Carboniferous period, of which Lepidodendron is the most characteristic, instead of being herbaceous, were large trees.

The prostrate creeping Stem is very leafy, and much branched. From the under surface arise the roots, and from the upper surface the upright fertile shoots, ending generally in two fertile spikes.

The Leaves are hair-pointed, and arranged in a close spiral round the stem.

The Modified Leaves bearing the sporangia are shorter and broader than the ordinary leaves, though sometimes they are quite the same.

The numerous minute spores (Fig. 4) are applied to various uses. They contain a quantity of resinous matter, and their wall is of a greasy nature. This resinous quality renders them readily combustible, hence they are used as "vegetable sulphur" for producing an artificial and sudden flame to represent lightning at theatres, and their greasy coat has caused them to be used for dusting over pills, thus preventing the contained pill from touching the tongue.

Fig. 1. Creeping Stem branches dichotomously, and also the Roots.
Leaves thickly set round the stem.
Spikes usually in pairs, mounted on a stalk.

Fig. 2. Leaf one-nerved and irregularly toothed, with a long hair-point variable in length.

Fig. 3. Fertile leaf bearing Sporangium at its base on the upper surface. Sporangium kidney-shaped, splitting into two valves, and producing only one kind of spore.

Fig. 4. Spore with netted markings fading away towards apex.
Three converging ridges, along which exospore ruptures.

Fig. 5. Prothallus of Lycopodium, discovered by Fankhauser in the autumn of 1872.
It is an underground solid structure, without chlorophyll, pretty smooth on the under surface, but deeply grooved on the upper. Antheridia and Archegonia are developed in the grooves.

Life History Diagram.—The discovery of the Prothallus shows that the Lycopod, in its reproductive processes, is more nearly allied to Ferns, such as Adder's Tongue (*Ophioglossum*), than to Selaginella, beside which its vegetative characters seemed to place it.

The fertile leaves of the spike bear sporangia on their inner base, the spores of which are of one kind. The spore on germination produces a prothallus, underground, solid, without chlorophyll, independent of the spore, and with Antheridia and Archegonia. The embryo resulting from fertilization forms a foot embedded in the tissue of the prothallus, and grows up into the young plant.

CLASSIFICATION OF LYCOPODIUM.

Sub-kingdom.—Vascular Cryptogams.
Class.—Dichotomæ.
Stem and Roots branching dichotomously.
Leaves small and simple.
Sporangia solitary.
Spores of one or two kinds.
Order.—Lycopodiaceæ.
Leaves without a ligule.
Spores of one kind.
Prothallus large and independent.
Genus.—Lycopodium, only British genus.
Species.—Clavatum.
Spikes usually in pairs, long-stalked.

Selaginella.

Selaginella, with only one British species, the lesser Club-moss, has a special interest from the fact that it not only belongs to the highest group of Cryptogams, but that it shows a gradual passage from the reproductive processes characteristic of Cryptogams to those of Phanerogams. It is this phase of its character which will receive special attention now.

The Reproductive Structures are of two kinds, and, generally speaking, the Macrosporangia are only produced on the lower leaves, and Microsporangia on the upper. In Pilularia, Sporangia of two kinds were produced, springing in tufts from the inner (or upper) surface of four modified leaves arranged in a whorl, but here they spring singly and separately from the upper surface of leaves arranged spirally. In the one case the leaves were all at one level, united at their edges, and *enclosing* the Sporangia, here the leaves are drawn out into a spiral, and bear the Sporangia without enclosing them.

The developing Embryo (as in Fig. 14) will show the points of contact with higher plants. For the first time there appears in the spore, along with the female prothallus, yet distinct from it, a mass of cells which supply nutriment to the young and growing embryo. This is the *Endosperm* of higher plants. Further, the embryo as soon as it forms the rudiments of the stem bearing its two first leaves, or *Cotyledons*, gives rise to a *Suspensor*, as in higher plants.

Fig. 6. Specimens may readily be obtained from hothouses, where they are grown on damp spots for their beautiful and delicate foliage.
Leaves on creeping stem in two lateral rows and two dorsal rows. Those of the upper surface, or dorsal row, are relatively smaller than those of the lateral row.
Upright Fertile Spike, with similar leaves arranged spirally, and bearing sporangia in their axils.

Fig. 7. Embed portion of fertile spike in paraffin and make longitudinal section.
Fibro-vascular bundle in centre of axis, united with those going to leaves.
Air-spaces surrounding fibro-vascular bundles, the interspaces composed of numerous green, branching cell-filaments.
Outer cells colourless.
Leaf with membraneous Ligule at its base, and bearing a Macrosporangium in its axil.
Leaf on opposite side bearing Microsporangium in its axil.
Microsporangium containing numerous small spores—the Microspores.
Macrosporangium, the largest, containing four Macrospores arranged like a tetrahedron, and several aborted mother-cells of spores.

Fig. 8. Microspore rendered transparent to show internal division.

The contents break up into cells, one of which does not form Antherozoids, and may therefore be regarded as a rudimentary Male Prothallus.

Fig. 9. Macrospore six weeks after escaping from sporangium, and before rupture of the exospore.

Prothallus rudimentary, within the spore, bearing Archegonia.

Endosperm, loose cellular tissue formed by free cell-formation, *i.e.* a grouping of masses of protoplasm around small internal centres, and forming cell-walls about them, independent of prothallus, but supplying nourishment to it.

Figs. 10 and 11. Archegonium before and after fertilization.

The neck of the Archegonium is at first closed, but afterwards opens to give access to the Antherozoids.

The central cell after fertilization divides first into two—one half further dividing and giving rise to stem and leaves, the other half also dividing and forming Suspensor.

Fig. 12. Embryo still within the spore.

The Suspensor is a temporary structure, and there are no indications of the root so long as it lasts, but when it withers away the end of the embryo in connection with it forms the root.

The Foot is always embedded in the Endosperm, serving as a means of connection between the embryo and its early food-supplies.

Life History Diagram.—The upright fertile shoot bears the sporangia in the axils of its leaves—either Micro- or Macro- sporangia. The Microspore divides internally into antheridial cells, all but one barren basal cell, which represents a Male Prothallus. The Macrospore forms an internal Prothallus bearing Archegonia, and the rest of the spore is filled with Endosperm for food-supplies. The Archegonia are exposed by the rupturing of the wall of the spore, and the Antherozoids liberated from the Microspore fertilize the central cell. The Embryo thus formed is at first provided with a Suspensor, and grows right down into the Endosperm living at its expense; but by and by the Suspensor withers, the root appears, the growing point begins to turn round, and the line of growth becomes horizontal, as in Fig. 12. Finally, the stem and root structures assume their upright and downright positions, and the young plant emerges from the spore near the point where its development began.

CLASSIFICATION OF SELAGINELLA.

Sub-kingdom.—Vascular Cryptogams.
Class.—Dichotomæ.
Order.—Ligulatæ.
Leaves ligulate.
Spores of two kinds—Microspores and Macrospores.
Family.—Selaginelleæ.
Stem long and leaves short.
Prothallus small, male and female, confined to the spore.
Genus.—Selaginella—the only genus.

Advance in Organization.—There are two distinct kinds of Sporangia—the Microsporangia, producing Microspores and the Macrosporangia, producing Macrospores.

The Microspore produces the smallest possible Male Prothallus in the interior of the spore, and not outside, as usual.

The Macrospore also developes an internal Female Prothallus, only protruding slightly when the exospore ruptures.

Endosperm is present, as in the seed of higher plants.

Embryo provided with Suspensor and two Cotyledons, as in higher plants.

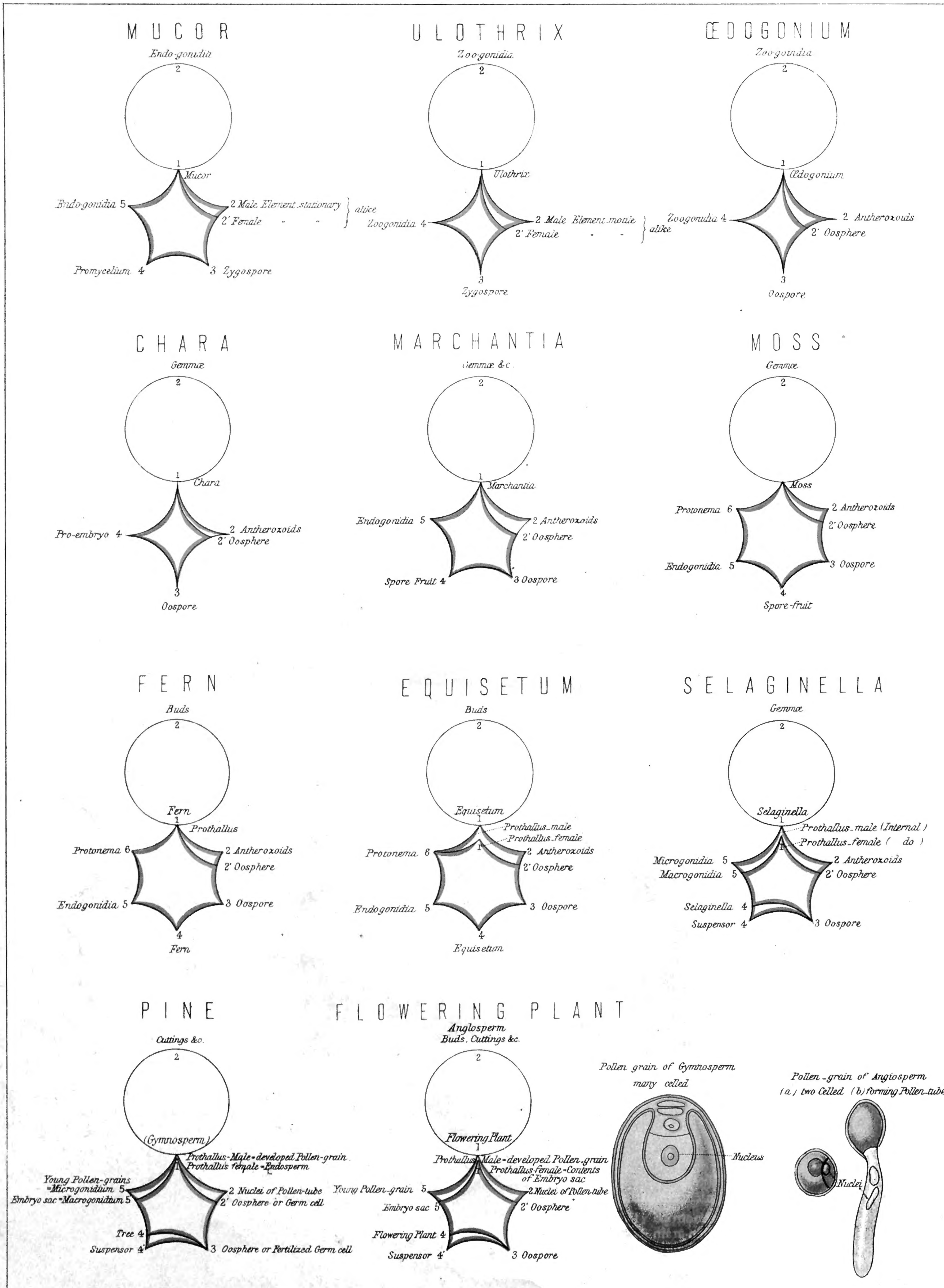

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PLATE XXVI—SEXUAL PROCESS TRACED FROM MOULD TO FLOWERING PLANT.

In dealing with the life histories of organisms, it has already been shown that the simplest form of the sexual process obtains in Mucor. A bud from one hypha grows out to meet a bud from another hypha, and some mysterious attraction brings them together. The ends of the two blend and become parted off to form a single body, which is thus the result of a process of Conjugation. In Ulothrix, likewise, the sexual process is, if possible, simpler. The contents of a cell, instead of growing out, breaks up into small particles, which round themselves off and acquire two cilia, by means of which they move about. When free in the water two moving particles from different cells meet and blend to form one body, as in Mucor.

These two forms may be taken as starting-points for tracing the sexual process in plants; the one representing the condition where the conjugating elements are passive and the plant is without chlorophyll, the other where the conjugating elements are active and the plant possesses chlorophyll.

It will not be necessary to go over each life history in detail, for that has been done to a certain extent already, but simply to point out the changes taking plâce, both in the sexual elements themselves and in their mode of blending, in passing from the lowest to the highest term of the series. It will be convenient to distinguish two principal stages in the life history of each plant—a stage with sexual organs called the *Sexual Generation*, and a stage with no sexual organs called the *Non-sexual Generation.* The Sexual Generation opens the chapter, and a return to that ends it. On glancing over the Diagrams it will be seen that the Sexual Generation is gradually suppressed, until in the Flowering Plant it is microscopic in its dimensions, and reduced to a few cells, while the Non-sexual Generation grows in importance, becoming the stately tree or the conspicuous flowering plant.

Note.—In this comparative view the term *Spore* is used in a different sense from that in the body of the work. In the lower forms it is a cell resulting from a sexual process, viz. Zygospore or Oospore, and it is restricted to that throughout the series. Other cells which multiply the plant are *Gonidia*, although from Liverwort onwards they are usually called Spores.

MUCOR.—The *Sexual Generation* is the conspicuous mould, producing the similar and stationary male and female elements, which blend to form a Zygospore.

The *Non-sexual Generation* is the inconspicuous Pro-mycelium, consisting of a single hypha, which produces Endo-gonidia, from the germination of which Mucor is reproduced.

ULOTHRIX.—The *Sexual Generation* is the filamentous Alga, producing similar and motile male and female elements, which blend to form a Zygospore.

The *Non-sexual Generation* is the Zoogonidia, derived directly from the internal division of the Zygospore, and reproducing the filament.

OEDOGONIUM.—The *Sexual Generation* is the filamentous Alga, producing no longer sexual elements which are alike or nearly so, but now clearly distinguishable—Antherozoids and Oospheres—the Oosphere becoming converted into an Oospore by the impregnation of the Antherozoids.

The *Non-sexual Generation* is similar to that of Ulothrix.

CHARA.—The *Sexual Generation* is the plant with whorled appendages, producing Antherozoids and Oospheres, from which result Oospores.

The *Non-sexual Generation* is the Pro-embryo, which gives rise to a bud producing the plant.

MARCHANTIA.—The *Sexual Generation* is the conspicuous green expansion, producing Antherozoids on the male plant, and Oospheres on the female plant. The Oosphere, or central cell of the Archegonium, is impregnated by Antherozoids, and converted into an Oospore.

The *Non-sexual Generation* is the Spore-fruit, producing Endo-gonidia, from the germination of which Marchantia is produced.

MOSS.—Similar to Marchantia, only in the Non-sexual Generation the germinating Endogonidium does not directly produce the Moss, but a Protonema is formed, from which a lateral bud arises and grows into the plant.

FERN.—The *Sexual Generation* is the Prothallus, a minute, green, heart-shaped expansion, corresponding to the leafy Moss. This produces Antherozoids and Oospheres, which latterly become Oospores.

The *Non-sexual Generation* is the Fern, corresponding to the Spore-fruit of the Moss. This developes Endo-gonidia, each of which produces on germination a Protonema. The Protonema is a row of green cells, often branched like that of the Moss, and afterwards developing into the Prothallus.

EQUISETUM.—The *Sexual Generation* is the Prothallus, male and female distinct.

The *Non-sexual Generation* is the Equisetum, the fertile shoots of which repeat the history of the Fern.

SELAGINELLA.—The *Sexual Generation* is the Prothallus, male and female distinct and internal.

The *Non-sexual Generation* is the Selaginella, which has in its embryonic condition a special structure called the Suspensor.

PINE.—The *Sexual Generation* is represented by the Male Prothallus, or cells forming the full-grown Pollen-grain, and the Female Prothallus, or Endosperm.

The Male Prothallus is exceedingly simplified. There is only one or a few cells to represent the vegetative part, and a single large cell to represent the antheridial part, or the part which formerly produced Antherozoids. The production of Antherozoids was suitable for plants living in moist situations; but as Conifers live in dry situations, Antherozoids would fail of their purpose, and the nuclei do not develope cilia for locomotion. So the representative of the antheridial cell puts forth a pollen-tube, along which the nuclei are conveyed to their destination, viz. the germ-cell.

The Female Prothallus is represented by the Endosperm, in which the germ-cells are developed.

The *Non-sexual Generation* is the tree quite comparable with Selaginella, the Embryo-sac corresponding to the Macrogonidium, and the young Pollen-grain to the Microgonidium.

FLOWERING PLANT.—The *Sexual Generation* is the Male Prothallus, or cells forming the mature Pollen-grain, and the Female Prothallus, or contents of Embryo-sac.

The *Non-sexual Generation* is the conspicuous Flowering Plant, producing Pollen-grains and Embryo-sac. The modified leaves of the Flower—Stamens and Carpels—which produce Pollen-grains and Embryo-sacs are usually called Sexual Organs; but they are really equivalent to the fertile leaves of Selaginella, the Pollen-grains being Micro-gonidia in Pollen-sacs, and the Embryo-sacs being Macro-gonidia in Ovules. Cells are afterwards developed in the interior of Pollen-grain and Embryo-sac, which represent the Sexual Generation.

MULTIPLICATION takes place in each case by a smaller or larger portion of the plant detaching itself and growing to the size and form of the parent. The directness and simplicity of this process are evident in the highest as well as in the lowest forms.

Fig. 1. Pollen-grain of Larch consisting of several cells.

Fig. 2. Pollen-grain of Monotropa (Dicotyledon).
(*a.*) Young Pollen-grain consisting of two nucleated cells.
(*b.*) Pollen-tube formed containing the two nuclei.

INDEX TO ILLUSTRATIONS—FOR COMPARATIVE STUDY.