Chapter XVIII.

CRYPTOGAMS.

The preceding pages on Phanerogams have treated of plants in their most conspicuous and highly specialized forms. There is another equally great series of plants - the Cryptogams - which should also be studied if we would form a broad conception of plants and plant-life.

The Cryptogams are the lower series of plants. They are of simpler structure than the Phanerogams; that is, the complete plant consists of fewer kinds of organs than is the case with a Phanerogam. The simpler structure of Cryptogams must not be understood as implying fewer functions; for all the functions of any plant - no matter how simple or how complex in structure may be the plant - but enable it to obtain and use food and to perpetuate its kind. In the Phanerogams there are many organs and a corresponding division of labor: thus the petals by their bright colors and secretion of nectar enlist insects in carrying pollen from plant to plant; the root hairs absorb the crude sap; and the leaves have the foliage function of manufacturing ~~the~~ crude sap into the elaborated form. As we trace back in Cryptogams towards the simpler and more primitive forms of plant life, we shall find a steady decrease in the number of organs or kinds of parts to each plant but a more general range of work uses for each part until, finally, in the simplest plants of all, the whole plant will be found but a single cell, absorbing and ~~elaboratin~~ assimilating food and reproducing its kind.

stet ~~Although Cryptogams are of simpler structure than Phanerogams, yet the transition from Phanerogams to Cryptogams is so very gradual~~ that ~~as to make~~ it is ~~less easy than it would seem to draw an exact line between the two series of plants.~~ The production of flowers affords a character which easily and conveniently separates Phanerogams with conspicuous flowers from the simpler Cryptogams but which perplexes the student who compares the floral structure of the pine, a Phanerogam ~~Cryptogam,~~ with those of such Higher Cryptogams as the equisetum and club moss. The best character separating Phanerogams from ~~from~~ Cryptogams is the production of seeds by the former. Phanerogams grow from seeds, formed in flowers; Cryptogams ~~Cryptogams~~ grow from spores, which are not produced in flowers except in a few of the highest Cryptogams.

Flowers of Phanerogams are clusters of modified leaves adapted to produce seeds. They accomplish this end by forming ~~producing~~, and then bringing about the union of, two cells, known as the generative cell of the pollen tube and the oosphere of the ovule. (Fig. 371). The cell formed by this

{Insert Fig. 371 here}

union is called an oospore. The oospore remains in the embryo sac of the ovule, grows, divides, and differentiates into a mass of cells, called the embryo of the seed. A young embryo is shown in Fig. 372. During the ~~whole~~ period of its

{Insert Fig. 372, made for Mr. Leavitt's part, here also.}

development from oospore to ~~until~~ maturity of the seed, the embryo is nourished by the parent plant.

The embryo may lie dormant in the mature seed for perhaps many years, able to go on with its ~~further~~ later growth and development when the conditions become favorable. The development of a phanerogamic plant from the oospore is therefore not continuous but consists of two stages of growth: the first of these includes the development of the embryo up to the ripening of the seed and while inclosed in the seed coats, and the second, all the later growth which follows sowing the seed and includes the escape of the embryo from the seed and its development into the adult plant. The ability of the embryo of a Phanerogam to cease growth and remain dormant without injury for years in the seed and then vigorously resume its growth under favorable conditions is a remarkable character of the seed.

The Cryptogams also have organs which produce reproductive cells and facilitate the union into one cell of two such reproductive cells or elements. The resulting cell is a spore - sometimes an oospore, as in Phanerogams - but it does not pass through the stage of a seed in its development. Its small store of food is exhausted in early stages of germination; if it develops further, it is through its own ability to obtain food and maintain itself from the first, making continuous growth.

Spore is a general term for any cell specialized to reproduce its own kind of organism. Spores of several Cryptogams are shown highly magnified in Figs. 373-376 . The puff of dust from a puff-ball consists of spores mostly; pollen grains are spores.

[Insert Figs. 373 – 376 here.]

Spores are simple, when ~~unicellular~~ one-celled, as in Figs. ~~501~~ and ~~502~~; or multilocular, when two-celled to many-celled, as in Figs. ~~503~~ and ~~504~~. In multilocular spores each cell germinates independently.

The Cryptogams are a large and varied assemblage of plants, ranging from stately ferns down to minute bacteria. They form three natural groups: Pteridophytes (ferns and their allies), Bryophytes (mosses and hepatics), Thallophytes (lichens, fungi, and algae). These groups grade into one another, yet the typical plants of each differ so profoundly froh those of the other groups that each group may be most advantageously studied by itself, as the Phanerogams have been studied.

It is the author's aim that the following pages shall treat not only of the general facts pertaining to Cryptogams but shall also enable the student to know some of the more typical Cryptogams to be seen about one in nature and to attain some knowledge of the relationships and probable nature of others in which he may become interested. The more usual scientific terms have been employed instead of round about expressions, because of the great value in future reading of such terms as may be retained by the student as a part of his permanent vocabulary.

~~Thallophytes (lichens, fungi, and algae).~~

~~Section II.~~ PTERIDOPHYTES.

Roman

Bold-face → **The Pteridophytes** (from *Pteris*, a fern) comprise Ferns, Equisetums, Club Mosses, Selaginellas, Azollas, etc. They are sometimes called the Vascular Cryptogams, because they are the ~~lowest plants~~ only Cryptogams in which vascular bundles, which made possible the higher types of stem culminating in familiar treesof great height with trunks of enormous rigidity and strength, appear in other than a rudimentary condition. Pteridophytes are the lowest plants with true roots.

Pteridophytes exhibit in their life history a regular *alternation of generations* , known as the gametophytic and sporophytic generations or, more briefly, as gametophyte and sporophyte. These generations are different from each other in appearance and structure and each produces its characteristic spores. The ~~spores of the gametophyte arise each~~ gametophytic generation produces its characteristic spores by the fusing together of two cells to form one cell, that is by a sexual process; ~~those of the sporophyte are produced~~ the sporophyte produces its spores asexually.

The spores of the ~~sporophyte~~ gametophyte give rise to the ~~gametophyte~~ sporophyte - never to the gametophyte, and ~~those~~ the spores of the sporophyte give rise in turn to the gametophyte. The order of generations is therefore as follows:

Gametophyte, *oospore*, sporophyte, *spore*, gametophyte, and so on.

For a more detailed account of the life history of a Pteridophyte, a fern may be studied to best advantage.

Ferns. If the under surface of the leaves of almost any of our native ferns is examined in midsummer, some leaves will be found to bear small clusters of somewhat spherical or pear-shaped brown objects each attached to the surface of the leaf (Figs. 377, 378). Each of the brown objects is a spore-case, called ~~or spore case~~ sporangium (Figs. 379, 383); the cluster of sporangia is a sorus (Fig. 378); the spores are loose cells in the interior of the sporangia, each spore consisting of a nucleated mass of protoplasm surrounded by a cell wall (Fig. 373).

[Insert here Figs. 501 - 508 of Gray's Lessons but with numbering of Figures and their explanation changed as noted] The numbers, as changed, are 377 - 384

Gametophytic generation. The spores from the sporangia germinate readily on moist earth if the conditions are kept favorable for a few days, and by further growth form a many-celled, somewhat heart-shaped plant, called a prothallium (Figs. 385, 386)

[Insert here Figs. 385 & 386, and also Fig 510 of Gray's Lessons but with its number changed to 387]

italics The prothallia are thin leaf-like plates 3 - 8 mm. in diameter, green colored, glabrous on the upper surface but with the under surface closely attached to the earth by numerous unicellular absorptive hairs, termed rhizoids (r, Figs. 514, 515), which penetrate the earth for food supplies.

The prothallium bears also on its under surface two kinds of reproductive organs, antheridia and archegonia. The archegonia are situated near the sinus, or notch, on the thick portion of the prothallium, somewhat buried in its tissue but with their slender necks protruding. The antheridia are shorter and superficial in position, many having place between the rhizoids (Figs. 386, 387).

italics The archegonium is shown in thin cross sections of the prothallium ~~show the mature archegonium to be~~ as a flask-shaped organ (Fig. 388), having a wall a single layer of cells thick and containing in the interior of the flask-shaped portion a large central cell (o), the oosphere. A canal (n) filled with mucilaginous matter extends from the oosphere lengthways through the middle of the neck to the exterior. In Fig. 389, a younger stage of the archegonium is represented with the canal cells n and v not yet completely disorganized and changed to mucilage, and with the canal closed at the apex.

[Insert Figs. 388 & 389 here]

Italics

The *antheridium* also has a wall one layer of cells thick and contains a central mother-cell whose contents divide and differentiate into spermatozoids (Figs. 390, 391). In ordinary preparations and under magnification of 300 to 400 diameters, the spermatozoids as seen in the antheridia are small, spherical, colorless objects of about the same size as the starch grains which occur in vegetative cells of the prothallium in the same sections. The living and fully mature spermatozoids are, however, elongated, ciliated, motile cells having the form shown in Fig. 392.

[Insert Figs. 390, 391, 392]

Italics

Union of Spermatozoid and Oosphere. When the surface of the prothallium is covered by a film of water, as by dew or rain, the spermatozoids escape from the antheridium and swim about in the water by movement of their cilia. Coming incontact with the mucilaginous matter protruding from the necks of the mature archegonia, they make their way down through this substance to the oosphere; one of the spermatazoids fuses with the oosphere, and the two cells become a single cell, called the oospore, their two nuclei fusing into a single nucleus.

The union of the spermatozoid with the oosphere (egg cell) to form the oospore is the sexual process, called fertilization. ~~It marks the close of the gametophytic, or sexual, generation of the fern plant.~~

Sporophytic generation. The oospore germinates at once, while in the archegonium and imbedded in the prothallium. In germinating it divides into two cells, these divide giving four, and these again, giving eight. Of these cells two give rise to the first leaf, one to the growing point of the stem, one diametrically opposite this to the primary root, and two others develop into a mass of cells called the foot. The *foot* attaches the embryo fern plant to the tissue of the prothallium and absorbs food from the latter until the young plant is firmly established in the earth and capable of independent existence. A very young fern plant is drawn attached to the prothallium in Fig. 393.

{Insert Fig 393 here}

Italics The *stem* of a fern may grow upward and become a trunk, as in the Tree-Ferns of the tropics (Fig. 394) and in many ferns of former geological ages, or it may remain underground, forming a perennial rootstock from which leaves are thrown up annually, as in our native ferns of the north (Fig. 395).

{Insert Figs. 394 & 395 here}

Italics A *primary root* is formed in Pteridophytes in ferns and equisetums only, but it is short lived. During the adult stage of these plants , only adventitious roots are present. Allthe roots are adventitious in the other families.

Italics The *leaves* of ferns are called *fronds* in systematic botany, this term having become extensively used in older works, but they are strictly homologous with leaves of Phanerogams, have essentially the same internal structure (Fig. 396) as the latter, and are covered by an epidermis which contains stomata on the under side..

Italics *Fertile leaves*, or *sporophylls*, are the leaves bearing sporangia. such leaves may closely resemble foliage leaves of the same plant, as in the Maiden-hair Fern and most of our native ferns, or they may differ from them greatly in size, form, and color, as in Osmunda, where they are much reduced in size and bear large sporangia on their margins.

Italics A *sorus* is a cluster of sporangia having a common origin(Fig. 378).

In ferns the sori have form and arrangement characteristic of the different genera, as in rows or lines oneach side of the midrib, on the veins, or near the margins.

An *indusium* is a covering for the sorus. It is formed by an overgrowth from the surface of the leaf, as in Fig. 378, or from the margin of the leaf, as shown in section in Fig. 396.

{Insert Figs. 396 & 397 here}

The *sporangium* or spore-case contains the spores, and with them arises from a superficial cell of the leaf. It has a wall a single layer of cells thick. Its dehiscence for scattering the spores is caused by an elastic ring. In the subfamily Polypodiaceae, comprising the largest number and most familiar species of our ferns, the ring consists of a row of cells with thickened inner and radial walls, which extends from the stalk up the dorsal side of the sporangium, over its outer end and down its ventral side half way to the stalk again. Upon evaporation of water from its cells, their outer walls of bend inward and the ring tends to straighten forcibly, and in so doing tears the sporangium open transversely between the ring and the stalk, ejecting the spores (Fig. 397).

Other methods of propagation. The general life history of ferns, as given above, may be shortened in rare instances by apogamy and apospory, which can not be taken up here. Each generation very commonly has special means for directly increasing the number of individuals of its own generation. For example, the prothallium may form branches which, becoming separated, become independent prothallia, or it may throw off plate-like masses of cells, called gemmae, which develop into prothallia. So also the sporophyte may produce its generation directly, as by the tips of its leaves striking root and forming new plants, as in the beautiful Walking-Fern, Camptosorus, (Fig. 377, or by the separation of the rootstock into parts, each of which becomes an independent plant.

Other families of Pteridophytes. – The Sporophyte. It should be kept in mind in the following account that what we commonly call a Fern, Club-moss, Equisetum, or Isoetes is merely its sporophytic generation.

The Equisetums, also called horse-tails and scouring rushes, (Figs. 398 – 401) are rush-like, often branching, plants with jointed and mostly hollow stems from running root stocks. The leaves are scale-like and arranged in sheathing whorls at the nodes. The stems are abundantly supplied with chlorophyll and stomata and have the function of foliage. The sporophylls, bearing sporangia on their under surface, are peltate in form and are aggregated in whorls at the tips of the fertile shoots into a cone (Figs. 398 – 400), sometimes called a flower from its correspondence to the staminate flower of the pine.

[Insert Figs. 398 – 401 here]

The Lycopodiums, also called club-moss and ground-pine, are low plants with creeping rope-like stems, thickly clothed with scale-like leaves (Fig. 401). These plants are the evergreens largely used for Christmas wreaths and other decorations. The sporophylls (fertile leaves) are aggregated at the ends of the fertile shoots in cone-like flowers (Figs. 402, 403).

Selaginella greatly resembles Lycopodium in general habit although some species have the leaves more loosely arranged. The sporophylls (Fig. 404) are borne in cone-like flowers at the ends of the fertile branches. Two kinds of spores, called macrospores (Figs. 405, 406) and microspores, are produced.

[Insert Figs. 511 – 519 of Gray's Lessons here, but with numbers changed as indicated, to 402 – 410]

The species of Isoetes are small plants grass-like or rush-like in aspect (Fig. 407). They are widely distributed in N. America, living some wholly submerged in water, others submerged during a part of the time, and a few others in marshy soil. They have a short corm-like stem, bearing a cluster of roots on its under side, above it is covered by the broad bases of a cluster of awl-shaped or rush-like leaves. The sporangia are immersed in the bases of the leaves (Figs. 408 - 410). Those of the outer leaves contain each several macrospores (Fig. 410); those of fertile inner leaves, innumerable very minute microspores (Fig. 409).

Marsilia and Azolla are other aquatic Pteridophytes for accounts of which reference may be made to the Manual.

Spores of the sporophyte. Only one kind of spore is produced in the sporangia of Ferns, Lycopodiums, and Equisetums. In the Ferns and Lycopodiums these spores produce prothallia, each bearing both antheridia and archegonia, that is monoecious prothallia. In the Equisetums the prothallia are generally dioecious; that is, some spores produce prothallia bearing only antheridia and others, only archegonia.

In Selaginella, Isoetes, Marsilia, and Azolla, the sex of the future prothallium is indicated by the spores; for the sporophyte in these genera produces two very different spores, each in sporangia by itself. The larger kind, called macrospores (Figs. 405, 406, and 410), give rise to prothallia bearing only archegonia; the smaller kind, microspores (Fig. 409). produce only antheridial prothallia.

Comparison of the Gametophyte with that of Ferns. The alternating generations gametophyte and sporophyte are each distinctly exhibited in the life history of Ferns ; because in forming each generation the protoplasm of the germinating spore soon grows out from the spore and forms an organism capable of independent existence and which may separate from the spore. The opposite extreme is exhibited by the gametophyte of Isoetes, in which allthe phenomena of germination, development of a prothallium, and formation of an oosphere occur in the limited space of the macrospore and at the expense of its original store of food, as shown in Figs. 411 and 412.

[Insert Figs. 411 and 412 here]

Other Pteridophytes afford intermediate conditions between Isoetes and Ferns in the reduction of the gametophyte. In Selaginella, for example, only a portion of the female prothallium is protruded from the macrospore.

Alternation of Generations in Phanerogams. The reduction of the gametophyte in Isoetes enables us to perceive an alternation of generations in Phanerogams corresponding to that in Pteridophytes and indicative of close relationship between these two groups of plants.

The sporophytic generation of the Phanerogam includes the whole development of the plant from the germination of the oospore, through the seed stage, to the adult stage producing in the flower pollen grains (microspores) and embryo-sac cells (macrospores), the latter in the ovules (sporangia).

In the gametophytic generation of the Phanerogam, the embryo-sac cell germinates, forming a few-celled prothallium and one or more reduced archegonia, of which the oospheres are the most essential parts (Fig. 371). The pollen grain germinates either on the stigma in Angiosperms or on the ovule itself in Gymnosperms, and forms in the pollen tube a few-celled prothallium having two generative male cells, which are conveyed to the embryo-sac by the pollen tube (Fig. 371). Passing into the embryo-sac, a generative ~~male~~ cell fuses with the oosphere, forming the oospore.

The generative cell from the pollen tube is at least functionally equivalent to a spermatozoid but is not usually ciliated in Phanerogams. The interesting discovery has recently been made, however, that in Gingko and Zamia of the more primitive Gymnosperms these generative cells are ciliated motile cells (a, Fig. 413), thus showing closer the relationship between Phanerogams and Cryptogams.

[Insert Fig. 413 here]

~~Section III.~~ BRYOPHYTES.

The Bryophytes (from Bryon, moss) comprise Mosses and Hepatics. In common with ~~the~~ Phanerogams and Pteridophytes, Brtophytes have a regular alternation of generations in their life history and in all Mosses and many Hepatics there is differentiation also of the vegetative portion of the plant into both stem and leaves.

Bryophytes may be distinguished from both Pteridophytes and Phanerogams by the presence in the Bryophytes of ~~both of~~ leaves and stem in the gametophytic generation, or portion, of the plant, its sporophytic portion being leafless, whereas in both the ~~two~~ higher groups stem and leaves belong to the sporophyte.

Of the two fimilies of Bryophytes the Hepatics are the more limited in distribution and the more primitive, affording very instructive connecting forms between the more typical Bryophytes and the Thallophytes. The Mosses are much more common and more widely distributed than the Hepatics, more numerous in species, and are the more representative family of Bryophytes.

Mosses. The popular idea of a moss is very vague, the term being applied to widely different plants, as Florida Moss, a flowering plant; Irish Moss, a seaweed; Reindeer Moss, Iceland Moss and Tree Mosses, lichens - all of which have very different structure from true mosses.

Mosses, that is true mosses, are abundant in moist places, as along brooks and in swamps and in moist ravines and woods. In such places at any season of the year, tufts of moss may be found with the individual plants having the general form ~~parts~~ and parts ~~form~~ shown in Fig. 414 , in which c represents

[Insert Fig. 414 here]

the capsule; p, its pedicel; l, a leaf; s, the stem. The portion above the dotted line is the sporophyte; the portion below the dotted line is an erect leafy shoot of the gametophyte and is commonly called a "moss plant".

Careful examination of the tuft of moss will often reveal many leafy shoots ("moss plants") bearing young sporophytes in various stages of development and also other shoots which have not yet produced their sporophytes.

The life history of a Moss is as follows:-

Gametophytic generation. A spore, from the capsule of the sporophytic generation, germinates on a moist surface in the light and produces a green filament which branches and spreads over the surface. The branched, thread-like, filamentous growth is called the protonema (Fig. 415). Some branches of the protonema grow down into the earth or other substratum to absorb food: such branches are rhizoids, r.

{Insert Figs. 415 & 416 here}

Buds (b, b, Fig. 415) form at the bases of other protonemal branches and from these buds arise erect branches, the "moss plants", consisting of a stem bearing leaves arranged in spirals (Fig. 416). Rhizoids, ri, similar to those of the protonema and consisting of multicellular filaments destitute of chlorophyll, are soon thrown out from the base of the stem to absorb food, and with them the moss plant becomes independent of the protonema.

The leaves of mosses have the form and color of leaves of the higher plants but are of simpler microscopic structure. They lack an epidermis and consist usually of a single layer of cells containing chlorophyll and of a bundle of elongated conducting cells having the position of a midrib.

The leaves of the bog mosses (Sphagnum) lack the midrib-like bundle of conducting cells but have instead colorless elongated cells for absorption and storage of water distributed between cells containing chlorophyll, as in Fig. 417 . The manner of arrangement of these two kinds of cells is different in different species.

{Insert Fig. 417 here}

The leaves of mosses which grow in dry situations, as Polytrichum, are so constructed as to curl together in dry weather, exposing less surface for transpiration.

Antheridia and archegonia are borne on the moss plants, in some species, either at the apex of the main stem or of short lateral branches or laterally along the stem in the axils of the leaves in other species.

The moss plants are

Synoecious or bisexual, when both antheridia and archegonia are produced on the same plant in the same receptacle.

Monoecious, when both antheridia and archegonia are produced on the same plant but not in the same receptacle.

Dioecious, when these organs are borne on different plants

A median longitudinal section from the upper part of a young bisexual moss plant is shown in Fig. 418, with parts as follows.

{Insert Figs. 418 — 420 here}

Antheridia, a, are barrel-shaped organs, each having for its outer part a wall one layer of cells thick and in its interior many small cells, each containing a single spermatozoid. In young stages the antheridium is closed (Fig. 420), but it burst open at the apex for liberation of the spermatozoids when they become mature. An empty antheridium is shown in Fig. 418, a.

Spermatozoids of mosses are motile cells having two cilia (Fig. 419). By movements of their cilia they swim in water covering the moss plants.

Archegonia are flask-shaped organs (ar, Fig. 418) having the same structure as the archegonia of the fern already described. The oosphere, o, is a large cell in the interior of the swollen base of the archegonium.

At maturity of the oosphere, the neck cells of the archegonium are pushed apart by the swelling of mucilaginous matter in the interior of the neck when the plants are wet with dew. This mucilaginous matter results from the disorganization of the row of cells extending from the oosphere up through the interior of the neck. The mucilage oozes out and by its sugary composition attracts the spermatozoids, which swim down through the mucilage. An oospore results from the fusion of a spermatozoid with the oosphere

The existence of the gametophyte does not end with the formation of the oospore: it continues to live and supplies the sporophyte with food during the lifetime of the latter.

Sporophytic generation. The oospore germinates at once in its arche archegonium and forms a many-celled embryo, ellipsoidal in form, which differentiates into the sporophyte. An archegonium containing such an embryo, e, is marked f in Fig. 418 .

The parts of the sporophyte are foot, capsule, and, in many mosses, a pedicel.

The foot is the lower end of the sporophyte; it wedges itself into the upper end of the moss plant and conveys food from it to the sporophyte. It is near f, Fig. 421 .

[Insert Fig. 421 here]

The pedicel, or seta, (Fig. 421, p), when present, supports the capsule and connects it with the foot. The pedicel often contains a strand of rudimentary vascular tissue.

The capsule is a cylindric or pear-shaped body in which the spores are produced (Fig. 421, c, and Fig. 422).

The calyptra is a small chaffy body borne loosely on the apex of the capsule (Fig. 421, d). It is most likely to be found before the capsule is fully mature, as it is easily detached. The calyptra is merely the upper end of the archegonium. As the oospore germinates in the archegonium, the growth of the sporophyte in the higher mosses soon ruptures the wall of the archegonium transversely and the upper, or neck, portion of the latter is then carried upward on the apex of the apex of the capsule.

The operculum is the helmet-shaped apex of the capsule of the higher mosses, as in Fig. 422, o, o'. At maturity of the spores, the operculum separates from the rest of the capsule along a circumscissile line and falls away (o'), exposing the peristome, as in Fig. 423, p.

[Insert Figs. 422 – 424, here]

The peristome consists of one or two rows of teeth, arranged about the mouth of the capsule and either separate, or more or less joined together, as in Fig. 423, p. The teeth of the peristome are hygroscopic: in wet weather they close together over the mouth of the capsule; when drier, they commonly bend outward, or recurve. They scatter the spores by these changes. The structure of the peristome, if a peristome is present, and the number of its teeth are important generic characters in mosses.

The spores are one-celled nucleated bodies (Fig. 424). The spores develop from a layer of cells in the interior of the capsule.

Sporophyte of Sphagnum. Sphagnum is the common moss of peat bogs, often called cranberry bogs (Fig. 425). In these mosses the tissues of the archegonial wall apex of the moss plant are stimulated to growth by fertilization of the oosphere. The archegonial wall keeps pace with the growth of the sporophyte and wholly incloses it until it is almost fully mature. But this is the more readily possible, because there is no pedicel present in the sporophyte of Sphagnum. What resembles the pedicel of other mosses is here called the pseudopodium (Fig. 426, ps); it is a part of the gametophyte, formed by the growth of the tissue of the gametophyte directly underneath the archegonium.

[Insert Figs. 425 , 426 here]

Alternation of generations in life history.

In the life history of mosses, as sketched in the foregoing account, there is a regular alternation of generations, the order being, that given for ferns and flowering plants; namely, gametophyte, oospore, sporophyte, spore, gametophyte, and so on. but in addition to propogation by spores in the regular course of development, there are means also of

Vegetative Propogation of Mosses. These all depend on the great power of mosses for reproducing the whole plant from a very small piece. Very small portions of the protonema are capable of independent life and the production of a leafy shoot; so also a single detached rhizoid, if kept moist, can give rise to protonema and moss plant. Leaves of a moss plant, inner cells of the pedicel, and portions of the wall of the capsule - all have the power of giving rise to protonemata bearing moss plants. #

In bog mosses (Sphagnum) which may form extensive masses of turf about ponds, advancing under favorable conditions from the shore towards the open center of the pond, the upper extremities of the stems and branches continue their growth from year to year, while the older and lower portions die away. and become changed to peat. By the gradual death from below upwards, the branches become separate and independent plants.

The Hepatics are a much smaller group of plants than the mosses and more rarely found. They should be sought for on the earth on springy hillsides somewhat shaded by bushes, on rotting logs along streams, and at the base of living tree trunks in moist woods and ravines. Some kinds resemble mosses in having distinct stem and leaves, although the leaves occasionally run together. In other kinds there is no distinction of stem and leaf, but the whole vegetative body is a flattened ribbon-like structure, like an enlarged fern prothallium and of the same bright green color: it is called a thallus. According to their kind of vegetative structure, hepatics are foliose or thalloid.

Foliose Hepatics. A foliose hepatic, Lophocolea, is represented in Fig. 427. Its stem (s) bears two rows of leaves on its upper side, one along the right flank and the other along the left (Fig. 428). A third row of leaves may be borne on the stem of a hepatic, but when present, this row is on the under (ventral) surface of the stem. Such ventral leaves are small and rudimentary; they are called amphigastria on account of their position. The ventral surface of a piece of the Lophocolea is shown in Fig. 429, a, a, being amphigastria.

[Insert Figs. 427-430 here]

The leafy shoot of Lophocolea belongs to the gametophytic generation and is homologous with the moss plant of mosses. Hepatics agree with mosses in having the gametophyte as the more prominent generation and independent in its existence also. Antheridia and archegonia are produced on the leafy shoot of Lophocolea. After fertilization of an oosphere by a spermatozoid, the resulting oospore germinates in the archegonium and develops into a sporophyte (Fig. 427), consisting of a capsule, c; a pedicel, p; and a foot attaching the sporophyte to the apex of the leafy shoot.

The capsule of Lophocolea splits lengthways into four valves at maturity (Fig. 427 ,c), discharging its contents of spores and elastic thread-like elaters (Fig. 430).

Thalloid Hepatics. Marchantia is one of the commonest and most readily recognized thalloid hepatics. Fruiting specimens are shown in Figs. 431 and 433, in which t indicates thallus; r, rhizoids, which penetrate into the earth. Specialized erect branches (b, b) of the ~~the~~ thalli terminate in umbrella-shaped receptacles, which bear the reproductive organs; antheridia and archegonia. Both kinds of organs are not produced on the same thallus; that is, the thalli are dioecious.

An antheridial receptacle is shown in longitudinal section in Fig. 432 . Four antheridia are shown (a). In each antheridium there develop very many minute ~~anthe~~ spermatozoids, which are discharged through pores in the upper surface of the receptacle.

[Insert Figs. 431 – 436 here]

The archegonial receptacle is shown in longitudinal section in Fig. 434 . It produces on its under surface archegonia very similar to those of mosses and ferns and each containing a one-celled oosphere, which becomes an oospore and capable of further development by fusion with a spermatozoid.

The oospore germinates in its archegonium. The two-celled stage of the embryo is given in Fig. 436 ,e. By further growth ~~and develop~~ at the expense of food supplied by the gametophyte, such an embryo finally develops into the mature sporophyte shown in Fig. 435, passing through the younger stages ~~of which are~~ m, n, o, Fig. 434.

The sporophyte in Fig. 435 has been drawn with capsule (c) burst open and discharging its contents of spores and thread-like elastic elaters; p is its pedicel; ar, the ruptured archegonial wall within which the sporophyte was contained until the stage of Fig. 434, o.

The spores ~~produced by~~ from the sporophyte of Marchantia germinate on moist ground and produce a short unbranched filamentous protonema with a flattened apex, from which the adult thallus springs as a lateral branch.

The thallus of Marchantia is highly developed and is very interesting in structure. An especial feature ~~cons~~ is its bearing on the upper surface peculiar cups (Fig. 433, c), having toothed margins and containing small biscuit-shaped green bodies, called gemmae. The gemmae originate by repeated division of single cells of the thallus. On becoming scattered from the cups the gemmae are able to develop into new thalli under favorable conditions. They serve as an important means of vegetative propogation of Marchantia.

Riccia. One of the simplest hepatics is Riccia natans, a floating species, which is sometimes collected on the surface of stagnant pools. A large specimen bearing mature fruit is given natural size in Fig. 437, in which t indicates the thallus, and r, r, rhizoids attached to the lower, or ventral, surface.

{Insert Fig. 437 here}

Antheridia and archegonia are imbedded in the upper surface of the thallus. The fertilized oospore remains in the imbedded archegonium and develops there into a very reduced sporophyte, spherical in form and consisting only of a thin outer wall and a central mass of spores.

Hepatics may be distinguished from Mosses as follows:

1. Thalloid hepatics by the thallus; foliose hepatics by the arrangement of their leaves in two prominent ranks along the flanks of the stem on the dorsal side, with ,without a third row of rudimentary leaves on the ventral side. All mosses have leaves in three or more prominent ranks.

2. The capsule of hepatics usually opens by two or four valves or irregularly and usually contains elaters mixed with the spores. The capsule of mosses usually opens by an operculum and its spores are not mixed with elaters.

Bryophytes contrasted with Pteridophytes and Phanerogams. The chief respect in which Bryophytes differ from the higher plants is in having the sporophyte leafless and wholly dependent on the gametophyte, while in Pteridophytes and Phanerogams the sporophyte bears the leaves and is the more prominentgeneration and is soon independent of the gametophyte.

The simpler structure of Bryophytes as compared with the higher groups is shown by the absence of true roots in Bryophytes and by the presence of only a strand of vascular tissue in the sporophyte.

THALLOPHYTES.

In passing from flowering plants and ferns to mosses and hepatics, we found stem and leaf - which together constitute the cormus - much less developed in the latter plants than in the former. But in contrast with this simplification of stem and leaf, we have observed another type of vegetative structure - the thalloid type - reduced to hardly more than a vestige in the gametophyte of flowering plants, better displayed in that of Pteridophytes and especially in the prothallium of ferns, and still more prominent and more varied in Bryophytes, where it may be a mass of filaments, as in the protonemata of mosses and some hepatics, or a flattened plate in that of others and also in the adult vegetative body of such species as Marchantia.

In the Thallophytes - the lowest of the four groups of plants and the group of which we are now to study representative kinds - the vegetative body is a thallus.

* A thallus is a vegetative body not differentiated into stem and leaves yet having the functions of both these organs. It is therefore a simpler, or less specialized, structure than a shoot (cormus) composed of both stem and leaves. The thallus is very varied in different Thallophytes: it may be colored or colorless, simple or branched, a single spherical or elongated cell or a filament of cells, a layer of cells or a cubical mass of cells. ~~It may~~ The thallus may be even leaf-like in some Thallophytes or stem-like inothers but

but does not consist of both a true stem and leaves in the same plant.

In the three higher groups of plants already studied, the sexual reproduction is of the archegoniate type, by which is meant that that the sexual elements are unlike in form and size and that the female element is contained in an archegonium. In Thallophytes having sexual reproduction, this ~~is always~~ occurs by the union of either similar or dissimilar elements but the female element is not contained in an archegonium. Reproduction is always by nonsexual means in the simplest class of Thallophytes. The absence of the archegoniate type of reproduction ~~in Thallophytes~~ affords the surest means of distinguishing a Thallophyte from a Bryophyte or higher plant in any doubtful case.

The Thallophytes are the largest group of plants in point of numbers, for

they comprise fully half of all known species of plants: they are also the oldest group according to geological evidence. Through variation and adaptation to different modes of life, they have come to consist of widely different classes of plants, some types of which will be outlined under the old

Small caps.

but convenient arrangement of Lichens, Fungi, and Algae, used in systematic botany and especially helpful to a beginner becoming acquainted with plants as they exist living about him.

FUNGI.

Fungi are Thallophytes with a thallus destitute of chlorophyll; common examples are toadstools, rusts, moulds, and bacteria. On account of their lack of chlorophyll, fungi are unable to convert inorganic matter into organic compounds necessary for their nutrition, but they use instead the stores of such matter accumulated by other plants and by animals. According to their relations to other organisms, fungi are saprophytic, symbiotic, or parasitic.

Saprophytic fungi live on dead organic matter of either plants or animals. The changes which they occasion in such matter we call decay or rot. Examples of saprophytic fungi are most toadstools, black mould of bread, many kinds of bacteria.

Symbiotic fungi live in association with living chlorophyll-containing plants, from which they draw supplies of organic matter and make such return that both organisms gain by the association. It is claimed that examples are the fungi which in association with algae form lichens, and also fungi associated with the roots of some Phanerogams.

Parasitic fungi derive their organic food from living organisms in which they thereby cause disease. Grain rusts and smuts and the black knot of the plum are examples.

Life work of fungi.

Saprophytic fungi have an important part in the economy of nature. If the remains of plants and animals were to accumulate, remaining unchanged after death, the worldjs supply of organic would soon be locked up in insol- compounds. By the work of saprophytes, such insoluble organic compounds as cellulose, wood, and flesh ~~etc~~ are promptly consumed and returned to the soil and atmosphere in simpler soluble forms which can be used by green plants.

Origin of fungi. Chlorophyll-containing plants must have been the more primitive forms, for all other forms of life are directly or indirectly dependent on them for organic food matter. Certain general features of resemblance of fungi to existing algae in structure and life history, indicate that the fungi may have originated from groups of algae of former times. This has come about presumably through the ancestors of the fungi having helped out their inorganic food supplies with organic matter, using at first dead matter and varying so in descendant forms that such dead matter became their main supply. The chlorophyll would disappear in such plants as it ceased to be used in converting inorganic into organic substance. By such a change in mode of life and in structure, saprophytic fungi would result. It is but an additional step to the parasitic mode of life in which death of the organic food is anticipated.

Evidence in favor of such origin of ~~al~~ colorless plants~~, including the fungi~~, is afforded by several small groups of plants which have more recently lost their chlorophyll but in other features of structure and life history agree so closely with related forms having chlorophyll that they they are still classed among them. Dodder, Indian Pipe, Mistletoe, and Aphyllon are familiar examples of such Phanerogams of parasitic or saprophytic mode of life that owe their yellowish or snow-white color to lack of chlorophyll. An example among the algae is Choreocolax, a small white or rose colored alga parasitic on Rhodomela. This theory of origin of the fungi does not apply to the subclass Myxomycetes, which have probably come directly from ancestors among Protozoan animals.

The Fungi have come to differ greatly from the Algae of the present time and require separate consideration. The subclasses of Fungi are Basidiomycetes, Aecidiomycetes, Ascomycetes, Phycomycetes, Saccharomycetes, Schizomycetes (Bacteria), Myxomycetes. The stem mycetes in these names means fungi, the part prefixed to it in each name refers to something distinctive of the class.

BASIDIOMYCETES.

Basidiomycetes include large and conspicuous fungi, such as mushrooms, toadstools, phalloids, and puff-balls. A fully developed basidiomycete consists of two main parts; the vegetative portion and the fructification. The toadstool or puff-ball as popularly understood - a mushroom is merely an edible toadstool - is merely the fructification of a plant whose vegetative portion, that is the thallus, is composed of very fine and cobwebby filaments buried in the ground or wood from which the fructification springs.

Hypha (hyphae plur.) is any one of the filaments of either the thallus or the fructification. A hypha consists of cells joined end to end in a single row, as in Fig. 447. The hyphae are branched and variously interwoven, but are the more coherent in the fructification.

Mycelium is the special term applied to a mass of loose, unconsolidated hyphae such as constitute the thallus of a basidiomycete. Mycelium of the cultivated edible toadstools is called "spawn" by gardeners. "Spawn" is sold in brick-like or flaky masses of the peaty compost in which it has been grown. The mycelium of wood-inhabiting species causes decay or rot of timber.

{Insert Figs. 447 & 448 here}

The fructification. In its most highly developed condition, the fructification consists, as shown in Fig. 448, of pileus, p; and stem, s. The stem has at its base in some genera a fleshy bag which inclosed the pileus in the young stage. Such a bag is termed the volva (Fig. 448, v).

The annulus, r, is a membrane spreading outward from the middle or upper portion of the stem in many genera. In early stages it reaches to the margin of the pileus.

The lamellae are the nearly parallel plates, l, extending radially from the stem along the lower surface of the pileus to its margin.

Basidia are cylindric or clavate cells standing side by side or between other cells in a palisade layer, termed the hymenium. The hymenium is the outermost layer of the lamellae. A cross section of a lamella is shown highly magnified in Fig. 449, in which b represents a basidium; c, a cystidium; h, the hymenium; t, tramal tissue.

{Insert Fig. 449 here}

Basidiospores are the spores produced on basidia, usually four to a basidium (Figs. 449 - 453, s). The basidiospores become scattered, germinate, and produce mycelia and fructifications under favorable conditions. The different ~~forms~~ types of basidia are shown in Figs. 450 - 453. Of these kinds the simple clavate or cylindric basidium (Fig. 450), bearing four spores at its outer end, is the common kind.

{Insert Figs. 450 — 453 here}

Basidiomycetes are defined as fungi which ~~bear~~ produce spores on basidia.

The differences among Basidiomycetes in the position of the hymenium in the fructification are the basis of separation into ~~subclasses and~~ families. In the subclass Gasteromycetes, which includes phalloids, bird's-nest fungi, and puff balls, the hymenium lines the surface of small cavities in the interior of the fructifications and does not become exposed to the outer air until the spores are mature. In the contrasted group of families, called Hymenomycetes, the hymenium is exposed to the air before the maturity of the spores. In the simplest condition of the fructification of Hymenomycetes, the the hymenium may be a simple plane surface, as in the Thelephoraceae; or it may cover the surface of simple or branched clubs, as in the Clavariaceae; or of slender teeth or spines, as in the Hydnaceae; or line the surface of

~~slender open tubes~~

slender open tubes arranged closely together side by side, as in the *Polyporaceae*; or it may cover the sides of lamellae, as in the *Agaricaceae* (Figs. 448 and 454).

Edible and poisonous toadstools. In the portions of our country where the flora has been most thoroughly studied, there are nearly as many species of Basidiomycetes as of flowering plants. Many of the former are too small, leathery, or woody to be used for food; of the remainder, a comparatively small number of the more widely distributed and attractive large, fleshy species have been eaten. More than a hundred kinds of these have been recorded as edible; about thirty ~~kinds~~ are regarded with suspicion; and half a dozen species are certainly poisonous - two of the latter are very common and the one of these most likely to be mistaken for an edible species is shown in Fig. 448.

A botanist with the aid of books may identify as he would a flowering plant any toadstool which he finds and he may then learn whether it has been recorded as edible or poisonous, but for most people who wish to make use of fungi as food, it is sufficient to learn to recognize unerringly several of

[Insert Figs 581 & 582 from old edition of Gray's Lessons here but renumbered 454, 455]

the more common edible kinds of their region and to eat no others. No kinds are poisonous to touch. There is no rule nor test by which edible and poisonous species may be separated as such, although an opinion to the contrary is sometimes erroneously held.

AECIDIOMYCETES

Aecidiomycetes are the "Rusts" and "Smuts", plants with their mycelium parasitic in the living tissues of stem, leaves, or fructifications of the higher plants. They do great damage to the cultivated cereals; wheat, oats, and corn, as well as to many plants of the flower garden.

The Rusts (Uredineae) are so called because one kind of their fructifications gives a rusty color to the host plants on whose surface they are produced. These reddish or orange colored fructifications are masses of uredospores. The masses are visible to the naked eye and may be easily found in early summer on the stems of wheat and oats attacked by rust or on the stems and leaves of carnations in the greenhouse. A group of uredospores is shown highly magnified in Fig. 457 ; the distribution of the groups of uredospores on the host plants is similar to that of the masses of Teleutospores of Fig. 456 .

[Insert Fig. 456 and 457 here]

Rusts are remarkable for their polymorphism, that is, for the several stages, or generations, which are included in their life history. There are four of these in the life history of common grain rust:-

1. Promycelial stage. Masses of teleutospores (Fig. 456) may be found in early spring, showing as elongated protruding black masses on the stubble of grain or grass attacked by rust during the preceding year. These Teleutospores germinate, the protoplasm of each cell forming a hyphal outgrowth,

termed the promycelium. Each of four cells of the promycelium produces a short lateral outgrowth terminating in a sporidium (Fig. 458).

{Insert Fig. 458 here}

2. Aecidial stage. The spridia, which mature when the buds and young shoots of the barberry are just starting, are carried by the wind and some lodge on the young barberry leaves, where they germinate, forming hyphae which penetrate into the interior of the tender leaves. Here they derive food from the living tissue and form a mycelium which produces organs or fructifications at both the upper and lower surfaces of the leaf. Those of the upper surface are spermagonia (Fig. 459, s) and they produce spermatia whose function is at present only surmised. The fructifications of the lower surface, termed aecidia, are highly characteristic and give the name Aecidiomycetes to their subclass. The aecidia (Fig. 459, a) are cup-like fructifications, usually clustered, containing one-celled aecidiospores in bead-like chains.

{Insert Fig. 459 here}

3. Uredosporic stage. The aecidiospores are scattered bythe wind. Some fall on young leaves of grain or grass, where they germinate, sending hyphae through the stomata into the interior of the leaves. The resulting mycelium makes a vigorous growth at the expense of the host and soon forms masses of uredospores (red spores) just under the epidermis. These masses rupture the epidermis by their growth and protrude through it, showing the characteristic reddish or rusty color already referred to. The short-lived uredospores (Fig. 457, u) are scattered by the wind and may fall on other

grain or grass plants, where they germinate in humid weather and form hyphae which penetrate these plants, so spreading the rust.

4. Teleutosporic stage. Toward the close of the season, the rust mycelium in grain or grass plants ceases the formation of new crops of uredospores, but forms instead thicker-walled and longer-lived spores, termed teleutospores (Figs. 456 and 460, t), which survive the winter.

{Insert Fig. 460 here}

The above is the complete life history of grain rust. The prevalence of rust in our western wheat fields far from any barberry or closely related plants has led to the belief that some of the mycelium may live through the winter in the grain stubble and produce crops of uredospores by which the rust is again started and spread in the following season.

The life history of the hollyhock rust differs from that of grain rust in having no aecidial stage. The sporidia are able to germinate on, and to infect, the hollyhock leaves, producing a mycelium which bears uredospores. This rust can therefore complete its life cycle on a single host - the hollyhock.

The Smuts (Ustilagineae) produce bag-shaped distortions, filled with black, sooty spores, in the leaves, stems, stamens, or fruits of grain and other plants.

¶ Corn smut, Ustilago Maidis, is common; its black distortions or pustules are sometimes confined to individual kernels of corn but often represent the greater part of the ear. The smut spores from the pustules germinate and develop on moist ground but more luxuriantly in water containing drainings from manure or other soluble plant food. They produce a promycelium bearing sporidia (Fig. 462). If the sporidia upon being scattered by the wind lodge

[Insert Figs. 461, 462 here]

on young and tender developing organs of the corn plant, they germinate there in humid weather and produce hyphae which penetrate into the interior of the young organs and produce there the characteristic smut pustules and distortions filled with thick-walled spores. These spores may germinate at once or winter over and continue ~~as described either at once or~~ the disease if the distortions are not gathered and burned as they appear.

There is no aecidial stage in the life history of a Smut. On account of the resemblance of the promycelial stage (Fig. 461) to that of Rust, Smuts have been grouped with the Rusts as Aecidiomycetes.

Relationship of Aecidiomycetes.

Aecidiomycetes are regarded as at least very closely related to Basidiomycetes on account of the resemblance of the septate promycelium of a Rust to the transversely septate type of basidium.

ASCOMYCETES

Ascomycetes are fungi bearing their distinctive spores, termed ascospores, in the interior of sack-like mother cells, called asci (Figs. 463 and 472). Eight ascospores are commonly formed in an ascus, but a greater or a less number may be regularly formed in some Ascomycetes.

[Insert Figs. 463, 464 here]

The thallus. Ascomycetes resemble Basidiomycetes in exposing the fructifications and ~~in~~ in having the thallus consist of a septate mycelium which is usually hidden in the earth, wood, or living tissues on which it feeds. Notable exceptions to such general habit are the Powdery Mildews (Perisporiaceae), of which the species producing their whitish cobwebby mycelium and colored fructifications on the leaves of the common lilac (Figs. 468 and 469) and willow are good examples.

The fructification. The asci and ~~vegetative cells~~ slender organs called paraphyses, are arranged side by side in a layer known as the hymenium (Fig. 465), which is similar to that described for Lichens. In the Exoasci - the Ascomycetes which cause "peach curl" in the leaves of the peach and "plum pockets" in the ovaries of the plum - the hymenium is a mere incrustation on the outer surface of the leaves or ovaries affected, with asci arising directly from the buried mycelium. In other orders of Ascomycetes, conspicuous fructifications are produced which bear the hymenium and connect it with the vegetative mycelium (Fig. 465).

[Insert Figs. 465 here]

In the order Discomycetes, the fructification is cup-shaped, disk-shaped, club-shaped or pileate and bears the hymenium on the upper and outer surface. The edible morels, Morchella esculenta and M. conica, which are frequent on lawns and in groves in April and May have pileate fructifications (Fig. 466). More common are the species of Pezizeae, whose cup-shaped fructifications, called apothecia, are often richly colored in scarlet, orange or green. They are found growing on moist ground in woods or on rotting wood whose decay their mycelium may be causing (Figs. 467 and 465).

[Insert Figs. 466, 467 here]

In the Pyrenomycetes the hymenium is inclosed by an investing wall, either completely inclosed as in Microsphaera, the mildew common on lilac leaves (Figs. 468, 469), or with a minute pore opening outward (Fig. 471). Such a fructification, more or less spherical in form, is termed a perithecium. The fructification may consist of single scattered perithecia not coalescent with others, as in the mildew on lilac leaves (Figs. 468, 469), or of many perithecia having their perithecial walls consolidated together at the base only (Fig. 471), or throughout, by a stroma, consisting of densely interwoven ~~agglutinated~~ and agglutinated hyphae, as in the Black Knot Fungus or in the Hypoxylon common on dead branches of alder or on fallen beech limbs.

[Insert Figs. 468-472 here]

Decay of wood caused by fungi.

Many Pyrenomycetes are of great economic importance. Beech limb wood ~~Limb wood of the~~ becomes "dosy" and almost worthless if left piled in the forest for a year. This result is due to the growth in the wood of the mycelia of pyrenomycetous fungi whose perithecia are eventually produced on the outer surface of the bark. The "black knot", Plowrightia morbosa, is a destructive parasitic Pyrenomycete, whose excrescence-like masses of perithecia are becoming very common on cultivated plum and cherry trees and on the wild red cherry (Figs. 470 - 472).

Carposporic type of reproduction. In the carposporic type of sexual reproduction, which prevails in Ascomycetes, the sexual spore results indirectly from the union of two sexual elements, that is, growth and division of the cell formed by the union of the sexual elements, takes place and the ~~sexual~~ resulting spores are finally formed from a part of, and sometimes at a slight distance from, the fertilized cell.

In ~~Sphaerotheca~~ Pyronema, a Discomycete whose mycelium grows in burnt ~~a mildew common on leaves of the Compositae~~, ~~[illegible] branches [illegible]~~ places in woods in half charred masses of leaves, the sexual organs arise at from the mycelium in small tufts (Fig. 473) and consist of swollen multinucleate cells, termed ~~oogonia~~ carpogonia and antheridia. These organs stand side by side: the ~~oogonium~~ carpogonium, c, is the more spherical in form and produces from its upper end a slender elongated cell, the trichogyne, t. The trichogyne grows up alongside the ~~trichogy~~ antheridium: and becomes united at its apex with the apex of the latter; the nuclei of the trichogyne disintegrate and disappear. A minute pore forms where the apexes of the antheridium and trichogyne are united, through which many nuclei migrate from the antheridium into the trichogyne (Fig. 474). The

[Insert Figs. 473-479 here]

partition wall between trichogyne and ~~oogonium~~ carpogonium then breaks down and the antheridial nuclei from the former pass into the ~~oo~~carpogonium and become mingled its nuclei (Fig.475); then a new wall forms across the opening and again cuts off the trichogyne from the ~~oo~~carpogonium (Fig.476). The nuclei fuse together in pairs in the ~~oo~~carpogonium; after such nuclear fusion, the ~~oo~~carpogonium is termed ascogonium. Ascogenous branches bud out from all points in the wall of the ascogonium and into them pass the nuclei of the ascogonium (Figs.475.,476). The ascogenous branches become branched and many-celled and invariably bend and recurve at the upper end so that the next to the last cell in the branch appears to terminate the branch (Fig.478) and does develop into an ascus (Fig,477).

In a very young stage, the ascus contains two nuclei, as in Fig.478, which fuse together to form the primary nucleus of the ascus (Fig.479). By repeated divisions there result from the primary nucleus [illegible] the ascus is to contain ascospores. Each of these [illegible] cytoplasm about it, is then cut out in a peculiar manner from the cytoplasm of the ascus and secretes a cell wall about itself, becoming an ascospore. Such formation of cells within a ~~parent~~ mother cell such as the ascus, is termed free cell formation.

While it is a matter of the greatest difficulty to make out the full series of developmental changes which occur in the interior of highly developed fructifications, still it is generally believed that in many of the Higher Ascomycetes a loss of sexuality has occurred so that the asci grow directly from the mycelium, omitting the formation of sexual organs and fertilization.

Nonsexual reproduction. In addition to reproduction by ascospores, many Ascomycetes have nonsexual reproduction by conidia. A conidium is any nonsexual, aerial spore.

The common blue mould, Penicillium glaucum, is usually propagated by conidia. This fungus is a frequent cause of the decay of apples stored in cellars. The mycelium spreads from the rotten portion of the apple into the adjacent sound portions, soon reducing such portions into a rotten mass. The dainty fructifications, consisting of tufts of bluish hyphae bearing chains of conidia (Figs. 480, 481), are produced on the surface of the decayed

[Insert Figs. 480, 481]

apples. This mould is also common on bread and other articles of food kept in warm dark and damp places. Its conidial are scattered by currents of air. If they lodge where the conditions are favorable, they germinate, giving rise to a mycelium which produces new crops of conidia. It is only under exceptional conditions that Penicillium produces perithecia and ascospores.

Our knowledge of the life histories of many fungi is very incomplete. At present, some are known only in their conidial conditions. Such kinds are grouped by systematic botanists in "form genera" under the title of Fungi Imperfecti.

PHYCOMYCETES

The Phycomycetes (Algal Fungi) are so called on account of their close relationship to the Siphoneae of the Green Algae, as shown by their unseptate many-nucleate mycelium and well-marked sexual reproduction of both the oosporic and zygosporic types. The absence of cross walls in the hyphae except where portions are cut off for reproduction, affords a ready means of separating Phycomycetes from any forms of higher subclasses of Fungi.

Cystopus (Albugo) candidus is a parasite on the Shepherd's Purse and on other plants of the Mustard Family. Affected plants show small whitish patches on their leaves and stems, which are also distorted. These white patches are groups of the nonsexual fructifications, ~~each~~ consisting of hyphae bearing conidia in bead-like chains (Fig.482). The conidia ripen along through the summer and are for the rapid spread of the disease.

The mycelium of Cystopus is buried among the internal tissues of the diseased leaves and stems, fromthe cells of which it absorbs food by short lateral branches, termed haustoria, which penetrate through the walls into the cell contents (Fig.483).

[Insert Figs.482,486 here]

The sexual organs are most likely to be found in brittle portions of the affected stems and towards the close of the season. These organs are antheridia and oogonia. The oogonia are formed by terminal or intercalary swellings on the mycelium (Fig. 484). The antheridia are swollen branches of the mycelium, cut off from it by a cell wall, which apply their obtuse extremities against the oogonium (Fig. 484). The antheridium puts forth a narrow tube which penetrates the wall of the oogonium and the peripheral protoplasm to the oosphere and discharges a nucleus into the latter. The antheridial nucleus fuses with that of the oosphere to form the nucleus of the oospore. After fertilization the oospore becomes thick-walled and may remain dormant in the stem until liberated by decay the following spring.

On germinating, the protoplasmic contents of both the conidium and the oospore are discharged as several or many naked masses of protoplasm, termed swarm-spores, each of which has two cilia and can swim about in water (Fig. 486). The swarm spore finally come to rest and grow into form of a hypha, penetrating ~~tender leaves or~~ a leaf stoma.

Oosporic reproduction is that type of sexual reproduction in which the sexual spore, termed oospore, is formed by the union of two dissimilar sexual elements, one of which, the oosphere, is formed in an oogonium.

Rhizopus nigricans, the Common Black Mould, often appears on bread or various articles of food left standing in a moist and close atmosphere. The mycelium of this mould forms a cottony covering over the bread on which it grows, ~~and spreads~~ spreading by stolon-like branches which, at the points where they touch the bread, send rhizoids, r, down into the bread and a cluster of usually from three to five branches upward into the air (Fig. 487). Each erect branch terminates in a sporangium, white at first but finally black, spherical in form, and easily visible to the naked eye (Figs.487, 8 - 490).

{Insert Figs. 487 - 491 here}

The sporangium becomes cut off from the hypha bearing it by a cross wall, termed the columella (Fig.489, c). The many-nucleate protoplasmic contents of the sporangium split into a large number of masses, each of which rounds off, secretes a wall, and becomes a colored spore - a conidium (Fig.491). The details in the formation of these conidia are wholly unlike those in the formation of ascospores in an ascus. The conidia are liberated from the sporangium by the liquefaction and breaking away of theupper part of the sporangial wall, whose lower portion remains as a narrow collar about the columella (Fig.490, w).

Zygosporic reproduction of Rhizopus. Old cultures of Rhizopus on bread, which have produced a very abundant mycelium and have become too old for study of sporangia are very likely to produce sexual organs and a crop of zygospores on the under portions of the mycelium next to, or immersed in, the bread. In forming the zygospores, short lateral branches of adjacent hyphae (Fig.492) come in contact at their tips (Fig.493); the terminal portion of each branch is cut off as a cell from the rest of the hypha, and is called

{Insert Figs. 492 - 495 here}

a conjugating gamete. The walls of the conjugating gametes are absorbed at their place of contact and their protoplasm fuses into a single mass, known as a zygospore (Figs.494,495). The zygospores secrete thick walls and become dark colored; they retain their vitality much longer than the conidia under unfavorable conditions.

Zygosporic reproduction is that form of sexual reproduction in which the sexual spore, termed zygospore, is formed by the fusion of two similar sexual elements.

Empusa musca is a Phycomycete parasitic on the common house fly, which it destroys in great numbers. Flies so killed may often be seen, especially in autumn, glued to glass or wooden surfaces by the white mycelium of the fungus.

SACCHAROMYCETES

Yeast Fungi or Saccharomycetes are microscopic unicellular plants, varying from subglobose or broadly ovoid to cylindric forms in different species. The opposite ends of the yeast thallus, that is cell, are alike in form, but are nevertheless differentiated as base and apex. This is shown by their difference in function, for the buds are always produced at the apex, that is at the end of the cell opposite to that - the base - by which it was itself attached to the parent cell (Fig.500)

The structure of the unicellular thallus of ~~the~~ common domestic yeast is shown in Fig. 503, in which the cell wall is marked w; the cytoplasm, c; the nuclear apparatus, n and m, n being the nuclear vacuole and network and m, the nucleolus. Nuclear division in the yeast cell is by the direct method, both portions of the nuclear apparatus becoming constricted in or near the middle and each pulling into two parts (Fig. 504) without the phenomena of mitosis, already described for Phanerogams and which prevails also in all Cryptogams so far studied by us.

[Insert Figs. 496–504 here]

Reproduction of Yeasts is by budding and endogenous spore formation.

Budding. In this mode of reproduction, a small protuberance forms slightly to one side of the apex of the parent cell (Fig. 497); the nuclear apparatus of the parent cell divides by the direct method into two masses similar in structure and equal or nearly equal in size and one of these becomes the nucleus of the bud; the bud grows and its protoplasmic connection with the parent cell is finally cut off by constriction of the cell wall (Figs. 498, 500). A second bud may form on the parent cell, near its apex also but on the other side of it from the bud first formed. The descendant cells soon produce buds of their own, still retaining connection with the parent cells if not broken away by violent agitation of the fluid in which the yeast is living (Fig. 500). A connected group of such parent and descendant cells constitute a yeast colony.

Spore formation. Endogenous spore formation of yeast occurs when conditions are not favorable to rapid growth and multiplication by budding, but still enable the organism to live. Under such conditions, the nuclear matter of the cell divides by the direct method into two masses and each of these may again divide into two. Each of these nuclei becomes surrounded by cytoplasm and a delicate membrane, and grows, thickening its wall, until the whole cavity of the mother cell is filled by these spores (Figs. 501, 502). Upon the recurrence of favorable conditions, these spores are set free from the mother cell and grow as independent plants.

Economic uses of yeast.

The common yeast plant has been cultivated by man for hundreds of years on account of the fermentation it causes in dilute sugary solutions. By its action the sugar of such solutions is converted into carbonic acid gas, alcohol and very small amounts of glycerine and succinic acid. The alcohol of wines, spirits, beer, and the ordinary (ethyl) alcohol of commerce are so produced. In bread making, this fermentation is employed for the leavening effect of the bubbles of carbonic acid gas, the small amounts of alcohol, glycerine and succinic acid being waste products.

In canning fruits in sugary solutions with the aid of heat, the fruit and sirup are raised to a temperature fatal the yeasts present either in or on the fruit or the fluid, and the mixture is then sealed in sterilized cans agaist the introduction of outside air having yeast cells floating in it as dust.

Relationship of yeasts.

The Saccharomycetes have been regarded by some botanists as a family of Ascomycetes, the mother cell with its spores being considered homologous with an ascus. This view and others in regard to their being reduced forms of other higher fungi, have been rendered very improbable by recent studies showing the profound differences between Saccharomycetes and the higher fungi in regard to nuclear phenomena and structure and the details of spore formation. At present it seems best to regard the Saccharomycetes as a distinct subclass of fungi.

SCHIZOMYCETES (BACTERIA)

Bacteria are unicellular plants of the smallest size. In some species the cells have a diameter of only .5 μ*(=1/50000 in.), a diameter only 1/14 that of human blood corpuscles.

II structure of thallus or cell.

The cells of Bacteria are of simple structure and consist of protoplasm surrounded by a cell membrane. The presence of this membrane may be demonstrated by treating the cells with a plasmolytic reagent such as 1 1/4 % aqueous solution of common salt (NaCl), which pushes or shrinks the cell contents away from the cell membrane (Fig. 509). A nucleus has not yet been found in Bacteria; chromatin granules are present however.

* 1 μ, that is 1 mikron = .001 millimeter = 1/25000 in., is the common unit in microscopical measurements.

Bacteria are grouped into families on the basis of characteristic form. The Coccus forms are spherical, as Micrococcus, Sreptococcus, and Sarcina; Bacillus forms are short straight rods varying from broadly ovoid to ellipsoid and cylindric, as Bacillus subtilis, Bacillus tuberculsis, and bacillus maximus buccalis; Spirillum forms are spirally curved rods, but if only ~~one turn of a~~ a fractional part of ~~a set~~ one turn of a spiral long and actively motile, they are called Vibrios, as Vibrio cholerae; Trichobacteria are thread~~-like~~ in form, as Cladothrix and Beggiatoa, and are likely to be confused with hyphae of higher fungi.

Several of the above forms may be seen by examining ~~with~~ under high magnification of a microscope a little of the matter which may be scraped from the teeth in the human mouth (Figs. 505 - 509).

{Insert Figs. 505-514 here}

Most kinds of Bacteria are colorless and transparent as seen through the microscope, but when seen growing in masses in pure cultures, are usually whitish or slightly yellowish waxy masses ~~although~~ but many kinds are bright colored in ~~such~~ the mass.

In Bacillus prodigiosus which grows on moist bread, causing the phenomenon of "bloody bread", the red color is due to red granules excreted by and wholly outside the cells of the bacilli: but in Beggiatoa, coloring grains of sulphur are inside the bacteria.

~~Some kinds of Bateria are motile in fluids; others are not motile.~~

~~Bacteria reproduce by fission and by spore formation. The former method~~

Bacteria are motile or non-motile. The motile kinds swim about in fluids by means of very slender cilia of protoplasmic nature which are protruded from one or both ends or the whole surface of the body. (Figs. 510-512).

Reproduction.

Bacteria reproduce by fission and by spore formation. In fission, a bacterial cell becomes slightly elongated and then divides by formation of a cross wall into two equal cells which may separate from each other (Figs. 506, 512, 513). Multiplication by fission is common to all bacteria and gives to them their name as a class, Schizomycetes (Fission Fungi).

By the more usual method of spore formation, the whole or a part of the protoplasmic contents of the cell shrinks away from the cell membrane, rounds off into ellipsoidal or spherical form, and secretes about itself a thick and resistent wall (Fig. 514): by the less usual method, which is said to occur in Leuconostoc, the original membrane of the cell becomes greatly thickened and the cell is then a spore. The spores are very resistant to unfavorable external conditions and can survive drying and extremes of temperature fatal to the ordinary vegetative stage. As only one spore is formed to a cell, there is no increase in number of bacteria by spore formation. Spores are not known for all kinds of bacteria.

Bacteria thrive in river water, in the soil, on slimy or moist surfaces of living bodies, and in organic matter containing organic substance liable to putrefaction. They are the causes of putrefaction. Most kinds of bacteria are harmless (non-pathogenic), but some kinds (pathogenic species) are the causes of such diseases as diphtheria, consumption (tuberculosis), typhoid fever, pear blight, etc.

ALGAE

Algae are Thallophytes whose cells contain chlorophyll. Like the higher chlorophyll-containing plants, they are able to form organic plant matter from inorganic matter. Algae live either in water, both fresh and salt, or on moist surfaces, such as those of rocks, earth, wood, and bark of trees. The largest species live in the ocean, some Antarctic species rarely attaining a length of 600 to 1000 feet - a length greater than that of the largest trees.

In addition to chlorophyll, the cells of Algae may contain other coloring matters in such amount as to modify or wholly mask the bright green of the chlorophyll. Such other coloring matters are phycoerythrin, phycophaein, and phycochanin.

According to color, Algae are divided into four subclasses;

Rhodophyceae or Red Algae, whose red or purple color is due to phycoerythrin.

Phaeophyceae or Brown Algae, whose olive-brown color is due to phycophaein.

Chlorophyceae or ~~Bright~~ Green Algae, containing only the chlorophyll.

Cyanophyceae or Blue-green Algae, whose bluish color is due to phycocyanin.

RHODOPHYCEAE

The Red Algae (Rhodophyceae) are very common along our coasts. Their thalli are often of bright rose color and very beautiful and varied in form.

It is these Algae, floated out on paper and pressed and dried, which are frequently preserved as souvenirs of a trip to the seashore. Although the Red Algae are chiefly marine, still a few of the genera, as Batrachyspermum (Figs. 524, 525 and Lemanea are widely distributed in our region in fresh water. These fresh water kinds are usually violaceous or brownish rather than rose-red.

[Insert Figs. 522 - 525 here]

The thallus in some of its higher forms in the Red Algae is differentiated into a cylindric axis with flattened, leaf-like branches, which even show in Delesseria sinuosa a midrib and lateral ribs (Fig. 522). In other forms the thallus is flattened and ribbon-like, as in the Irish Moss, Chondrus crispus (Fig. 523), and in still simpler conditions it consists of branching filaments, each composed of a row of cells, as in Batrachyspermum (Figs. 524, 525).

Reproduction of the Red Algae is either sexual or asexual. The asexual reproduction is by nonmotile spores, usually produced in groups of four and hence called tetraspores (Figs. 526, 528). In only a very few exceptional species

[Insert Figs. 526 - 528 here]

are sexual organs found on the plants producing tetraspores.

The sexual reproduction is of the carposporic type. In its simplest condition, as observed in Nemalion, a spermatium from an antheridium fuses with the trichogyne of an ~~oogonium~~ carpogonium (Fig. 529). The nucleus of the spermatium then passes down through the trichogyne and fuses with that of the carpogonium. After such fertilization, the carpogonium divides (and several carpogenous filaments grow out from its sides (Fig. 530). Each of these filaments bears a carpospore at its end (Fig. 531).

[Insert Figs. 529-531 here]

Cystocarp is the term applied to the whole fructification consisting of either carpogonium and carpogenous filaments and carpospores, as in Nemalion (Fig. 531), or of these structures and an investing wall which is regularly formed in some genera.

The phenomena of carposporic reproduction in some genera of the Red Algae, as in Dudresnaya for example, are made very complex by the cytoplasmic fusion of carpogenous cells with vegetative cells of the thallus, termed auxiliary cells. At present these fusions are believed to furnish nutritive matter to the nuclei from the carpogonium which alone become the nuclei of the carpospores.

PHAEOPHYCEAE

The Brown Algae (Phaeophyceae) are olive-brown in color. With the exception of Diatoms, which live in fresh and also in salt water, the Brown Algae are mostly marine algae and are the most common and conspicuous algae along our coasts in the tide pools and on the rocks in the region between high and low tides.

[Insert Figs. 532-535]

The thallus exhibits as great variety in the Brown Algae as in the Red Algae. The Gulf-weed, Sargassum, detached masses of one species of which accumulate in great areas in the warmer portions of the Atlantic, has a distinct stem and leaves and has also air bladders by which the plants float, as shown in Fig.532. The common Devil's Apron and Sea Colander(Figs.533, 534) have a stem-like axis bearing on its upper portion flattened leaf-like branches and at the lower end root-like "hold fasts" which firmly attach the plants to rocks and other objects in the sea bottom. From such highly developed forms there are all intermediate conditions to such filametous forms as Ectocarpus (Fig.535) and to the unicellular thallus of Diatoms (Fig.542).

Rockweed, the common name applied to species of Fucus and Ascophyllum, is very common along rocky coasts in the region between tides, where it may form large masses with the individual fronds (thalli) six inches to three feet long. The fronds are tough and leathery and branch dichotomously. The branches are flattened and have a midrib in species of Fucus but lack it in Ascophyllum. Hollow inflated places in the fronds of some species serve as air bladders for buoying up the plants when submerged (Fig.536).

[Insert Figs. 536 - 541 here]

The reproduction of Rockweed is of the oosporic type. The reproductive organs, termed oogonia and antheridia, are developed in small sunken pits, the conceptacles, which are scattered in the surface of swollen terminal and lateral branches of the fronds (Fig.536). The position of oogonia and antheridia in their respective conceptacles is shown in Figs.537, 538.

In Fucus, the protoplasm of the oogonium divides into eight masses which round off into oospheres and are discharged from the conceptacle and liberated from the oogonium into the sea water. The protoplasm of the antheridium subdivides into a large number of spermatozoids (Fig.539) which are set free from the antheridium when mature (Fig.540). The minute spermatozoids swim in the sea water by means of their two cilia and collect about the much larger and nonmotile oospheres (Fig.541). Fertilization is accomplished by the penetration of a spermatazoid into an oosphere and their fusion into one cell, the oospore. The oospore secretes a cell wall, attaches itself to a rock and develops into a new plant.

Diatoms are unicellular and usually brown algae which secrete a siliceous cell wall, consisting of two valves. These valves are so joined together that the older and larger overlaps the other like the lid of a box.(Figs.542,b; 543). The surfaces of the valves are ornamented with very fine lines and curious markings (Figs. 542, 547).

Diatoms occur in large numbers both in fresh and salt water and on moist ground. They are very abundant in the ooze at the bottom of ponds and of stagnant water.

[Insert Figs. 542,547 here]

Motility Diatoms are motile and glide slowly backward or forward in water in the direction of their long axis, or creep along objects. In the forms provided with a raphe, that is, with a longitudinal slit, r, Fig.542, in the middle of the valve, such movement is by protoplasmic filaments protruded from the raphe. Some Diatoms are attached to objects by a gelatinous stalk secreted by the Diatom (Fig.545), and are often seen on other algae examined with the microscope.

Reproduction.

Diatoms multiply by division of each cell into two cells by a plane midway betwien and parallel to the two valves. Each cell retains one valve of the parent cell and forms a new valve which fits within the older valve at the girdle. As the old valve is silicified and incapable of further growth, the individuals become smaller and smaller by repeated division (Fig.545, 2nd, 3d from the left). After a certain minimum size is reached, the protoplasm abandons its valves and forms an *auxospore*, much larger than the valves from which it came. The auxospore secretes new valves of the maximum original size of the series. In some Diatoms, the protoplasm of the parent cell divides into two masses, each of which grows and becomes an auxospore; in others, the protoplasm of one individual forms one auxospore; and in still others, the auxospore is formed by the fusion of the protoplasm of two individuals, as in Surirella, Fig. 547.

CHLOROPHYCEAE

The Green Algae (Chlorophyceae) have the bright green color of foliage of flowering plants, ferns, and mosses, because their chlorophyll is not masked by the presence of other coloring matters. The Green Algae include nearly all the fresh water algae, and there are also many marine species. Although especially abundant in sluggish and stagnant water still many species are common on moist surfaces of earth, stones, and bark.

The Green Algae show very great range in the form of the thallus and in their modes of reproduction. They form the most complete subclass of Algae and lead back the most directly from Bryophytes and higher groups to the simplest forms of plant life. The Green and Brown Algae form somewhat parallel lines of plants, ~~evolution.~~

The Characeae are a small order of plants intermediate between Green Algae with typical oosporic reproduction and the higher plants with the archegoniate type of reproduction. They are rather stiff and brittle algae, growing in erect position on the bottom in ponds and sluggish streams where the water is from one to four feet deep. The thallus is stem-like, consisting of a cylindric axis which gives off whorls of branches at the nodes (Fig.548). These branches may also branch in the same manner.

In the genus Nitella, a single large internodal cell constitutes the portion of the thallus between one whorl of branches and the next: such cells are excellent for microscopic observation of the rotation of currents of protoplasm in closed cells. In Chara the internodal cells of the main axis and branches are soon covered and concealed by a pseudo-cortx of longitudinal rows of cells which develop at the nodes from basal cells of the lateral branches (Figs. 549, 550).

[Insert Figs. 548 – 553 here]

The sexual reproduction of the Characeae is by means of spermatozoids and oospheres, the former produced in antheridia and the latter in oogonia. Both organs develop at the nodes (Fig. 550). It has been computed that in the aggregate 40000 spermatozoids are contained in a single antheridium.

The spermatozoids are spirally coiled and biciliate at the smaller end (Fig.551). In form they differ from the spermatozoids of other Algae and more closely resemble those of Bryophytes and Pteridophytes.

The oogonia are large enough to be seen with the naked eye. Each contains a very large oosphere richly stored with starch and other food matter. The oosphere is closely ~~invested~~ enveloped by five spirally arranged filaments which start from the small nodal cell below the oosphere (Fig.553). Above the oosphere, a crown is formed - in Nitella of ten cells cut off two from each filament (Fig. 553) and in Chara of the five terminal cells cut off one from each filament. When the oosphere is mature, the cells of the crown separate slightly, forming a passageway to the oosphere through which the oosphere swims to fertilize the latter, thus foming an oospore.

In germination the oospore gives rise to a simple filamentous row of cells (proembryo, suggestive of protonema of mosses), from the first node of which rhizoids are produced, and from the second, erect branches which become adult plants. There is no sporophytic generation, as occurs in mosses.

The Siphoneae live in both fresh and salt water. They may be easily recognized with low magnification of the microscope by their unicellular thallus; cross walls are wholly wanting in the thallus except where reproductive cells are cut off from the vegetative portion of the thallus. The thallus of Phycomycetes has the same structure but contains no chlorophyll.

Vaucheria is widely distributed in fresh water. Its thallus consists of bright green, branched filaments, often six inches long, with the basal end having colorless rhizoids for attachment to the earth.

The sexual reproduction of Vaucheria is of the oosporic type - by antheridia and oogonia, which are each short lateral branches of the thallus (Fig.554).

{Insert Fig. 554 here}

The protoplasm of the oogonium develops only a single oosphere, but that of the antheridium divides so as to form many minute spermatozoids, each consisting of but little protoplasm in addition to its nucleus. A thick-walled oospore results from the fertilization of the large non-motile oosphere by a motile spermatozoid which swims to it. The oospore does not germinate at once, but lies dormant for a time as a so called "resting spore".

By resting spore is meant any thick-walled spore, resistant to unfavorable external conditions, which does not germinate at once but lies dormant for some time - perhaps for months - and in this condition carries the life of the plant from one season of growth to the next, as through the winter or through a period of drought.

Asexual motile spores, called swarm spores, are produced singly in sporangia consisting of the swollen tips of filaments of the thallus. After ~~swimming~~ escape from the sporangia, the swarm spores ~~about for a short time,~~ swim about for a short time, then come to rest on the bottom of shallow pools and germinate at once forming new plants.

Among the curious genera of the Siphoneae are Botrydium, Codium, Acetabularia, and Hydrodicton.

Botrydium is of world-wide distribution. It forms groups of small, green, balloon-shaped vesicles on damp clayey ground in the bottom of dried pools.

[Insert Figs. 568, 571 of Gray's Lessons here, but change numbering & explanation as noted]

These vesicles are about the size of a pin head; they are attached to the ground by branching rhizoids (Figs.555, 558).

Codium and Acetabularia are marine genera of southern coasts. Codium is the "sea purse", so called on account of its form. Acetabularia has the form of a delicate toadstool (Fig.559).

[Insert Figs. 559-561 here]

Hydrodicton is the Water Net very common in water in ditches and streams in the Mississippi valley - especially so in Minnesota and Missouri. The delicate green nets (Fig. 560) are colonial organisms consisting of as many individuals as there are one-celled bars to the net (Fig. 561). In forming these nets, the swarm spores, which may be produced either in any one of the cells (individuals) of a parent net or by the germination of a zygospore, finally come to rest and group themselves together in the characteristic form of a net, growing permanently together in this form.

In the other Siphoneae than Vaucheria, sexual reproduction, when occurring, is of the zygosporic type - that is, by cells of the same form and size which fuse together in pairs, forming a zygospore.

Confervoideae. The Green Algae which one may find in a collection made at random from a sluggish rill or ditch or a shallow pond may belong to the Characeae or Siphoneae but are more likely to be Confervoid species, with a multicellular thallus of bright green color. In Ulva or Sea Lettuce and in Enteromorpha, both of which are very common along the sea coast, the thallus is membranous, but in ~~other~~ most genera, ~~with the exception of most Desmids,~~ it is composed of uninunucleate cells joined together in simple or branched filaments. Some of the more easily recognized kinds are Oedogonium, Ulothrix, Spirogyra, and Desmids.

Oedogonium has a thallus of unbranched filaments which show under a magnification of 250 diameters parallel annular striae on the outer surface of the filaments near the cross walls as in Fig. 562. These transverse annular striations are a peculiar growth phenomenon, caused by the transverse fissuring of the cell wall as the volume of the cell contents becomes greater than the capacity of the cell. An elastic cellulose ring is formed just underneath the wall before the rupture occurs, and after the rupture this ring stretches across the fissure and retains the cell contents. Bulbochaete, a closely related alga, has similar annular striations, but its thallus is branched and the branches end in long hyaline bristles swollen at the base.

[Insert Figs. 562, 563 here.]

Both Oedogonium and Bulbochaete have in addition to non-sexual reproduction by swarm spores, sexual reproduction of the oosporic type. The oogonia are greatly enlarged and nearly spherical cells of the filaments (Fig. 564).

Ulothrix. A fresh water species of Ulothrix is sometimes found attached to stones in brooks (Fig. 564). Its thallus consists of unbranched many-celled filaments attached at the base by a colorless rhizoidal cell (Fig. 565).

In Ulothrix, any cell of a filament may become a sporangium, its protoplasm dividing and differentiating into either swarm spores or sexual elements, termed planogametes, but not into both in the same sporangium.

P The swarm spores serve for non-sexual reproduction; they are produced only two or four to a sporangium (Fig. 566). The swarm spores are nucleated masses of protoplasm, each containing a chromatophore (that is, a chlorophyll mass or rudiment) and a red spot and having four cilia for locomotion (Fig. 567). The swarm spores escape from the sporangium through a lateral opening in the wall formed by absorption of the wall. After swimming about for a time, they come to rest and germinate, each forming a filament.

[Insert Figs. 564, 573 here

Planogametes are motile sexual elements which show no distinction of sex either by form or function.

The planogametes of Ulothrix are produced very many to a sporangium (Fig. 568). They are smaller than the swarm spores and have only two cilia, but resemble them in other details of structure. The planogametes fuse together (conjugate) in pairs (Fig 564), forming by their united masses a new cell with with one nucleus, one chromatophore, two red spots, and four cilia (Fig.570). After moving about, this cell comes to rest , loses its cilia (Fig. 571), and becomes thick-walled. Upon germinating, it produces a sporophytic generation, consisting of a unicellular filament attached at one end (Fig.572). Its contents finally divide (Fig.573) and are set free as swarm spores, two to eight in number, each of which germinates and forms a new thallus like that which bore the planogametes.

Sexual reproduction evolved from non-sexual reproduction

It has been observed that if the planogametes of Ulothrix fail to conjugate, they may germinate independently, like the swarm spores, but do not produce as luxuriant a thallus. Such independent germination of sexual elements is significant; it is regarded as indicative of the evolution of the sexual processes of reproduction of the higher plants from the exclusively non-sexual methods of the simplest plants.

Spirogyra has a thallus in the form of an unbranched filament, composed of many rather long and large cells, each of which has its ~~chromatophores~~ chlorophyll-bodies arranged as green bands extending spirally the whole length of the cell and next to the inner surface of the wall (Figs. 574, 575). These filaments are very beautiful objects under the microscope; species with the spiral bands not too closely crowded together are excellent objects for showing the general details of structure and parts of a living cell. By careful focussing, the nucleus may be sharply revealed at the center of the cell, imbedded in cytoplasm from which delicate threads of cytoplasm extend radially through the cell sap to the layer of cytoplasm next tothe cell wall (Fig. 575). The ~~chromatophores~~ chlorophyll-bodies are colored portions of this layer which forms a lining to every part of the wall.

[Insert Figs. 574, 576 here]

Spirogyra is very common in the water in ditches through meadows and in shallow streams and ponds.

The reproduction of Spirogyra is of the zygosporic type - by the conjugation of two similar cells to form a zygospore. Two adjacent filaments send out processes toward each other from opposite cells (Fig. 578). Where two processes meet, the walls are absorbed and the protoplasm of the two cells may either flow together into the connecting tube between the two cells and there secrete a thick wall, as a zygospore, or it may all flow from one cell through the connecting tube into the other cell and there fuse with the protoplasm of that cell to form a zygospore, as drawn in Fig. 576. Upon germination, the zygospore gives rise to a new filament.

Desmids are unicellular with a cell composed of two symmetrical halves, which are usually nearly separated from each other by a deep constriction, as in Fig. 578. Desmids are very common in stagnant water and also in watering troughs where they largely compose the flaky masses which collect at the surface at midday and settle to the ~~sides at~~ bottom and sides of the trough at night. Desmids occur singly or arranged together in chains.

[Insert Figs. 577, 580 here] The reproduction of Desmids is by fission and by formation of zygospores.

Desmids multiply by fission. A partition wall forms transversely across the middle of the Desmid, dividing it into its symmetrical halves; each descendant cell then develops its missing half by forming an outgrowth on the side next to this partition. This is shown in Fig. 578, in which a and b represent halves of the same Desmid originally, and a' and b', young stages of their missing members which are being produced by a and b respectively, next to the partition wall, p.

The sexual reproduction of Desmids is of the zygosporic type. The protoplasm of each of two individuals ~~breaks out~~ emerges from the cell wall in the middle region of the cell. breaking the wall into two parts, as in Fig. 580. The two masses of protoplasm fuse into one mass, the zygospore (Fig. 580).

Protococcoideae. The Protococcoideae are unicelluar Green Algae whose cells live separately or are united into colonies. Their reproduction may be non-sexual; by simple division of vegetative cells, as in Pleurococcus (Figs. 587, 591), or by swarm spores, as in Haematococcus (Figs. 581, 586), or rarely sexual; by conjugation of planogametes, as in Chlorochytrium.

Haematococcus (Protococcus or Sphaerella) lacustris is usually found in urns or in shallow pools in rock hollows, which are periodically filled with water. In such places the rock sides become covered with a red crust, consisting of small spherical cells, as in Fig. 581. The red color is due to a pigment in the interior of the cells, which is present in such amount in the resting condition of the plant as to wholly obscure the other cell contents.

Life history.

If some of this resting stage of Haematococcus be scraped from the rock, dried for a time, and then kept in a dish of water over night, the cell contents divide (Fig. 582), rupture the thick outer wall and push out through it a bladder-like expansion in which four, eight, or sixteen large daughter cells are

[Insert Figs. 581, 586 here]

finally formed (Fig. 583). Each daughter cell develops two cilia, bursts out from the mother cell, and swims away ciliated end foremost, as a large and red swarm spore (Fig. 584). As shown in the figure, the wall of this swarm spore becomes greatly distended and delicate strands of protoplasm may radiate to it from the central mass.

After a time these swarm spores may come to rest against some object, lose their cilia and radial strands of protoplasm, and then divide their contents so as to form a new generation of swarm spores, but containing less red pigment than those formed by division of the resting stage of the plant. Any swarm spore may lose its cilia and assume the resting stage of the plant shown in Fig. 551. In this resting condition the red pigment gradually increases to the maximum amount.

Under certain conditions, the ~~cell~~ contents of of the resting cells of Haematococcus may divide into four, eight, sixtien, or thirty-two very minute swarm spores (Figs. 555, 556). After coming to rest, these swarm spores apparently grow into normal resting cells.

The so called "red snow" of arctic regions is due to a closely related species of plant which propagates at freezing temperature.

Pleurococcus forms athin green coating in moist places on various surfaces, as tree trunks, earth, stones, and bricks. If a bit of the green matter is carefully removed, mounted in water, and examined with a magnification of 250 to 400 diameters, it will be seen to consist of aggregations of bright green cells. These cells consist of a cell wall and green protoplasmic contents.

In the latter, a nucleus may be seen in some of the cells which have been kept for half an hour in a saturated solution of iodine in a strong aqueous solution of potassium iodide (Figs. 587, 589).

[Insert Figs. 587, 591 here.]

Reproduction of Pleurococcus is by division. In the microscopic preparation referred to there may be seen cells grouped together and with more or less flattened common faces of contact. These may show two cells which have resulted from division of a single ancestral cell (Figs. 588, 589); three or four, from two such cells (Figs. 590, 591); and so on to aggregations of many cells (Fig. 592).

The thallus of Pleurococcus is a cell of spherical form - which is the simplest form we can imagine for an organism, is not differentiated into base and apex, and its successive divisions are by intersecting, not parallel, planes, so that masses rather than filaments or membranes result. The simple structure of Pleurococcus and other unicellular plants makes them of great interest for comparison with more highly organized plants.

Occurrence in lichen thallus.

Pleurococcus is the algal constituent in the thalli of many common lichens, as Physcia stellaris.

Nostocs resemble, under the microscope, long strings of minute bluish-green beads, intricately coiled and looped (Fig. 599) and imbedded in a jelly. In many kinds, colorless cells, termed heterocysts, h, occur at intervals in the filaments. Reproduction is by the long filaments breaking up into short filaments, which grow out into long filaments, or by spore formation. In spore formation, the contents of some cells may round off into spores and secrete a thick wall, somewhat similar to that of Cylindrospermum, Fig. 598, s.

[Insert Figs. 596, 599 here]

In Gloeocapsa, the descendant cells remain inclosed in the original gelatinous walls of ancestral cells, but each new cell secretes a new membrane about its own contents (Figs. 596, 597). Curious masses of 2, 4, 8, or more cells result, with many-layered walls. These masses eventually break up into the individual cells.

Relationship to Bacteria.

The Cyanophyceae are sometimes called the Fission Algae. The Bacteria are believed to have originated from them.

CYANOPHYCEAE

The Cyanophyceae are of a peculiar bluish green color. They exist as filaments or masses composed of many cells, (Figs. 591, 588). or as separate cells. The outer portion of the cell wallof many kinds is ina mucilaginous condition which makes the wall appear very thick when the living organism is examined in water and also causes its outer portion to appear rather indistinct. The Cyanophyceae usually occur in jelly-like masses in water or on moist surfaces.

Oscillaria, Nostoc, Cylindrospermum, and Gloeocapsa are easily recognized genera of Cyanophyceae.

Oscillaria forms a bluish green slime on moist mud in ditches and on other moist surfaces. If a bit of such matter be examined under magnification of 50 diameters, it shows straight or slightly curved rather stiff filaments radiating from the mass, as in Fig. 583. Under higher magnification, these filaments show several characteristic oscillatory movements, but all made slowly. One of these is a gradual swaying of the free end of the filament towards the right and then a similar movement an equal distance towards the left, and so on.

{Insert Figs. 593, 595 here}

The thallus.

The filaments of Oscillaria are composed of disk-shaped cells closely fitted together (Fig. 584). These filaments break up into short filaments, termed hormogonia, which are composed of only a few cells each (Fig. 585, h). The hormogonia grow out into long many-celled filaments.

~~{Insert Figs. 594, 596 here}~~

LICHENS.

~~Lichens are plants consisting of a Fungus and an Alga living together in intimate connection and together foring a compound thallus.~~ Lichens are very common on trunks of trees, on rails, stones and rocks, and on sterile ground. They endure extremes of heat and cold and prolonged drought, reviving and growing again when the conditions of moisture and temperature become favorable. They are found on mountain peaks and in the polar regions: "Riendeer Moss" is a species of Cladonia. Some common lichens are shown in Figs. 438 - 440.

The thallus of a lichen is in form

{Insert Fig. 438 here}

Frutículose, when it is shrab-like, as in the Usnea shown natural size in Fig. 439, and in Ramalina, both of which frequetly grow on trunks of shade trees.

Foliaceous, when flattened into leaf-like form but separable from the substratum on which it grows, as in Parmelia and Physcia (Fig. 438), both very common on trunks of shade trees.

{Insert Figs. 439 & 440 here}

Crustaceous, when the thallus has a very indefinite outline and is so closely adherent to the substratum on which it grows as to be a mere crust inseparable from it, as in species of Biatora and Lecanora which mottle beech trunks trunks and in the Placodium of Fig. 440, whose rusty-orange color adorns bowlider and ledge throughout our region.

Lichens are defined as plants consisting of a Fungus and an Alga living together in intimate association and together forming a thallus. The structure of the lichen thallus is shown in Fig. 441, drawn from a cross section of the thallus of Physcia ~~stellaris~~ In the figure, c represents the cortical layer of the upper surface of the thallus; u, that of the under surface; m, the medullary layer of interwoven filaments, called hyphae; g, the gonidial layer; r is a rhizoid, one of the outgrowths from the under surface of the thallus which attach it to the bark or other substratum.

{Insert Figs. 441 & 442 here}

The first three of the layers as given above belong to the fungus and consist of colorless hyphae. The hyphae of the cortical layers are short-celled and so consolidated together as to somewhat resemble in sections the parenchyma of flowering plants; hence here called pseudoparenchyma. The gonidial layer contains groups of ~~bright~~ green cells, which are the algal constituent of the thallus. Fungal hyphae run through the gonidial layer from the medullary to the upper cortical layer and extend about and among the algal cells. Under high magnification, the peculiar contact of the fungous hyphae with the algal cells may be made out, as in Fig. 442.

In most species of our lichens the algal cells are in a distinct layer of the thallus, as in Physcia (Fig. 441); but in some kinds of lichens they are scattered through the whole thickness of the thallus.

Apothecia are the fructifications of lichens (Figs. 438 - 440, a).

They are scattered over the upper surface of the thallus in Physcia and are shallowly cup-shaped or saucer-shaped bodies with a sunken black disk. They are fructifications of the fungous constituent.

A vertical section of an apothecium of Physcia is given in Fig. 443. The marginal portion of the apothecium is the exciple (2), having the structure of the thallus in Physcia. The essential part of the fructification is the hymenium (h), which consists chiefly of elongated sack-like mother cells, each an ascus and each containing eight two-celled ascospores. The asci stand side by side in the hymenium intermixed with slenderer thread-like organs, the paraphyses. An ascus and ascospores are shown highly magnified in Fig. 444.

[Insert Figs. 443 – 446 here]

The ascospores become scattered, germinate under suitable conditions, and develop a new thallus if in contact with algal cells of certain kinds. In the laboratory, the fungous growth from the ascospore has been made to complete its development on nutrient culture media, but in nature it must make contact with algal cells or starve. Algal cells of the thallus are capable of independent existence.

Vegetative propagation of lichens is by means of small bits of the thallus. These small pieces, consisting of algal cells and adnate hyphae, become detached from the rest of the thallus and burst out through the cortical layer in small powdery heaps, called soredia. Upon being scattered, these pieces may develop into complete thalli.

Spermagonium is a term frequently used in connection with lichens. Spermagonia are readily found in Physcia. They are more marginal in position than the apothecia, much smaller, and sunk in the thallus but with their location very exactly shown by their very minute blackened mouths which look as though pricked in the thallus with a dirty needle (Fig. 438, s). The spermagonium has hyphae projecting from its sides into the cavity of the organ. From the tips of these hyphae minute cells, called spermatia, are abstricted.

Development of apothecium. The apothecia of lichens originate in the interior of the thallus. In most species of our lichens, these fructifications grow outward through the thallus in early stages of their development and stand above it with concave, plane, or convex hymenial surface. Such fructifications are discomycetous (gymnocarpous of older books). In some lichens the fructification remains buried in the thallus and opens to the exterior by only a minute pore, as in Pyrenula: such are pyrenomycetous (angiocarpic).

The adhering parts of the thallus carried upward by the apothecium constitute its exciple. The exciple is therefore

Thalline, when it has the structure of the thallus, containing both algal cells and fungous hyphae arranged as in the thallus, as in Physcia (Fig. 443, e).

Proper, when no algal cells are present in the exciple, as in Lecidia.

MYXOMYCETES

The Myxomycetes are a group of organisms in the border-land between plants and animals. In young stages, Myxomycetes resemble the Protozoan animal, Amoeba, but in their mature stage of fructification, they assume plant-like conditions. The fructifications, termed sporangia, are varied in form (Figs. 515, 517). Some of them are very likely to attract the attention by their dainty, graceful forms and by their colors, ranging from white, yellow, and red to rich brown and green. They are most likely to be found on the sides of old logs and stumps in moist woods from July until winter.

Three stages may be described in the life history of most Myxomycetes, as follows:-

1. Swarm-spore or amoeboid stage. Upon germination of the spores (Fig. 518) in water, there issues from each a naked mass of protoplasm which protrudes a single cilium and is called a swarm-spore (Fig. 519). The swarm-spore swims about with a jerky, dancing motion by lashing strokes of its cilium. After a time, the cilium is ~~withdrawn and the~~ drawn in and the little mass of protoplasm creeps over moist surfaces, protruding pseudopodia and closely resembling an amoeba (Fig. 520).

{Insert Figs. 515-521 here}

2. Plasmodial stage. When two or three of these amoeboid cells creep into contact with one another, they coalesce into a single mass which attracts other amoeboid cells to it. The resulting mass is called a plasmodium (Fig. 521); it creeps

about in dark places over the surface of rotten wood, bark, or leaves, or sinks deep into such matter, on which it feeds. The plasmodium is a mass of protoplasm of about the consistency of thick cream, usually white, yellow, or red in color. It may cover a surface of several square inches.

3. Stage of fructification. In most species the plasmodium eventually emerges to the light and air and shapes itself into fructifications, the sporangia, which contain the spores (Fig. 518). The sporangia are either simple, although often clustered together (Figs. 515, 516), or combined into cushion-like masses, aethalia, consisting of contorted and imperfectly developed sporangia (Fig. 517).

Mode of life.

Most species of Myxomycetes are saprophytic in mode of life; but there is one species, Plasmodiophora Brassicae, which is a parasite in roots of the Mustard Family, causing a serious disease in the roots of the cabbage and the turnip, as a result of which the affected parts become swollen and distorted, hence the common names for the disease of "club root", "finger and toes", etc.

Practical Exercises on Cryptogams.

Sections. Sections are thin slices cut to reveal the internal structure of objects, or their three dimensions.

P – A median longitudinal section is one cut lengthways through the middle of the object. It contains the long axis of the object. In practical work, the adjacent sections on either side can often be used in its stead.

Cross-sections or transverse sections are those cut perpendicular to the long axis of the object.

Tangential sections are those ~~cut~~ cut from the more superficial regions of an object parallel to a tangential plane.

Vertical sections are sections cut through an object perpendicular to some plane surface stated or implied.

Optical sections are the section-like views of the interior structure of an object to be had with a compound microscope by skillful focussing. They are due to the fact that this instrument shows most distinctly the points ~~of~~ a sufficiently transparent object which lie in a plane at a fixed distance beyond the end of the objective and perpendicular to the central line through the eye-piece and objective;

Portions of the object between the plane of the optical section and the end of the objective always blur somewhat the distinctness of outline of parts seen in optical section. The pupil should try to look beyond these intermediate portions, as through a veil at the features beyond it.

Sectioning. There are various elaborate but time-consuming methods of ~~cutting sections~~ section-cutting which must be used in many advanced botanical investigations; but such methods are not necessary in an elementary course, since any one who can deliberately thread a needle can learn to cut excellent sections free-hand. The fern-leaf to be sectioned in Exer. 38 is one of the best objects for a first lesson in section-cutting.

Small objects and soft or flexible objects are held between the jaws of a holder made from elder-pith by splitting a rod of pith longitudinally at one end for about three-fourths of an inch.

To cut vertical sections through the sori and fern-leaf referred to, a small piece of a leaf bearing sori should be inserted into the slit in the pith holder so that the broad faces of the leaf lie parallel with the faces of the slit. Hold the jaws of the pith together against the leaf with the thumb and index finger of the left hand, as shown in Fig. 600,

{Insert Fig. 600 here}

and then, with the section razor, shave off thin slices across the end of the pith and through the fern-leaf and sori.

The razor should be held by the right hand exactly as a common razor is held in shaving (Fig. 600). A small pool of alcohol is kept on the concave upper surface of the razor while sectioning and this alcohol should be kept near enough the edge of the razor so that as the sections are being cut, they may float without friction on the surface of the alcohol.

The sections should not be chopped off as a cook slices potatoes, but instead the whole length of the edge of the razor should be used in cutting each section. That is, in advancing through the object, the whole length of the edge from heel to point or from point to heel should be drawn through the object.

Try always to cut sections of the utmost tenuity. Thin sections are easily drawn because their structure is clearly shown: thick sections are more difficult to understand. Potassium hydrate, used in 7% solution in water, is a friend in time of need if your sections do happen to thick. It renders clearer and more transparent the sections which are treated with it. It is invariably used on material which has been stored in alcohol, as it restores in some degree the natural turgidity of the tissues of such material. It is less necessary with material preserved in formalin.

After ~~the~~ a sufficient number of sections have been cut, some water is poured on them and they are floated and pushed towards the point of the razor. They are then abruptly poured into a watch glass. The watch glass is a convenient dish in which to keep the sections while sorting out the pith and also while looking over the set of sections with the dissecting microscope in order to select the thinnest and most perfect for further study.

As soon as the sections have been emptied from the razor into the watch glass, the razor should be wiped dry with a cloth and then stropped and put away ready for use when needed again.

Pteridophytes

Exercise 38. A Fern, sporophytic generation.

Examine a fern in fruit. Decide which of its organs are like those of Phanerogams and which are different from those of Phanerogams.

Drawing. A careful sketch of this fern, reduced in size to a height of 4 in. Point out in the sketch the several parts as root, stem, leaf, etc., in each case noting your reasons, based on general form and structure, for applying a name which you have heretofore used only for Phanerogams. That is, how is the organ you call a root, root-like?

On the under surface of some leaves (the fertile leaves) you find masses of small brown objects. Look closely at these masses (each a sorus or fructification) with a magnifying glass. What is the form of the small brown objects (sporangia)? Does the sorus consist of other organs besides the sporangia? If so, describe them and form an opinion as to their probable use to the sorus.

Drawing. A portion of a fertile leaf, showing the sori, ~~and~~ their form, and their arrangement with reference to midrib, veins, or margin of the leaf. (X3 to 5)

Cut from the fertile leaf a small square piece bearing sori and insert it in the slit in the pith holder in the proper position for cutting vertical sections through both ~~the~~ leaf and sorus. Cut a series of thin sections with the section razor, as directed on a preceding page.

Place a drop of water on the center of a clean glass slip, add to it a drop of potassium hydrate. Then select from the sections immersed in water in the watch glass one section which shows well, upon examination with the magnifying glass, the attachment to the leaf of the several parts, and place this section in the fluid on the slip. Then lower a clean cover glass on the fluid and section. This operation is called <u>mounting</u> the section in water and potassium hydrate. A cover glass is always placed over any object in fluid which is to be examined with the compound microscope.

Study this mounted section with the dissecting microscope, or preferably with a compound microscope and magnification of 50 diameters. You should see sporangia, paraphyses (hair-like bodies), indusium (a covering membrane), and the internal structure of the fern leaf.

<u>Drawing</u>. Vertical section of fern leaf, showing the attachment to the leaf of the parts of the sorus. (Magnified so that the ~~figure~~ drawing will be 2 in. square.)

Examine ~~ripe~~ mature sporangia with the magnifying glass. Find the ring, also the slit through which spores are thrown,

the cavity in which spores are contained. The spores
P may be found by tearing open in a drop of water on a glass slip, a ripe sporangium which has not yet discharged its spores. Add to the drop some sporangia and then lower over the preparation a cover glass. Examine this mount with the compound microscope, using magnification of 70 diameters.

Drawing. A sporangium, showing its parts. (The figure should be an inch in diameter.)

Drawing. A spore. (Magnified to diameter of 1 in.)

Exercise 39. A Fern. Pteris cretica, gametophytic generation.

Clean the earth away from the under surface of a fern prothallium without injuring the prothallium. This cleaning is best done with dissecting needles and forceps while the prothallium is immersed in water in a watch glass.

Examine the prothallium carefully, noting the difference between its upper and lower surfaces, and its differentiation into base and apex. The latter, the more luxuriant and with its cells bright green, is situated at the inner end of the notch or sinus. Examine with the dissecting
P microscope the hair-like rhizoids which extend from the prothallium into the earth and search also for other

outgrowths of the prothallium about or among them. The archegonia are most likely to be in the region between the rhizoids and the sinus, and the antheridia on the older parts of the prothallium between the rhizoids. These organs may be more readily seen by using a lower power of the compound microscope, provided the prothallium is mounted temporarily in water on a glass slip, as directed for the sporangia and spores of the fern.

Drawing. ~~Under side~~ of fern prothallium, showing the several parts and outgrowths of the prothallium. (X 5)

Insert the prothallium base downward in the slit in the pith holder to such depth that the apex (at end of sinus) of the prothallium is slightly below the end of the pith. Then cut many thin cross-sections of the prothallium. Select two of the thinnest of these sections. One of the selected sections should bear rhizoids and the other should be without them. Mount these sections in water and potassium hydrate.

Search the mounted sections with the compound microscope, using a magnification of 70 diameters for preliminary examination and location of the archegonia (flask-shaped bodies partially imbedded in the prothallium) and antheridia (wholly on the outside of the prothallium but not filamentous). Each of these organs is then to be examined critically, using magnifications of

250 and 400 diameters.

Use now the smallest diaphragm which will not give the disagreeable effect of a dark shelf ~~partially cutting off~~ between the image and the source of light, and by carefully and slowly focussing down on an archegonium, you may look into its interior and see, if the archegonium is mature, the tubular canal extending down through the neck to a rather large, spherical cell (oosphere) which nearly fills the interior of the main and swollen portion of the archegonium.

Drawing. Diagram of an archegonium, showing its cellular structure as seen in longitudinal optical section. (Magnified to length of 2 inches.)

Examine in the same way an old antheridium; also a younger antheridium whose wall is not burst open. While in the antheridium, the spermatozoids show as small colorless objects. By comparison of the two antheridia, locate the mother cell in which ~~they~~ spermatozoids develop. Form an opinion as to ~~the~~ how the spermatozoids are set free.

Drawing. Diagram of an antheridium, showing its cellular structure as seen in optical longitudinal section.

(Magnified to diameter of 1 in.)

Examine, using a magnifying glass if desirable, a prothallium which has a young fern plant (sporophyte) attached to it. From which side of the prothallium does the fern plant spring? From the area occupied by antheridia or that of the archegonia? What are the parts of this young fern?

Drawing. Prothallium and young fern, showing their connection. (X 5)

Exercise 40. Equisetum and Isoetes or Selaginella, sporophytic generation

Illustration 1. Examine a plant of Equisetum which has underground, as well as aerial, parts. Locate parts which are undoubted roots and other parts which are certainly stems. Are not all the underground portions roots? State reasons for your opinion. Divide lengthways into halves a portion of
R stem which will be provided for this purpose. Is the internal structure of the stem at the nodes like that of the internodes?

The leaves of Equisetum are scale-like; what is their arrangement on the stems? What is their color? What organs have the foliage function?

Some plants of Equisetum are branched. The branches may be recognized by their close resemblance in structure to the stems from which they spring. Do these branches invariably start from the stem in the leaf-axils, as branches do regularly in Phanerogams? If the stem be split longitudinally in a plane through the base of the branch, the true relation of parts to each other and the stem may be seen in any doubtful case.

Drawing. An Equisetum, complete plant. (Reduced to length of 4 to 6 inches, if you have a large specimen.)

Examine the flower-cone of Equisetum. Its sporophylls (peltate in form) are arranged how along the axis of the flower? Remove one or more sporophylls from this axis and study one of them with the dissecting microscope. The sporangia containing the spores are situated where on the sporophylls?

Drawing. A sporophyll, showing the sporangia. (X10)

Place some of the spores on a glass slip but do not wet them nor put a cover glass over them. Look at these spores through the compound microscope, using a magnification of 50 or 70 diameters. While ~~still~~ watching these spores through the microscope, breathe gently down on them - not to displace them but merely to dampen them with the moisture of the breath. Observe the position that the elaters (appendages) take with reference to the body of the spore as they are alternately moist and then dry again.

Do you see spores of more than one kind?

Drawing. Spores of Equisetum, sporophytic generation. (Magnified to diameter of 1 in.)

Illustration 2. Examine fertile plants of Isoetes or Selaginella so as to make out their general structure. The sporangia are borne on some of the leaves — on their axil-side almost at the base of the leaf. Find leaves which bear sporangia.

Drawing: Diagram showing the location on the fertile leaves or sporophylls of the sporangia. (X 5)

Are the spores of the same sporangium alike in form and size? Do the spores of different sporangia differ in form and size? How many kinds of spores do you find? Is there constancy in the relative positions of these unlike kinds on the plants?

Make temporary mounts in water of spores of each kind and examine each with the compound microscope, using first low and then high magnification. Macrospores and microspores are terms applied respectively to the larger and smaller spores produced by some Pteridophytes.

Drawings. A single spore of each kind found. (These drawings should represent the spores very highly magnified but with the same magnification.)

Exercise 41. A. Moss, gametophytic generation.

Examine with the naked eye and with a magnifying glass a "moss plant". Of what parts does it consist? ~~It is a shoot (cormus) consisting of stem, leaves, and rhizoids.~~ The hair-like bodies are ~~rhizoids are hairlike~~ rhizoids, ~~folia~~ which have for the "moss plant" the function of roots but not the structure of roots.

Drawing. The "moss plant" (x 3). Point out its parts.

Detach from the moss plant one of its most typical leaves and also a rhizoid. Mount each of these objects in a drop of water and examine each carefully with high power of the dissecting or lowest power of the compound microscope. Do you find in the moss leaf a midrib and skeletal framework like those of leaves of the Flowering Plants and Ferns?

The rhizoids do not contain chlorophyll but in other respects have structure ~~somewhat~~ like that of the protonema which bears moss plants as its erect branches.

Drawing. Both the leaf and the rhizoid, sufficiently magnified to show structure. The under surface of the leaf is the more instructive surface.

Microscopical. 1. Cutting and preparing longitudinal sections of the upper end of the moss plant. Cut the stem of the moss plant in two 1/8 to 1/4 in. below the apex of the stem. Insert, leaves and all, the piece having the apex into the slit of the pith holder in such position that the long axis of the stem will lie parallel with the upper edges (not sides) of the slit. It is well to tuck some of moss leaves down deep into the slit so that the moss stem may not slip in the least while being sectioned. If the short piece of moss plant is now accurately placed in the pith, it should next be cut into thin longitudinal sections, as a log is cut into boards, when slices are shaved off from across the end of the pith and the object it holds. Try to cut these sections of the moss plant truly longitudinal and so thin that half a dozen are obtained from the piece. Float and wash the sections of moss plant and pith into a watch glass, cull out the pith, then mount on a glass slip in a drop of water two or three of the sections which, upon examination of the whole lot with the dissecting microscope, appear to be most nearly median longitudinal sections. (The outer (slab-like) tangential sections often afford good antheridia but usually so hidden among the leaves as to be of little value to the beginner.)

Add potassium hydrate to the drop containing the section, cover all with a cover glass, and the preparation is ready for study.

2. Study of the sections. Examine these sections with the compound microscope, using magnification of 50 to 70 diameters. Fragments of leaves are attached along the sides of the stem. From the somewhat flattened

apex or receptacle of the moss plant there may stand out archegonia (flask-shaped in form), antheridia (cylindric or barrel-shaped) and paraphyses (hair-like). If the sections are from a moss plant of a bisexual species, both antheridia and archegonia are likely to be found on the same receptacle; but if dioecious, only one kind of these organs will be found on any moss plant.

Drawing. Median longitudinal section of tip of moss plant, enlarged to length of 2 to 3 in. Point out the parts.

Examine both an archegonia and an antheridium using magnifications of 250 and 400 diameters. The terms applied to the parts of these organs are those used in Ex. 39 for archegonia and antheridia of Ferns. What differences do you observe between the Fern and the Moss with respect to (a) the archegonium; (b) the antheridium?

Drawing. Diagram showing the structure of the archegonium of the moss, as seen in optical longitudinal section. Point out its parts.

Drawing. Similar diagram of the antheridium. Point out its parts.

(Note.—Sometimes a set of sections may have an archegonium very much larger than the others. Look carefully into the interior of the swollen basal portion of such an archegonium. It may often be seen to contain the embryo of the sporophytic generation, as in Fig. 418, e. f.)

Exercise 42. The Moss, sporophytic generation

Compare the fruited moss of the present exercise with your drawing of a moss plant in Ex. 41. Which part of the plant before you belongs to the gametophytic generation of the preceding exercise? The additional parts which you now see, belong to the sporophytic generation of the moss. These parts are capsule (globose or pear-shaped upper end of sporophyte), pedicel (stalk supporting capsule), and foot (lower end of sporophyte, wedged into upper end of moss plant). A small chaffy body termed calyptra, is sometimes to be seen on the apex of the capsule. If you find the calyptra examine it carefully. Does it resemble anything you saw in Ex. 41?

Drawing. The moss plant in fruit. (Natural size or X2) Name its parts. Indicate which parts belong to the gametophytic generation and which to the sporophytic.

After removal of the calyptra, observe the helmet-shaped apex (operculum) of the capsule. Detach the operculum from the capsule and you expose the peristome. Are the teeth or parts of the peristome separate at their peripheral end and capable of recurving? How many rows of these teeth? How many teeth compose the peristome?

If you wish to use the low power of the compound microscope for counting the teeth, the pith holder may be used to hold the capsule in such position on the stage of the microscope that you may look down on the peristome. To do so cut the pedicel in two so as to leave a short piece attached to the capsule. Insert this piece into the slit of pith holder from the side.

After wetting with alcohol the capsule which you have been studying, you may tear it open in some water and potassium hydrate on a glass slide. Spores of the sporophytic generation will be set free in the fluid. Tear off also one or more teeth of the peristome. Cover these spores and teeth with a cover glass and then examine them with the compound microscope, using magnification of 70 and 250 diameters.

Drawing. The capsule with operculum removed, so as to show structure of peristome. (x10).

Drawing. A spore and a tooth of the peristome as seen with magnification of 70 diameters.

Note concisely in what respects the sporophyte of the Moss (a) differs from that of the Fern, and (b) resembles that of the Fern.

Exercise 43. A Hepatica: Marchantia, general morphology.

Examine and compare with the Moss studied, the plants of Marchantia to determine which parts have the vegetative or foliage function and which parts are reproductive or fruiting organs.

The vegetative portion of Marchantia is a thallus. How is this thallus attached to the ground? How does this thallus differ from the vegetative shoot of a Moss or Fern?

Find the stomata. They are much larger than those in the leaves of Flowering Plants. What is the extent of the chambers into which they lead?

The cups found occasionally on the upper surface of Marchantia contain gemmae. Are the gemmae quite loose in the cups? What is the form of a gemma? Marchantia may be grown from gemmae as Flowering Plants are grown ~~may be from~~ buds or bulbils by a gardener.

The erect branches which rise from the thallus, terminate in receptacles. The male receptacles are

are more discoidal in form and contain antheridia.

The female receptacles are deeply divided into finger-shaped rays. Do the female receptacles grow on thalli which bear the male receptacles? The archegonia are pendant from the under side of young stages of the female receptacles and are readily found if vertical sections of such stage are prepared and examined with the compound microscope. By the time the female receptacle attains its full size, the oospheres have been fertilized in their respective archegonia and have gone on with their development, each into a sporophyte.

With the dissecting microscope, find these sporophytes as they are suspended from the fruiting female receptacle. Their protruding parts when fully mature are capsule and pedicel, but the pedicel does not elongate and push the capsule out through the wall of the archegonium until the capsule is just about mature and ready to burst. The loose membranous envelope outside the archegonium is termed perianth. Find the younger as well as the fully mature stage of the sporophyte.

Drawing. The sporophyte in both a fully mature stage and in a young stage. (X10). Name the parts.

Mount in water and potassium hydrate some of the spores and elaters which protrude from a ripe capsule. Examine with a low and then with a high power of the compound microscope.

Drawing. A spore and an elater, highly magnified.

Drawing. Male and female plants of Marchantia, about natural size. Point out their parts.

Thallophytes.

Exercise 44. Lichens. Physcia.

Examine carefully the specimen of Physcia. What is the form of its vegetative body? Does this vegetative body consist of both stem and leaves? Do the upper and under surfaces of the vegetative body (thallus) of Physcia look alike? What kind of bodies do you find in or rising from the upper surface of the thallus? Such bodies are termed **apothecia**, if cup-shaped; spermagonia, if they have very minute blackened orifices (to be looked for on the marginal lobes of the thallus); and **soredia**, if wart-like powdery masses.

What term will you apply to the outgrowths from the the under surface of the thallus? What seems to be the use to the lichen of these outgrowths? You can find these outgrowths on the under side of the thallus of lichens, the same species of which grows equally well on bark of living trees, old boards or rails in fences, and the hardest and most insoluble bowlders.

Drawing. Lichen on a piece of bark, natural size. (The form of the margin and its lobing is very characteristic in the different species.) Point out and name the parts in the drawing.

With the scalpel cut out from a dampened and pliant specimen provided for such destructive use, a small square of the thallus whose edge should not exceed the diameter of the pith holder. This square portion of thallus should bear one or more well developed apothecia – probably not the very largest and certainly not the smallest ones. Insert this piece of thallus and its apothecia edge downward in the slit in the pith holder so that the natural upper and under faces of the thallus will lie parallel with the faces of the slit.

Cut a series of sections across the end of the pith holder and through both the apothecia and thallus. After the sections are in water in the watch glass select that section which shows best the connection of all the parts or layers common to both the apothecium and thallus, and the thinner the section is the better. Select also the thinnest section of the thallus, or one which tapers out very thin at one of its ends. Mount both of these sections in water and potassium hydrate. Save the other sections in the watch glass until the end of the exercise.

Study with magnification of 250 to 400 diameters the structure of the thallus from upper to lower surface. This structure is shown most clearly where the section is thinnest. What is the cellular structure of the upper surface? of the under surface? of the region between these surfaces? To what is the green color of the thallus due? What is the form of these bodies? Do you see any colorless filaments (hypha) in the thallus abruptly expanded into one of the green bodies? Are the green bodies, in your opinion, greatly distended and green-colored portions of the hyphae, or distinct bodies occupying spaces between the hyphae, or what is their relation to the hyphae?

Drawing. Vertical section of thallus of lichen, as seen highly magnified. Beginning at the upper surface, name the layers of the thallus in their order; cortical layer of upper surface, gonidial layer, medullary layer, cortical layer of lower surface.

Drawing. Vertical section of apothecium and thallus, showing the attachment of the apothecium to the thallus and the relation of its constituent layers to those of the thallus as seen under magnification of 50 diameters.

The marginal part of the apothecium is the exciple.

The depressed upper surface of the apothecium is the hymenium. What parts compose the hymenial layer and how are they arranged? If the section is very thin you may determine the answer by study of a portion of the hymenium under magnification of 250 or 400 diameters. ~~with the 6 m. objective.~~

If the structure of the hymenium does not show clearly, take the apothecium portion of a thin section out from the watch glass and mount it in equal parts of water and potassium hydrate. After covering with a cover glass, soak up with filter paper the excess of fluid at the margin of the cover glass and then press down gently on the upper surface of the cover glass with the forceps in order to spread apart somewhat the parts of the hymenium by crushing it.

Examine a portion of the hymenium in this preparation. The dark colored ellipsoidal bodies are the **ascospores**. The ascospores appear grouped together; from this grouping, what do you conclude as to how and where they are produced? What is the largest number of ascospores which you find in one natural group? Is it not the usual number?

Drawing. A single ascospore, highly magnified.

Drawing. An ascus (mother-cell) containing the maximum number of ascospores.

Drawing. A paraphysis, one of the slender bodies which stand between the asci in the hymenium.

Exercise 45. Fungi. Basidiomycetes. Fructification of a Toadstool.

Without injuring the specimen, observe its several parts and general structure. It is the fructification of a plant whose vegetative body or thallus, which has here the special name mycelium, was left buried in the soil when the fructification was gathered. The full complement of parts which some toadstool fructifications have are pileus (cap), stem, volva (bag enveloping base of stem), annulus (collar-like membrane about upper part of stem), lamellae (thin leaves or plates on under surface of pileus).

Drawing. Side view of toadstool to show its parts. Point out and name the parts of this toadstool. (X3, if the small Coprinus grown in laboratory culture is used; natural size, if larger toadstools of fields are used.)

Insert pieces of two or three lamellae which remain joined together at the pileus, in the pith holder in position for cutting cross sections, and then cut a series of very thin sections. (If the small Coprinus of laboratory culture is used, drill a cylindrical hole nearly as large as the pileus down into the end of the pith holder between its two jaws. Insert the pileus, in unexpanded condition, into this hole, and then cut thin cross sections of the object. They will afford instructive cross sections of all the lamellae, attached to the substance of the pileus on the outer end and resting against the stem at the center.)

Place some of these sections in water and potassium hydrate on a slip, and after draining off this fluid and then rinsing away the last trace of it with a couple of drops of pure water, finally mount them in water and add a little eosin solution to stain the colorless portions of section red.

Study the sections with compound microscope, using power of 50 diameters to see general structure of the sections and to find the thinnest place of a lamella, then change to 250 to 400 magnification.

The small globose or ellipsoidal bodies (brownish-black in color if you have sections of Coprinus) which you find scattered about or grouped in certain regions, are basidiospores.

Drawing: A single basidiospore, highly magnified.

Some basidiospores are scattered about, perhaps by our methods of preparing the section, but the most appear to be grouped together. Do you detect the cause of the grouping? Is it the same as that for the grouping of the ascospores of lichens?

The large cells which bear the basidiospores are termed basidia. What is the maximum number of basidiospores per basidium?

Drawing. A single basidium and its basidiospores, highly magnified.

The layer composed of the basidia, sometimes alternating with sterile cells, termed cystidia, is the hymenium. Does the hymenium cover both surfaces of a lamella? Is the hymenium of one lamella connected with that of the next? The layer of cells in the middle of a lamella is the trama.

Drawing. Cross section of a small portion of lamella to show ~~show~~ its parts, as seen magnified 50 diameters. Point out and name the parts.

Exercise 46. Aecidiomycetes. Grain Rust.

1. Teleutosporic stage. Note the distribution on the stem of wheat or oat stubble of the dark masses of teleutospores. Do these teleutospores seem to have originated wholly on the outside of the stem, or do they project out from the interior of the stem?

Moisten one of the masses of teleutospores first with alcohol and then with water. Detach some spores from the mass and mount them in water and potassium hydrate. Examine these spores with the compound microscope using powers of 50 and 250 to 400 diameters. Of how many cells does each spore consist? Can you see the thickness of the wall, and where the inner surface of the wall is in contact with the protoplasmic contents of the spore?

Drawing. Wheat or oat stem showing distribution of the masses of teleutospores. (Natural size.)

Drawing. A teleutospore, showing its structure, as seen highly magnified.

2. Aecidial stage. Find on young barberry leaf the prominent wart-like aecidia of grain rust. On which surface are they? Examine the opposite surface with a magnifier; do you find

anything indicating abnormal development there?

Cut a series of thin vertical sections through the aecidium and the leaf, as you did of the apothecium and lichen thallus. Mount some of the thinnest of these as usual.

Examine these sections with compound microscope, using magnification of 50 and then 250 diameters. What is the structure of the aecidium? How are the globose aecidiospores arranged in the aecidium? Can you detect hair-like hyphae in the intercellular spaces of the leaf? Can you trace any of the hyphae to the aecidium? Spermagonia, flask-shaped in form, will now be found imbedded in the side of the leaf opposite the aecidia.

Drawing. Cross section of the leaf, showing aecidium and spermagonium, as seen under magnification of 50 diameters.

Drawing. A single aecidiospore, highly magnified.

Exercise 47. Ascomycetes.

Illustration 1. Pyrenomycete. Microsphaera Alni Lilac Mildew.

Examine closely the surface of the lilac leaf, using the 1 in. magnifier. Do you find the delicate white filaments, which cover, more or less densely, the greater part of the leaf, to be connected with the small spherical, often black, bodies which may be seen in places on the leaf? The interlaced white filaments are the hyphae which together compose the peculiar thallus, termed a mycelium, characteristic of Ascomycetes as well as of Basidiomycetes. The spherical bodies are fructifications (perithecia) produced by this mycelium.

Moisten with water the mycelium on a small portion of the leaf. Attempt gently to lift some of the dampened hyphae from the leaf with a dissecting needle and watch the hyphae through the magnifier while making the attempt. Are they attached to the leaf?

Drawing. The mycelium and perithecia of lilac mildew on the lilac leaf, natural size. Point out these objects.

Cautiously separate some of the moistened mycelium from the leaf by inserting a sharp scalpel between the two. Mount this mycelium in water and potassium hydrate. Examine with the compound microscope.

Drawing. Portion of a hypha of the mycelium, showing its structure and branching.

Remove in the same way one or more fructifications (perithecia) from the leaf and mount them in water and potassium hydrate. Examine, using magnification of 50 and 70 diameters. Observe the form and branching of the colorless hyphal appendages of the perithecial wall. Do you find an opening from the interior of the perithecium?

Crush a perithecium by pressing down on the cover glass with forceps. Examine again, using magnification of 250 to 400 diameters. Some of the contents of the perithecium have been protruded through the wall. Apply to these contents the same terms already used for corresponding bodies in the lichen apothecium.

Drawing. Perithecium and its appendages, as seen under magnification of 50 diameters.

Drawing. An ascus containing ascospores, as seen highly magnified.

Illustration 2. Discomycete.

Examine the specimen supplied. The flattened or saucer-shaped portion is a fructification, termed apothecium. Do you see any hyphae extending upward into the apothecium from the buried mycelium which produced the fructification?

Drawing. The apothecia on the substratum of wood or soil — a habit drawing, natural size.

Cut out from the rotten wood on which the apothecia rest a small portion supporting one apothecium, and insert this in the pith holder so that you can cut vertical sections down through the apothecium and lengthways of the fibres of the wood.

If the apothecia are not seated on wood, merely cut vertical sections of a single apothecium. Mount one or two of the best median sections either temporarily in water and potassium hydrate as usual, or after staining as in the case of the lamellae of a toadstool.

Examine the sections with compound microscope using magnification of 70 diameters. Do you find hyphae of the mycelium in the rotten wood? What is the relation of the apothecium to this mycelium? What is the structure of the apothecium? What fructification of the same general structure have you studied heretofore. Apply to this the same terms so far as they seem applicable.

Drawing. Vertical section of an apothecium and the mycelium and wood from which it springs, as seen under magnification of 50 to 70 diameters.

Examine, with magnification of 250 to 400 diameters, a thin portion of the hymenium of the mounted specimen; or if too thick to show the structure clearly, mount another section but of only the apothecium, in water and potassium hydrate and then crush the section by pressure on the cover-glass until the parts of the hymenium are sufficiently distinct. How are the spores borne? What is the characteristic number per ascus? How do the spores escape from the ascus? Can you distinguish between the wall of a spore and the protoplasmic contents?

Drawings. An ascus containing ascospores; an ascospore, a paraphysis. All as seen highly magnified.

Exercise 48. Phycomycetes. Rhizopus nigricans, Common Black Mould.

Illustration 1. Non-sexual generation.

Look closely through the glass side or cover of the crystallizing dish at the culture of Rhizopus. How does this mould spread over the bread and perhaps even against the sides of the dish? Do there any recognizable difference between the parts of this mould which are held up in the air and those parts which are in contact with the bread or glass?

With the forceps pick out from a marginal portion of the mass one or two branched hyphal portions of the mould which will give a fair sample of the structure of the whole mycelium. Place these samples in some alcohol on a glass slip. Drain the alcohol from the slide and put some water on the mould in its place, and then add some potassium hydrate. With dissecting needles next arrange the mould in this fluid into as natural form as possible, disentangling specimens which have become matted together, and watching the work through the dissecting microscope; next cover with a cover glass.

Study the mounted mould, using the dissecting microscope and 1 in. magnifier, with which the general structure can be just made out; ~~but~~ or using preferably magnification of 50 diameters with compound microscope if there are plenty of such microscopes. Do you find cross walls anywhere in the hyphae? Observe rhizoids, also sporangia (globose ends of the erect hyphae). Focus carefully on a hypha, using magnification of 400 diameters. Can you distinguish a cell-wall and protoplasmic contents for the hypha? What is the distribution of the protoplasm in the hypha? What is the structural appearance of the protoplasm?

Drawing. Rhizopus nigricans, Black Mould, — habit drawing showing the stolon-like connection of a young plant with the parent plant and also showing the parts of a plant, (X10).

Examine young and old sporangia using magnification of 70 and 250 diameters. You see numerous spores scattered about in the preparation; where do they originate? How do they become free?

Drawing. Longitudinal diagram of the structure of a sporangium whose spores are not yet mature, as seen in optical section. Columella is the term for the partition wall separating the layer of spores from the rest of the hypha.

Drawing. An old sporangium most of whose spores have been set free. Indicate the identity of the parts here with those of the previous diagram.

Drawing. A single spore (conidium), as seen with magnification of 400 diameters.

Illustration 2. Sexual or zygosporic stage of Rhizopus nigricans.

Transfer a little zygosporic material of ~~Black Mould~~ Rhizopus to water on a slip and move the mass up and down and about in the water to wash out the bread from the material. Drain off the water and repeat the washing until the bread is wholly wased away. Then mount the material in potassium hydrate and water but before covering with the cover glass tear apart the material sufficiently with dissecting needles so that the structure and relations of parts can be seen in any part of the specimen. But very little zygosporic material should be used for the mount.

Examine the mount with the compound microscope, using magnification of 70 and 250 diameters. The comparatively large, dark-colored spherical objects in the preparation are zygospores. The preparation shows several, perhaps all, stages in the production of zygospores by the mycelium; what are these stages? Are the zygospores as dark-colored in all stages of their formation as when fully mature? Does the zygospore develop from a single cell?

Drawing. Series of stages in the production of zygospores by the hyphae of the mycelium, as seen highly magnified.

Exercise 49. Saccharomycetes. Common Yeast.

Fermentation. Observe what visible change is occurring in the bottles containing a quarter of a yeast cake and some sweet cider or the same amount of yeast and water sweetened with a little sugar or some juice from canned fruits. The fluid in the bottles was clear before the yeast was shaken up with it yesterday and it was also clear as soon as the yeast had settled to the bottom of the bottles. Can a change in the nature of the fluid be detected by taste?

The light has been excluded from one of the bottles and the other has stood in the light, is there any appreciable difference in what is going on in the two bottles?

The nature of the bubbles of escaping gas may be tested while the morphological work indicated in the following paragraphs is being done and after material for such work has been taken from the bottles. These tests are,—

(1) Lower a small lighted splinter into the gas which fills the space in the neck of the bottle above the fluid. What is the result?

(2) Insert a perforated rubber stopper into the neck of the bottle so as to conduct the gas through glass and rubber tubing fitted to the stopper, down into a dish of lime water. The end of the tube should reach below the surface of the lime water. Do the bubbles of gas change the appearance of the lime water in the course of perhaps fifteen minutes or more?

Carbonic acid gas, as tested, would extinguish the flame of the splinter and cause the lime water to become milky.

Morphology. Take a drop of the turbid fluid from one of the bottles, ~~and~~ place it on a slip, and cover with a cover glass. Examine the mount using a magnification of 250 to 400 diameters. The innumerable small, ovoidal, non-motile bodies which you see are probably complete yeast plants, but bacteria and starch grains are also present in the preparation. The yeast plants are much smaller than the starch grains and much larger than the very minute and nearly invisible bacteria.

Is the ovoidal body of the yeast plant a thallus? Can you see yeast plants in a position showing their third dimension, that is thickness? Are the two ends of the yeast plant exactly alike in form and in function? If not you may indicate one end as base and the other as apex.

Do you see two yeast plants which float about in the mount so that you are certain of their being connected together? What stages do you see in the formation of two full grown plants from a single plant? Are the descendant plants produced from any particular region of the parent plant?

Drawings. A single yeast plant. Stages in the formation of two mature plants from one. (As seen highly magnified).

Remove the preparation from the microscope and run under the cover glass a drop of iodine solution in potassium iodide. Lift and lower the cover glass at one edge with the dissecting needle so that the iodine solution will be distributed about the yeast plants or cells.

Examine the preparation again. Iodine stains protoplasm brown; are any portions of the cells so colored? Vacuoles less intensely stained than the protoplasm about them, are likely to be seen in the interior of the cells. Do you find a cell-wall? If there is a wall, perhaps gentle pressure on the cover glass with the forceps may burst the wall and cause the protoplasm to protrude through the fissure, but objective should be raised far above the preparation before exerting such pressure.

Drawing. An optical section of a yeast cell, showing its structures.

Exercise 50. Bacteria. Bacteria of the human mouth.

Scrape a little matter from between your teeth ~~with~~ using a splinter of wood or a scalpel. Put this matter in a drop of water on a glass slip and then pick the matter into fine bits with the dissecting needles. Lower a cover glass on the preparation ~~and then~~; press it down on the preparation so as to crowd the matter from the teeth into a very thin layer.

Study the preparation, using magnification of 250 and 500 diameters and reflecting the light from the mirror through just as small an opening in the diaphragm as you can employ without getting the image of a dark shelf under a part of the usual field of view. You may see, in the preparation, scale-like epithelial cells from the mouth, but in addition to these, particles of food ~~left between the teeth and~~ swarming with great numbers of bacteria. The slender elongated filaments, resembling hyphae are those of Bacillus maximus buccalis, a species of Bacteria characteristic of the mouth. The coccus kinds of Bacteria are very minute and nearly invisible. ~~and~~ spherical in form. Some Bacteria are motile and others are non-motile. Do you see any kinds which have independent movement and do not merely ~~float~~ drift about in the fluid? What is their form?

What is the color of the bacteria of the mouth?

Drawing. A group of Bacteria of the mouth, as seen under magnification of 250 diameters.

Drawing. An individual of each kind of Bacteria which you can find in the preparation, enlarged so as to show the form distinctly.

Run a drop of iodine under the cover glass. It kills the Bacteria which it comes in contact with. What does it show to be the structure of the filaments of Bacillus maximus buccalis? From your preparations form an opinion as to how Bacteria reproduce.

Exercise 51. Algae. Rhodophyceae, Red Algae.

Examine the specimen, using a magnifier if it will be of help. What is the color of the specimen? The vegetative body is of what kind? What is its manner of branching? What idea do you form of its general habit when growing under water? Does the plant bear anything which you think may be its fruit?

Drawing. A red alga, natural size.

Mount some of the remaining portion of the alga in the usual manner, if you have a filamentous species.

Examine this preparation with compound microscope using powers of 60 to 250 diameters. What is the structure of the thallus? Do its cells contain colorless protoplasm? What is the location of the fruit on the plant? Can you see the individual spores which compose this fruit? Are the spores in groups of four? Tetraspores occur in fours.

Drawing. A small branch, showing its structure and the location of the fruit, magnified.

Drawing. One of the fruit masses, showing its structure, and also its spores if they can be seen.

If your specimen shows cystocarpic fruit, find such stages as you can, showing the development of carpogonia into cystocarps. Are antheridia present?

Drawing. A young carpogonium, highly magnified.

Exercise 52. Phaeophyceae. Fucus vesiculosus, Rockweed.

Observe the color form and different kinds of parts of the specimen. Why is the vegetation body of this plant a thallus? Has it not a midrib? The fruiting tips are covered with wart-like elevations. Examine one of these elevations with a magnifier; does the elevation appear to be a solid mass? Does the specimen show attachment to the rock?

Drawing. Upper portion of a plant of Rockweed somewhat reduced. Point out the parts.

Cut a series of thin cross sections of a fruiting tip, holding the piece of the tip in the pith holder. Select from the series a thin section, median with respect to some of the elevations in the surface of the tip, and mount in water and potassium hydrate.

Examine the section with the dissecting microscope. The openings or pits which you observe are conceptacles. What is the location of the conceptacles with reference to the elevations of the surface of the conceptacle? Are the conceptacles closed chambers? What is the relation of their wall to that of the fruiting tip?

Drawing. Cross section of a fruiting tip. (X 4).

Female conceptacle. Study the organs which project into the cavity of a conceptacle, using a magnification of 50 or 70 diameters at first. If you are looking at a female conceptacle, you observe a few rather large olive-brown, ellipsoidal bodies projecting here and there from the wall into the cavity of the conceptacle. These bodies are oogonia. (If your specimen does not have oogonia it is a male conceptacle and you should study it as directed in a following paragraph, returning here later for study of the female conceptacle and securing the specimen for study from a series cut by another student).

Examine individual oogonia with magnification of 250 and 400 diameters. How is the oogonium attached to the wall of the conceptacle? The wall of the oogonium is very transparent. Do you see any oogonia with the surface of the colored central mass creased or seamed in a manner suggestive of the mass being composed of several parts closely pressed together? If so, how many such parts are to be seen on the upper side of the object? How many, in your opinion, compose the whole object? Such bodies are not always to be seen composing the contents of the oogonium. Each is an oosphere.

Drawing. An oogonium, as seen with magnification of 400 diameters.

Male conceptacle. If you have completed the study of the female conceptacle, exchange sections with some student who found male conceptacles. Examine the conceptacle with ~~with~~ magnification of 250 diameters. What is the form and structure of the organs which project from the wall into the cavity of the conceptacle? Do you see similar organs which have become detached from the wall and have floated to some clear place in the preparation? If so, make out as much as possible of the structure and parts of a complete organ, using magnification of 400 diameters. Does the branched structure you are studying bear rather large cells with orange-colored contents? Such a cell is an antheridium. Do you find an antheridium whose contents have rounded off into little masses?

Drawing. A branch bearing antheridia, highly magnified.

Drawing. A mature antheridium, showing the structure of the contents, highly magnified.

Exercise 53. Diatoms.

Place two drops of the water containing Diatoms on a glass slip and cover with a cover glass. Examine the preparation with the compound microscope using magnification of 250 to 400 diameters. The boat-shaped or elongated objects, perhaps gliding slowly in the direction of their long axis, are probably Diatoms. What is the color of the contents of the Diatoms? Do you detect lines or markings on the outer portion of the Diatom? What is the arrangement of such lines? Are they at unequal distances apart?

Drawing. A Diatom, as seen ~~with~~ magnification of 400 diameters.

The protoplasm of a Diatom is inclosed by two colorless, siliceous valves, one of which overlaps the other like the two parts of a pill-box. You may see the Diatom in two positions; that is, you may look directly against the broad surface or back of the overlapping or overlapped valve (valve view), or you may have a side view, as we would say of the pill box, and see both valves and how much one overlaps the other (girdle view). Are you able to make out both the valve view and the girdle view for any species of Diatom in your preparation? Is the outline of the Diatom the same for both views?

Drawing. Valve view and girdle view of a Diatom, as seen highly magnified.

Study the movement of a motile Diatom. In what direction does it move? Do you see how the Diatom moves itself?

Diatoms in their varied forms whether free or attached, singly or connected together into colonies, are easily recognized as Diatoms by their valves in pairs, by the markings on their valves, and by the olive-brown color of their protoplasm.

Drawing. The different kinds of Diatoms which you detect in your preparation, highly magnified.

Exercise 54. Chlorophyceae, Green Algae. Nitella.

Examine, if possible, an entire plant of Nitella, which may be floated out in water for the purpose. Is its vegetative body a shoot consisting of stem and leaves or is it a thallus? Why do you so regard it? What is the color of Nitella?

Drawing. Plant of Nitella, natural size or reduced. Point out the parts.

With as little mutilation as possible, remove from the upper portion of the plant a vigorous branch which has one or more well developed and sound cells above where the cut is made for removal. Place this branch in several drops of water on a glass slip and then cover with a cover glass.

Examine the uninjured cells in the preparation using the compound microscope with magnification of 70 diameters. Focus so that you see into the interior of the cells and look about there at different levels for matter in motion. If you do see a moving object try to keep it in view by moving the slide and making such changes of focus as are necessary. Is the movement common to the whole interior of the cell? Is the moving matter in actual contact with the cell wall? What kind of matter do you see moving?

Drawing. A cell of Nitella, drawn 3 in. long, showing the outer and inner surface of the cell-wall, the location of all mov[ing] matter and its direction of movement. Place little arrow heads on the parts representing matter in motion with points in the direction of the movement.

Drawing. Ideal diagram of cross-section of the above cell, showing more definitely the distance from the cell-wall of the moving parts.

Exercise 55. ~~Chlorophyceae~~. Siphoneae. Vaucheria. ~~[illegible]~~.

If you have living material, float some of it out in water on a white plate and separate one plant from the tangled mass. Observe the color of the thallus; form of thallus; parts of same. Is there distinction of base and apex?

Examine closely with the 1 inch magnifier; do you find cross walls in the filaments? What Fungus have you seen having hyphae of similar structure? Do you see from the sides of the filaments any outgrowths which differ in form from vegetative branches of the filaments?

Drawing. A plant of Vaucheria, showing general habit and parts. Natural size.

Mount in water on a slip portions of filaments from which outgrowths are most numerous. Examine with magnification of 70 and 250 to 400 diameters. Are any of these outgrowths beaked and with a ~~very~~ large spherical object green in color in their interior? If so, they are oogonia, and their green central body is either an oospore or an oosphere. If an oospore, this green body will be invested by a close-fitting but distinct cell-wall of its own. Search in the vicinity of the oogonium for an antheridium. This is also a short branch but of smaller and more uniform diameter and with colorless contents. Where and how does the wall of the antheridium ~~break~~ open for the escape of the spermatozoids? Is there an orifice in the wall of the oogonium through which the spermatozoids may reach the oosphere?

Drawing. Portion of thallus of Vaucheria, bearing an antheridium and an oogonium and with the latter containing an oosphere. Highly magnified.

Drawing. An oogonium containing an oospore or even highly magnified.

Non-sexual spores are sometimes to be found in cells cut off from the extremities of the filaments. If you find such objects, draw them.

Exercise 56. ~~Chlorophyceae~~. Confervoideae. Ulothrix.

Examine the specimen of Ulothrix with the naked eye and also more closely with a magnifier. What is its appearance or habit when growing? Describe its thallus. Is its thallus differentiated into base and apex? Is the thallus branched?

Drawing. Ulothrix, showing general habit of the plant, natural size.

Mount some of the filaments in water if they are living, or in water and potassium hydrate if they have been preserved in fluid.

Examine the preparation with the compound microscope using magnification of 70 and then of 250 diameters. How does the structure of the filament differ from that of Vaucheria? Do the green matter of the cells arranged in any special manner in the cells? Do you find any cells with their contents rounded off into several distinct masses. Such cells are sporangia. Do you find any cells which have lost their contents? If so, is there indication of where those contents may have escaped from their cells?

Drawing. A filament of Ulothrix, showing its cellular structure as seen with magnification of 250 diameters.

Study a well developed sporangium using magnification of 400 diameters. Determine if possible the number of protoplasmic bodies which it contains.

Drawing. A sporangium, highly magnified.

Exercise 57. ~~Chlorophyceae~~. Spirogyra.

Float out the specimen in water and separate from the mass perfect filaments. Examine these filaments with aid of magnifying glass. What is their form? Are their opposite ends differentiated into base and apex? Are the filaments unicellular? Has the green matter any special arrangement? Are the filaments cylindric, or ribbon-like in form?

Mount these selected filaments in water on a slip and examine them with the compound microscope, using magnification of 50 diameters.

Drawing. A single plant of Spirogyra. (x10.)

Structure of the cell.

Examine a cell of the filament with magnification of 250 and of 400 diameters. Can you distinguish clearly between the cell-wall and cell-contents? How many of the green chlorophyll-bodies do you see in the cell-contents? Focus down slowly until you see the cell in median optical section: do you see granular, nearly colorless matter next to the wall? Such matter is cytoplasm, the principal constituent of protoplasm. Is this layer of cytoplasm continuous about the whole inner surface of the wall? What is the position of the chlorophyll-bodies with respect to their layer of cytoplasm? Is the granular cytoplasm in the form of a layer next to the wall, or does it occupy the whole interior of the cell? Look carefully at the center of the cell. Is the central region is hidden from you by a chlorophyll-body, find a cell in which the central region is not so concealed. Do you find a spider-shaped but nearly colorless object in the central region? Compare its substance with that of the cytoplasm next the cell-wall. Is it continuous with that peripheral cytoplasm? Upon careful study of the central mass of cytoplasm, you may see in its interior a clear and almost shining central object, the nucleus. What is the form of this living nucleus? The nucleus is a constituent of protoplasm. Cell-sap fills spaces between the central and peripheral masses of cytoplasm.

Drawing. A cell of Spirogyra, showing its structure. Make the drawing 3 in. long. Point out the parts.

Zygosporic reproduction. Mount some material showing formation of zygospores in water on a glass slip. (Take especial care not to tear the filament apart or break them in spreading out the material in the drop. ~~If the material has been preserved in alcohol, potassium hydrate should be added also.~~) Examine the preparation with compound microscope using magnification of 250 diameters.

Do you see filaments lying side by side with connections between their opposite cells? Find some cells which contain [illegible] oval body. In such cases is there protoplasm in the opposite cell?

Each of the oval bodies is a zygospore. Does the zygospore contain the protoplasm of more than one cell? What stages do you observe in the formation of a zygospore?

Drawing. Portions of filaments of Spirogyra showing the stages in the formation of a zygospore, as seen highly magnified.

Exercise 58. ~~Chlorophyceae~~. Pleurococcus vulgaris

Observe the distribution and general habit of Pleurococcus on the object before you, using the magnifier. Have you seen this plant out of doors? Does Pleurococcus form a membrane over the surface of the object?

Set that portion of the surface of the object from which Pleurococcus may be removed the freest from foreign matter. With sharp scalpel carefully cut underneath the masses of Pleurococcus so as to lift a small amount of it on the scalpel.

Place a portion of this Pleurococcus in a mixture of water and potassium hydrate on a glass slip, carefully drain away the fluid but keep the alga. Wash the alga with water and drain this off to remove all trace of the potash. Then put water and an equal volume of iodine solution on the alga and mount it in this fluid. Let this preparation stand and stain for study of the cell towards the close of the exercise.

Mount another portion of the Pleurococcus which you removed, in water and potassium hydrate on a glass slip and then press the cover down gently on the preparation. Look at this preparation with low power of the compound microscope and then change to to power of 400 diameters.

On the object from which the material was taken you saw green masses of varying size, scattered about; do you see a similar variety in size and grouping of the masses in your preparation? Study some of these masses closely. Of what are they composed? Do the smaller masses differ from the larger except in being aggregations of fewer cells?

What form do the individual cells have when full grown? Do you see a case affording good evidence of how two cells have originated from one? How three or four have originated from two? How have the large masses of cells been formed?

Drawings. A mature cell (thallus) of Pleurococcus drawn at least 1/2 inch in diameter. A group of two mature cells. Intermediate stage or stages showing how two cells originate from one.

Drawing. A group of three or four cells, of such form that they must have arisen from a group of two cells.

Drawing. One of the larger group of cells, as seen with magnification of 400 diameters.

Structure of the cells. Focus down carefully so as to get a good optical section of a cell which shows its structure well. What parts do you see?

Use now the preparation which you have been staining with iodine. Press the cover down so as to crush the large masses. Study with magnification of 400 diameters the structure of single cells in optical section. In such a preparation, the nucleus often stains darker brown than the rest of the protoplasm. Note the form of the nucleus if it may be seen.

Drawing. Optical section of a cell of Pleurococcus, drawn one inch in diameter. Point out the parts.

Exercise 59. ~~Algae~~. Cyanophyceae, Blue Green Algae. Oscillaria.

Mount some of the living Oscillaria in one or two drops of water on a slip. Examine the preparation with magnification of 250 diameters.

Observe carefully the color of Oscillaria and compare it with the algae studied before.

What form has the thallus of Oscillaria? Do you see any prominent outgrowths or cells of different character, which you think may be reproductive organs? Are all thalli of Oscillaria of the same length? Do you think the short filaments grow until they become long filaments? Do you see anything indicative of the origin of the short filaments?

Drawing. Oscillaria, showing its microscopic structure, as seen highly magnified.

Drawing. Reproduction of Oscillaria, highly magnified.

What kinds of movements do you observe different thalli of Oscillaria exhibiting? Describe these movements. Account for such of them as you can.

Appendix.

II. Cryptogamic laboratory studies.

The account of Cryptogams has been prepared to co-ordinate and broaden the conclusions in regard to plant structure and processes which the pupil should acquire from laboratory study of cryptogams. These laboratory exercises need not necessarily be the same for all schools either in the number of exercises or in the subjects taken up. The majority of high schools do not probably devote at present more than a half year to the whole course in botany. As some teachers [illegible] may prefer to spend three-fourths of this time on Phanerogams, it is evident that the remaining fraction of the time will permit of only a very general view of cryptogamic botany and the recognition of but very few of the leading types and large groups. The author believes that such schools will do well to confine their laboratory work to such types of Cryptograms as Ferns, Mosses, Lichens, a Fungus (Toadstools), and an Alge (Spirogyra). Bacteria Yeasts, Pleurococcus and Ascomycetes are very important additional types, if the time permits. But whatever types are taken up, should be studied thoroughly. It is a mistake [illegible] a trivial - to use the time of a class in such superficial examination of a large number of Cryptogams that they are not recognized when seen again; their structure and life history not understood nor their general position in the world of plants. Such superficial study which is often "made easier ~~eas~~ or "popular" by the avoidance of the usual botanical terms, does not enable the pupils to read understandingly in future years articles which treat of even the cryptogams included in their school course.

Some teachers may wisely direct the attention of their pupils to the study of the general morphology of the larger or easily recognized kinds of Cryptogams, such as Ferns, Equisetums, Selaginellas, Isoetes, Mosses, Hepatics, Lichens, Toadstools, Rusts, Smuts, Ascomycetes, Moulds, Myxomycetes, Red and Brown Algae, Vaucheria, Spirogyra, and Pleurococcus. By making field trips with the class after such plants and learning to know them out of doors in their natural environment as one knows birds, and by careful studies in the laboratory of the gross structure and parts of these selected examples ~~cryptogams~~ taken in connection with the account given in the text, a very real knowledge of Cryptogams could be gained and ~~which~~ its acquirement could well ~~cover~~ occupy a term or a half year of school work.

Most of the work in such a course would be done with no higher magnification than that afforded by inexpensive dissecting microscopes of the Barnes pattern fitted with 2 in. and 1 in. doublet magnifiers, but there should be as many of these instruments as there are pupils working at the same time in the laboratory. To enable one to see some of the most interesting cryptogamic structures, a good compound microscope fitted with $\frac{2}{3}$ in. and $\frac{1}{6}$ in. objectives and 2 in. and 1 in. eye piece, and a double nose-piece is absolutely necessary. At least one such microscope should be available for demonstration with the above work.

Other schools, which provide a compound microscope for each pupil or at least one for each two pupils working in the laboratory at the same time, will have no limitations on the subjects to be covered by laboratory work and should be able to select from the range of types of Cryptogams treated in the descriptive text and practical exercises, a set well suited to the cryptogamic flora of their region whether near the coast or far inland.

There should be no hesitation in omitting such portions of the text as contain detailed descriptions of kinds of cryptogams which cannot be included in the laboratory work. Otherwise, the amount of new matter presented to the pupil may prove more than he can thoroughly assimilate. The portions wisely omitted by some schools are not those which other schools under different environment could best omit. The accounts of the different types treated will be found none too exhaustive by pupils who examine the real objects of which they treat.

With regard to the use of the compound

microscope by beginners. I would urge the importance of doing as much of the work as possible with the naked eye or with the aid of the dissecting microscope, resorting to the compound microscope only for the clearer resolution of the detailed structure of objects whose general structure has been already made out by the more familiar methods of observation. Otherwise, the conclusions which beginners may form from the use of the compound microscope may be erroneous. The lowest magnification which will show what it is desired to see, should always be used. The arrangement of the subject matter in this book so that the larger cryptogams, calling for but little use of the microscope, afford a transition to the more minute kinds which come later in the course, is an advantageous arrangement for the laboratory work of beginners.

Laboratory outfit for Cryptogams. The outfit ~~used~~ for the work on Cryptogams is as follows:

1. Necessary.
 1 dissecting microscope, ~~fitted with 2 in. and 1 in. magnifiers~~ for each pupil working in the laboratory at the same time
 Compound microscopes
 1 pair fine steel forceps for each pupil
 1 scalpel for each pupil.
 2 dissecting needles for each pupil.
 Glass slips, 3 X 1 in.
 No. 2 cover glass, circles, 3/4 in. diameter.

2 Syracuse watch glasses for each pupil
1 section razor for each pupil
1 razor strap for every four pupils
1 yellow Belgian oil hone. Some shaving soap or palm oil soap.
1 oil stone. Some sperm oil for oil stone.
Pith ~~[illegible]~~
Filter paper in large sheets, which are to be cut eventually into 1 in. squares.
Reagent bottles ~~for~~ one set to each table and holding the following
~~Reagents:~~
Potassium hydrate — 7% aqueous solution
Iodine solution — 1 gram iodine in a solution of 4 grams potassium iodide in 300 cubic centimeters of ~~water~~ distilled water.
Eosin solution — saturated solution in alcohol.
Glycerine, dilute — 10 c.c. water and 20 c.c. glycerine.
Alcohol, 95% or 90% strength
Distilled water or rain water
Glass crystallizing dishes, ~~plain~~ tumblers, common ironstone china white plates, wide-mouth bottles with cork or glass stoppers — all for general laboratory use
~~4 oz. and 8 oz. salt-mouth bottles, with cork stoppers, for collecting algae~~
~~2 oz., 4 oz., and~~

2. Needed for making and preserving permanent microscopical preparations.
1 bottle Bell's cement or Brunswick black, smallest size camel's hair brush, small bottle xylol for cleaning cement from brush after use, Pillsbury cabinet for storing mounts
3. Recommended for storage of the stock of dried material.
4 Insect-proof tin boxes in case.

10. 4. filter paper

Reagents
spring oil
~~Alcohol~~

Iodine sol. in K. I.

7% aq. sol. of KHO.

Eosine sol in alcohol

13. Crystallizing dishes

14. For mounting specimens
Bell's cem. or Brunn. black, xylol, small camel's hair brush & Pill. Cab.

15. For ~~[illegible]~~ storing dried specimens — Insect proof tin boxes.

5. Preparation consists of 5 cg. iodine, 20 cg. potassic iodide, and 15 g. distilled water.

5 | 1
20 | 4
1500 | 300

4 Insect-proof tin boxes or cases — Recommended for storage of the dried specimens.

Dissecting microscopes of the inexpensive Barnes pattern, fitted with 2 in. and 1 in. doublet magnifiers are excellent for the work. ~~The 2 in. magnifier is the more useful in making dissections and preparations, the 1 in. is used in their study and magget be dispensed with if each student had a compound microscope.~~

The compound microscopes should have $\frac{2}{3}$ in. and $\frac{1}{6}$ in. objectives and 2 in. and 1 in. eye-pieces, double nose-piece, ~~and~~ cylinder diaphragms or the still better, but more expensive, and more fragile iris diaphragm in the plane of the stage. When working with high magnification, it is impossible to get both good illumination and sharp definition by the use of rotating diaphragms.

The BA4 microscopes of the Bausch & Lomb Optical Co., Rochester, N.Y., are ~~a suitable grade~~ microscopes of a suitable grade for use if there is to be one for each student or each two students working in the laboratory at the same time. Some of the still lower priced stands of this firm ~~will~~ be good if the makers will furnish them with accurately centered cylinder ~~diaphragms~~ in place of rotating diaphragms.

If only one, or two ~~one or 2 mi~~ microscopes are to be used for the whole class, ~~the~~ microscopes of the BB4 grade are to be preferred.

~~Do not omit the hone in the~~

The hone indicated (to be had from Bausch & Lomb Optical Co.) is a very essential piece of laboratory apparatus. Section razors will be dull and causing disappointment in the sections unless the laboratory has facilities for sharpening the razors. It is a simple matter to hone a section razor. Wet the yellow surface of the hone with lather, ~~edge is stropped, length of the~~ and then ~~advance the razor, the whole, all points the edge off, the razor from heel to hone and while doing so draw the~~ ~~point successively across the hone~~ sharpen first on the concave side of the razor until the edge is slightly

Laboratory outfit.

1. Dissecting microscopes of Barnes pattern fitted with 2 in. and 1 in doublet magnifiers — as many such instruments as there are pupils in laboratory at same time
If only 1 or 2 compound microscopes are provided for the class both the 1" and 2" magnifiers are absolutely needed; if compound microscopes are provided so that there is one for each student or 2 students, then the one inch magnifier may be omitted!

5 2 dissecting needles

3. 1 pair of fine steel forceps

4 1 scalpel

2 doz. glass slips, 3 X 1 in

1/8 oz. cover glass, circles, 3/4 in diam.

7. 1 section razor

8 1 oil stone, 1 hone, and strop — one to every 4 pupils.

11 Reagent bottles

12 Reagents; glycerine, potassium hydrate, eosin, iodine sol., alcohol

2. Compound microscope — B A4 or B B4 type, ~~fitt~~ having 1/6 in, 2/3 in. obj., 2 in. & 1 in. eye pieces, and double nose pieces if only one or two are to be owned by the laboratory,

B4 type if many instruments are to be used.

6 Syracuse watch glasses

~~dropping bottles~~

feathered its entire length, but only very slightly; then finish honing by passing the razor without pressure over the whole length of surface of the hone so that the edge moves in advance of the back, and also so that the razor moves from heel to point across the hone. In this finishing process the strokes alternate back and forth so as sharpen the two sides alike. This should continue until the thread or "feather" is wholly removed from the edge, leaving the latter keen. Then strop the razor.

Very convenient and inexpensive reagent bottles for microscopical work are 1 oz. bottles, tall form, mushroom glass-stopper, with a piece of tapering solid glass rod sealed to the lower end of the stopper. When the stopper is in place in the bottle this rod reaches almost to the bottom of the bottle. To lift a drop of glycerine on such a rod slightly tilt the bottle to wet as much of the rod as possible, and then while the bottle is tilted, remove the rod from the bottle. The drop is carried suspended from the lowest part of the under side of the rod. If the rod can be removed from the slightly tilted bottle without letting the under side of the rod touch the bottle, the drop can be delivered where desired. — — Staniford & Co., 30 Hanover St., Boston, Mass., furnish such bottles at $1.25 per dozen.

Alcohol and distilled water, which are used in larger quantities than glycerine and the other reagents, can best be kept in shallow and wide bottles having a stopper fitted with a medicine dropper (pipette), or they may be kept in 8 oz. flat-bottomed flasks having rubber stopper fitted with mouth tube and delivery tube after the manner of wash-bottles.

Material. All the exercises can be made to best advantage with living material, which should be used whenever practicable. Some of this may be grown in cultures in the laboratory, but foresight on the part of the teacher will be needed so that the culture may be started sufficiently long before they are needed by the class; some material may be had from greenhouses; but the main supply, from fields, groves, streams, or coasts where it grows naturally. The extent to which this latter source may furnish the laboratory supply as needed, will depend on how accessible it is through ~~the~~ absence of deep snow and ice, and on the time which can be taken to gather it. In my own experience, it has been necessary to go, rather than to send, for it. My pupils do not seem to see cryptogams out of doors until they have actually studied them, and by this time class work needs new and different kinds. The most satisfactory results are had when the class can go with the teacher.

Dried specimens of Ferns, Equisetums, and other Pteridophytes, also Mosses, Hepatics, Lichens, Toadstools, Rusts, Smuts, Ascomycetes, Myxomycetes, and Algae of various kinds are very useful both to exhibit in connection with the recitation work and also to use, when needed, in the place of fresh specimens for showing the general form and parts of plants. Selected plants in fruit

[illegible]

should be used for these dried specimens. Many of the kinds named are dried and pressed after the manner of flowering plants intended for an herbarium; special directions will be given for the preparation of the material in connection with each laboratory exercise. Pains should be taken to prepare every dried specimen so that it shows faithfully the natural habit of the plant.

The sets of dried specimens may be used year after year. Insect-proof tin boxes originally designed for the storage of herbarium collections of fleshy fungi can be highly recomended also for the convenient storage of the collections of cryptograms. Should insects be found destroying any of the specimens, their destructive work can be at once stopped by setting in the tin box among the specimens a saucer containing 5 to 10 cubic centimeters of carbon bisulphide, and then closing the box tightly for a day or two. These boxes may be obtained from the Cambridge Botanical Supply Co., Cambridge, Mass.

Preserved material. Material to be used for microscopic study should not usually be dried but preserved in 70% alcohol. Such a stock of material of types not often to be met with nor easily had, is of great value in a working laboratory. It enables one to have at hand ready for use at any time kinds of cryptograms which are in condition for study of their reproductive organs for only a short interval of the year, or which do not occur in the region of the school.

Some kinds of preserved type material may be obtained from the Botanical Supply Department of Marine Biological Station, Woods Hole, Mass., during July. (Address to Dr. Bradley M. Davis, University of Chicago, Chicago, Ill., during other months): or from the Cambridge Botanical Supply Co., Cambridge, Mass.; or from Ithaca Botanical Supply Co., Ithaca, N. Y. Orders for such material should be given early in the season.

Permanent Microscopical Preparations. Such temporary preparations as one would like to mount permanently for use in future classes may be mounted

in glycerine and then sealed. First slip a small triangular piece of filter paper or a small fragment of cover glass wholly under the cover glass of the preparation at one edge to sustain the pressure of the cover glass. Then displace the potassium hydrate solution in which the preparation was mounted temporarily with pure water by placing a large drop of water in the slide against one edge of the cover glass and a piece of filter paper against the edge at a point diametrically opposite. The potassium hydrate will be drawn from under the cover glass into the filter paper and the water of the drop will flow under the cover taking its place. If it is desired to stain the preparation, this may be done in the simplest manner by now drawing under the cover glass a drop of alcoholic solution of eosin or other stain and leaving this in contact with the sections until they have absorbed the stain. The excess is then displaced by water and this by a glycerine mixture consisting of two volumes of concentrated glycerine and one volume of pure water. Enough glycerine should be placed against the edge of the cover glass so that it may concentrate about the sections by evaporation of water at the edges of the cover.

Sealing the preparations. After the concentration of the glycerine under the cover glass for two days or more, the excess of glycerine on the slip about and beyond the cover glass should be cleaned away. Remove this excess as completely as possible with a small piece of filter paper slightly moistened with water, and then finish the cleaning up to the very edges of the cover glass with a soft cloth, as an old linen handkerchief, moistened with 95% alcohol. As one portion of the cloth becomes smeared with the glycerine, change to a clean portion. After the removal of the excess of glycerine, the preparations are sealed by applying with a small camel-hair brush a ring of good microscopic cement, as Bell's cement, or Brunswick black, about the edge of the cover so as to cement the edge of the cover to the slide and completely inclose, that is seal, the glycerine under the cover. This ring of cement will harden in a day or two and then it should be covered by a second coat heavier and broader than the first and extending beyond the first to the clear glass on each side.

Storing mounts.

Permanent microscopical preparations of a school collection are best stored in the Pillsbury Portable Cabinets, holding 10 boxes of 25 slides each or 20 boxes of 25 slides each as may be desired.

Some schools may desire to purchase permanent mounts of the more difficult kinds to prepare. Such preparations are advertised by dealers in microscopical apparatus. Among the students taking botanical courses in colleges, there are usually students making very superior microscopical preparations who would be very willing to prepare at reasonable notice and at the usual prices, whatever preparations might be desired.

Suggestions for the Exercises.

Exercise 38. Any fruited fern, showing the complete plant will answer well for this exercise. If native ferns of the region are not available at the season when this exercise is reached, ferns collected during the summer, and pressed and dried are very satisfactory. Polypodium vulgare (fig. 395) is of convenient size, and has an easy outline for sketching. The covering of the sporangia is well shown in the Bracken Fern or Brake, Pteris aquilina. Pteris cretica, a small fern very commonly grown in greenhouses is excellent, and may be had fresh at any time.

Exercise 39. Fern prothallia are not often found out of doors. They may be easily raised from the spores by sowing them on earth provided one can keep the sowings in atmosphere moist and ~~warm~~ warm as in a greenhouse, until the prothallia are ready to use. Prothallia produced from ~~[illegible]~~ self-sown spores may usually be obtained in great abundance in greenhouses ~~[illegible]~~ on the earth in pots in which ferns are grown, if the earth has not been too recently disturbed, or on the moist walls, benches or floors. One pot will often have an ample supply for a large class. Some specimens may be found which show attached to the little prothallium, the young fern plant, as in Fig. 398.

Prothallia can be preserved for class use in 70% alcohol, but this is not advised if living prothallia can be had when needed, as the alcohol soon completely dis~~places~~solves the chlorophyll, leaving the prothallia colorless and in this respect unnatural and misleading to pupils.

Sectional preparations of the fern prothallium showing the reproductive organs are the most difficult preparations to be made in the course on account of the difficulty of cutting very thin sections. Still if several pupils cut sections, enough fairly good ones should ~~have always~~ be~~en~~ found ~~in my classes~~ to answer the class needs. Some sections may be expected to show only ~~the~~ archegonia and others only antheridia.

Exercise 40. Illustration 1. Living or dried and pressed specimens of any species of Equisitum may be used, but the smaller, branched species are preferable. If Equisetum arvense is used, both the fertile and sterile plants plants will be needed. The flower-cones should be collected in a liberal supply before their spores are discharged. They may be kept on hand pressed and dried, to be moistened and softened with water a few hours before the use. Fresh stems or those preserved in alcohol or formalin are best for the study of the internal structure of the stem.

Illustration 2. Living or dried and pressed specimens of Selaginella rupestris, a species to be found on the soil on dry rocks, is excellent, as are also the other species of Selaginella, some of which may be had fresh from greenhouses.

Isoetes is very common in ponds and sluggish, muddy streams. The species which live wholly under water at all times are easily recognised by their peculiar color together with their grass-like appearance. The plants mature in summer and autumn. The collections for class use should be made then. Some specimens should be pressed and dried to show the external structure and habit of the plants and their color. Specimens intended for study of the sporangia and spores should be preserved in alcohol or formalin after being stripped of the roots and upper portions of the leaves for economy.

Exercise 41. Material fresh or preserved in 70% alcohol or formalin should be used. Any species of moss will answer. Polytrichum and Funaria are often used because both are very common, but a bisexual species of Mnium or Bryum is preferable because one section, or one set of sections will usually bear both antheridia and archegonia. This is a great advantage if the class make their own preparations.

Moss plants in the proper stage of development for this exercise are very aboundant on shaded, moist rocks and banks during the whole summer. Large tufts or patches of moss covering many square inches and consisting of closely crowded moss plants, resembling Fig.416, or rarely showing a very young sporophyte, are often found. Select from such a tuft a moss plant with its leaves rather ~~tufted~~ massed together at the apex, or sometimes rosette-like, and cut longitudinal sections of the upper end. If these sections show antheridia and archegonia, you can pull out of the tuft in a short time and preserve in a small bottle of alcohol enough plants like the one you sectioned to supply a large class for years. ~~You may not chance on a bisexular species in the first tuft you collect for material; I did on my second or third trial.~~

The longitudinal sections of the moss plant are not difficult to cut free-hand; but one must take pains ~~in placing~~ to place the part to be sectioned properly in the pith and he must work deliberately with a keen razor. These sections afford a class one of the most instructive and fascinating objects of the course.

Exercise 42. Living material or that dried and pressed should be used. The former may usually be obtained in moist woods on banks or rotten wood at any season of the year when not concealed by snow. Dried material may be prepared in quantity during the summer or autumn. The individual plants to be used should be separated from the tufts before drying and pressing.

Exercise 43. In Vermont, Marchantia polymorpha is in condition for the work indicated in this exercise early in July. Male and female plants should be preserved in the usual fluids for study of stomata and cups of the thallus, and for young and maturing fructifications and antheridia. An earlier collection should be made of female receptacles for preservation in fluid, if the time available for the course will allow the study of archegonia.

Exercise 44. Physcia stellaris is an excellent lichen to use for this exercise on account of its large colored ascospores. It can be collected fresh for use at any season of the year from the trunks of maple or elm shade trees, or in woods. The material should be collected when the thallus is moist and pliant. It is desirable to take up some of the bark under the lichen with it. A chisel facilitates the task.

The supply of specimens can be dried and kept in a small box or envelope for use year after year, but they should be dampened and kept moist while being studied.

Supplementary Exercise on Lichens. Lichens are so varied in forms of thalli, that a very valuable supplementary exercise might be based on recognition of the fructification and on classification of the thalli as foliaceous, fruticulose, and crustaceous. The material, preferably collected by the pupils, should consist of as many species as possible and collected from bark, rocks, and rails or other dead wood, and from the ground.

Exercise 45. If this exercise can come in the course at a season when living fleshy fungi can be had from the fields and woods, they should be used. Any species would answer but the poisonous Amanita phalloides of Fig. 437, or the edible Agaricus campester of Fig. 454 should be preferred. A small species of Coprinus which grows readily in the laboratory on cultures of horse-dung is of very convenient size for sectioning and has colored spores and large basidia.

To grow this Coprinus, the cultures should be started about a month before the functifications will be needed. Get horse-dung, preforablythat which has become old, dry, and dusty in the stable, fill two or three large crystallizing dishes or tin boxes to the depth of an inch, water thoroughly so that the lumps will soften and may be torn open and worked together. Cover each dish with a plate of glass and stand away in some place in the laboratory in diffuse light where the cultures will not be disturbed, but where they will be seen from time to time and not allowed to dry out. A succession of variovs kinds of fungi are likely to be seen.

A small Discomycete may be very abundant at the end of a week or two. If so, its small cup-like fructifications should be harvested, and preserved in alcohol as a desirable by-product to be used in Ex.47 or else plantings should be made of these fructifications and of the matter under them into new cultures which will fruit at just the time the material is needed.

In two or three weeks after starting the first cultures, fructifications of Coprinus should begin to appear and others will appear day after day for two weeks or more. As these fructifications appear, pluck them from the cultures with a pair of forceps before the pileus expands and drop them into a bottle of 70% alcohol, for a time of need. Such preserved material is quite as satisfactory as the living material for microscopic study.

The more important ~~[illegible]~~ summer and autumn kinds of fleshy fungi such as Amanita phalloides and Agaricus campester may dried, ~~and~~ slightly pressed, and preserved in an insect-proof tin box for use in teaching about ~~about~~ this species ~~these specimens~~ during the winter months and for showing the general parts ofthe fructifications. Dry choice selected specimens on a wire tray suspended 6 to 10 inches above a lighted lamp. The current of hot air will soon dry the specimens. Expose a tray of the dried specimens to moist air, as on a damp night or foggy morning, until they are pliant and can be shaped with the fingers so that the stem is bent into a plane parallel with the pileus and the latter flattened out. Then place the fungi between driers only just pressure ~~great~~ enough to prevent curling while drying out again and, keep in a dry room until dry and rigid. Then store in the insect-proof tin boxes until needed.

Supplementary Exercise on Basidiomycetes. Some teachers may prefer to take more time for practical studies of toadstools, because of the economic importance of these plants. I would suggest, that such time be devoted, in part, tpward directing the pupils attention to toadstools as they grow out of doars; that many and unlike kinds of these plants, comprising both fleshy and woody kinds, bracket-shaped kinds, kinds with a stem and kinds without a stem, both Hymenomycetes and Gasteromycetes, should be got together and then arranged by the pupils in the families given in the text. Experts recognize Basidiomycetes in doubtful cases by their bearing spores on basidia. Have different members of the class prepare sections from kinds in the different families represented to demonstrate that all agree in having basidia.

Exercise 46. 1. Stems showing teleutospores of a grain rust can usually be found in abundance in the stubble of wheat or oats at any time after harvest. The dry stems may be kept indefinitely in envelopes.

2. The young leaves of the barberry usually bear the wart-like aecidia of grain rust in abundance in the springtime. The supply of such leaves for class use should be preserved in 70 % alcohol or formaline.

In early spring, orange-colored teleutasporic fructifications of a rust are prominent on branches of the red cedar. When these fructifications, the so called "cedar apples," are swollen and soft and gelatinous, they offer excellent germinating teleutaspores with promycelia and sporidia.

Exercise 47. Of the two illustrations given, the first is valuable because it affords study of the mycelium type of thallus and because the material for study is so easily to be had; the second illustration shows better the structure of the fructification, and should enable the pupil to comprehend the fungus nature of one component of most lichens. The study of an

Ascomycete is often omitted in laboratory manuals, yet Ascomycetes and Basidiomycetes are by far the largest subclasses of Fungi.

Illustration 1. Leaves of the common lilac which are well coated with the white mycelium and dark perithecia of Microsphaera Alni during the summer months, should then be collected and dried and pressed for class use. If some leaves are preserved in 70 % alcohol, they ~~would~~ will be useful for microscopic preparations of the mycelium.

A willow mildew (Uncinula) with simpler perithecial appendages is also very satisfactory for this study. It grows on willow leaves. The class will probably study with the more intrest, the fungus whose mycelium they have probably observed disfiguring the familiar lilac.

Illustration 2. Small Discomycetes such as may be grown in cultures of horse dung (See Exercise 45) or those whose scarlet or orange-colored, saucer-shaped apothucia may be seen growing on decaying wood in wet woods during summer and autumn, are suitable for this ~~work~~ work.

The former may be studied from fresh or alcoholic materiel, Hyphae of the mycelium may be seen in the living plants extending from the soil up into the fructifications. It is important to keep the attention on the thallus in an elementary course on Thallophytes. It is the thallus which rots the wood and carries on the peculiar life work of a fungus.

In collecting the Discomycetes growing on wood, cut off from the log a thin layer of the wood on which the fructifications stand and keep the latter undisturbed on their woody base. Simply dry these objects which should finally be wet and kept in a moist atmosphere for an hour before using; or put a supply of the pieces of wood bearing apothecia into 70% alcohol as they are collected. Such alcoholic material is good for the microscopic preparations.

Exercise 48. Rhizopus nigricans, the common Black Mould, is sometimes found on bread kept in a close, moist and warm atmosphere. The mould spores from such a source may be used to start cultures in the laboratory. Place a slice or part of a slice of bread in a large crystallizing dish, wet the bread well, smear the upper surface with some of the mould used as the source, then cover the dish with a large glass plate and set away in a dark and moderately warm place. The mould spores will soon germinate, producing a mycelium which covers the bread in two or three days.

The culture is in the best stage for Illus. 1 when it shows plenty of white sporangia and some black ones. If left undisturbed, all the sporangia will become black in a week or so. After a few days more, examination of the densely felted mycelium close against the bread and penetrating the bread, should show plenty of zygospores. If the material shows the desired series of stages in the production of zygospores, a supply ~~of the material~~ for class can be removed from the bread and preserved in a vial of 70% alcohol.

A piece of bread bearing zygospores may be exposed to the air of the laboratory until dry and hard, then wrapped in paper and stored away in a dry place for use in starting cultures the next year. Merely crumble same of the zygosporic portion of this dried bread over the wet bread in the crystallizing dish.

Exercise 49. Twenty-four hours before the class will work with yeast add compressed or dry yeast in the proportion of a quarter of a cake to a pint bottle, ~~to~~ two or more bottles of fresh sweet cider, or water sweetened with sugar, or syrup from canned fruits. The bottles should not be stoppered. One of them should be placed in a dark box or wrapped in dark cloth to exclude all light, and then both left standing in a warm room where they will not be disturbed until needed for class use.

The small amount of lime water needed can be had from the chemical laboratory or from a druggist.

Elaborate staining methods are necessary for the demonstration of the yeast nuclear-apparatus.

Exercise 50. If any kind of decaying matter, as old hay, is left in water for a few days, the fluid will swarm with Bacteria; but no more instructive kinds will be had than those from the human mouth.

Supplementary Exercise. Myxomycetes can afford a very instructive exercise. Their sporangia are beautiful objects and their plasmodia has furnished the material for studies on the physical and chemical properties of protoplasm. The fructifications of these organisms are abundant through the summer and autumn. The fructifications are preserved dry in boxes. The exercise could include

1. Stage of fruitification;
   The sporangia — their form, parts, internal structure.
   The spores and capillitum.
2. Swarm spore stage. The spores, especially, if they have been keept a few months or a year, germinate in the course of a day or two upon being sowed in water in a watch glass. The watch glass should be covered to prevent evaporation of the water. A drop of the water will show the swarm spores.
3. Plasmodium. The swarm spores soon collect at the edges of the water and creep up the moist glass surface forming a thin plasmodium.

Exercise 51. If near the seacoast so that fresh material may be conveniently had, such should be used. Dried specimens show well the general habit and beautiful form of many species, but they should be accompanied by a supply of fruiting material preserved in 70% alcohol or formalin for microscopic study. Nemalion is one of the most desirable kinds for study of carposporic reproduction.

Dried specimens of most algae are prepared by floating out the alga as naturally as possible over a sheet of white paper immersed in a pail of water. The paper is then gently raised from the water with the specimen adhering to its upper surface. The specimen is then covered with a piece of white muslin cloth, and the supporting paper, algae, and cloth are then placed between driers and dried under pressure, like flowering plants. The driers have to be changed frequently until the supporting paper, specimen and cloth are free from moisture. The cloth is then raised from the specimen, pains being taken to leave the latter adherent to the paper underneath it.

~~Lesson 25. Vaucheria is very common in~~

Exercise 58. Rockweed is so very common along the coast that schools in its vicinity will be able to use living material. Of late years the Cambridge Botanical Supply Co. have at different times during the year, sent living material of this and other seaweeds far inland for class use.

Dried specimens answer very well for showing the general habit of Rockweed, while assorted male and female fruiting type, preserved in 70% alcohol are good for the microscopic work.

Some time may be saved in the laboratory work by distributing the tips for sectioning so that some of the pupils cut sections from male tips and others from female tips. Each may cut more than he needs for his own use.

Rockweed, Laminaria and other large species of Brown Algae are dried ~~prepared~~ for class use by being spread about in a dry room until thoroughly dry. They will become pliant again in a moist morning, when they may be arranged between driers and pressed into permanent form.

Supplementary Exercise. Schools near the seacoast and also schools farther inland that purchase their supplies of plant material may substitute with advantage an exercise on Ectocarpus, (Fig. 535) one of the Brown Algae, for that indicated with Ulothrix, a Green Alga. Ectocarpus has a branched, filamentous thallus made up of cells placed end to end. Some cells, which may be distinguished in microscopic preparations from the ordinary vegetative cells by their swollen condition and darker color, become sparangia and are used for reproduction. There are two kinds of these sporangia; unilocular sporangia, and multilocular sporangia. Unilocular sporangia are those which contain all together in the one cavity of a sporangium several or many swarm spores. Plurilocularsporangia are those which are chambered by very thin walls so that each planogamete is in a chamber by itself. The swarm spores are biciliate and each produces a new filament or germination. The planogametes are also biciliate, but they conjugate in pairs, producing zygospores by their fusion.

Exercise 53. Living Diatoms are very common in all regions. They will be found on the surface of other water plants and also on the mud in lakes, ponds and marshes. They are easily kept alive in the laboratory, and ready at any time

for class use. A collection of the surface mud taken from the bottom of a pond contained so many interesting kinds of Diatoms that it was placed in a pint glass fruit jar and water was added to fill the jar two-thirds full. The lid of the jar was loosely placed, but not fastened, on the jar to retard evaporation. Water has been added occasionaly to replace that lost by evaporation. The Diatoms have remained abundant in the jar for five years. On the moist ~~inside~~ inner surface of the jar just above the water, there is a bluish-green film which consists of a mixture of Nostocs, Gloeocapsa, and a very slender species of Occillaria and ~~which~~ furnishes the midwinter supply of these Blue Green Algae for study.

Exercise 54. Living material is necessary for this exercise, which is devoted to the phenomenom of rotation of the protoplasm in closed cells. Either Nitella or Chara may be used, but the former is much the more satisfactory. If Chara is used, only the younger cells situated at the ends of the main stem or branches will show the movement. The shock caused by removal of the portion used, may stop the rotation temporarily but it is likely to start again in 10 or 15 minutes if the preparation is kept in a room at 70° or 80° Fahr.

Schools at a distance from the coast, that prefer to omit the exercises on Red and Brown Algae and study more at length the fresh water Algae of their immediate vicinity, will find the reproductive organs of the Characeae instructive by their approach to those of Bryophytes.

Exercise 55. Vaucheria is so very common in sluggish streams that it is a very valuble type for illustrating oosporic reproduction. Living material of Vaucheria is much to be prefered for class study as the filaments, with their protoplasm forming a thin layer next the wall and with a large amount of cell sap in the central portion, collapse badly when preserved in alcohol. It is said that Vaucheria may sometimes be had from greenhouses during the winter.

Supplementary Exercise. Oedogonium is so common in sluggish rills and on submerged and decaying herbage near the margins of ponds that it is a useful type for supplementary work. The peculiar transverse striations in the wall of the cells make it easy to distinguish this species and they always interest a class. Its oogonia are abundant also; but the parasitic dwarf male generation makes the laboratory work difficult, for it is not easy to find the spores which produce these parasitic plants. Perhaps the species with this parasitic male generation are less common elsewhere than where my collections have been made.

Exercise 56. Ulothrix should be sought for in masses of short green swaying filaments attached to stones in the bottom of brooks and to the bottom and sides of watering troughs. The general habit is well shown by specimens dried and pressed in the usual manner. Fruiting material should be preserved in formaline.

Exercise 57. Living material should be used for the first part of this exercise, which is mostly given to the structure of the living cell. If difficulty is experienced in seeing that the layer of cytoplasm lines the cell wall, run some glycerine or a 5% aqueous solution of common salt under the cover glass. These dense liquids will receive water from the cell-sap and will push the cytoplasm from the wall towards the interior of the cell.

Iodine solution may be run under the cover glass of another preparation, if thought desirable. It kills protoplasm and staines it brown. If the living filaments of Spirogyra are exposed to sunlight for a time before being used for the test with iodine, the function of the chlorophyll bodies will be shown by the blue color taken by the starch grains. These starch grains are formed at the pyrenoids.

Zygosporic material of Spirogyra is most likely to be found, according to my experience, in midsummer in warm standing pools of shallow water in rather open swampy woods. It should be preserved in formaline or alcohol, preferably the former.

Supplementary Exercise. Haematococcus (Protococcus) pluvialis is a useful Algae to use for demonstration of living swarm spores and their formation. According to Dr. Hazen*, if the red crust of resting sells is scraped from the rocks it covers, dried for a short time and then placed in a dish of water over night division of the contents of many of the cells will occur.

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* Hazen: The Life History of Sphaerella lacustris (Haematococcus pluvialis). Memoirs Torrey Botanical Club, vol. 6, pt. 3.

Exercise 58. Pleurococcus may be had in living condition at any season of the year. The lower bricks in a wall or those which have lain undisturbed on the ground in a shady place for several years will afford an abundant supply. Specimens collected from tree trunks usually have slightly larger cells but there is some risk of getting a crustaceous lichen instead of simple Pleurococcus from a tree trunk.

Exercise 59. Oscillaria is abundant during the open months of the year as a bluish-green, slimy coating on mud and on wooden posts standing in stagnant water. If some of this material is scraped from the mud or wood, it may be kept alive in a fruit jar during the winter, as described in Exercise 53.

Supplementary Exercise. ~~Glaeocapsa~~ Gloeocapsa is very common and is an excellent alga to close the course with on account of its simple spherical thallus and very evident manner of reproducing by division. The material may be dried, preferably on mica, when collected, and a little of this material soaked for use when needed.

{ Insert in p. 2 of ms. }

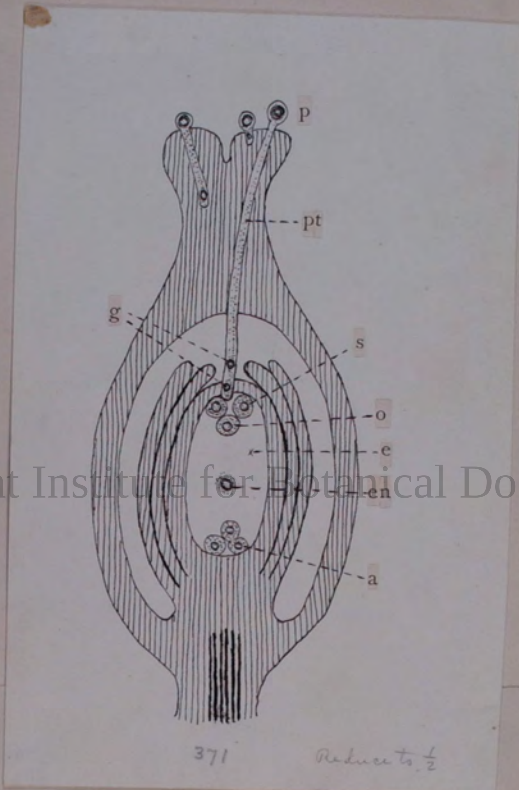


Fig. 371. Diagram of section of a one-ovuled pistil of an Angiosperm to illustrate formation of its oospore; g, generative cell of pollen tube; o, oosphere; pt, pollen tube; p, pollen grain on stigma; e, embryo sac; en, nucleus of embryo sac; s, synergid; a, antipodal cell.

{Insert in p. 4 of manuscript.}

Fig. 373. ~~Unilocular~~ One-celled spore of a cultivated species of Pteris, a fern.

Fig. 374. ~~Unilocular~~ One-celled spore of Equisetum arvense, having four appendages or arms.

Fig. 375. ~~Bilocular~~ Two-celled spore of Physcia stellaris, a lichen.

Fig. 376. Muriform (multilocular) spore of Teichospora nigro-brunnea, an Ascomycete.

{To be inserted in p. 6 of ms.}

~~minate upward in a leaf-stalk. The subterranean trunk or stem of any strong-growing herbaceous Fern shows a similar structure. Most Ferns are circinate in the bud; that is, are rolled up in the manner shown in Fig. 197. Uncoiling as they grow, they have some likeness to a crosier.~~

~~487. The fructification of Ferns is borne on the back or under side of the leaves. The early botanists thought this such a peculiarity that they~~

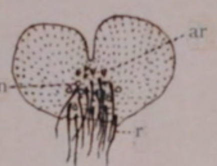
~~always called a Fern-leaf a FROND, and its petiole a STIPE. Usage continues these terms, although they are superfluous. The fruit of Ferns consists of SPORE-CASES, technically SPORANGIA, which grow out of the veins of the leaf. Sometimes these are distributed over the whole lower~~

FIG. 377 The Walking-Fern, Camptosorus, reduced in size, showing its fruit-dots (sori) on the veins approximated in pairs. 378 A small piece (pinnule) of a Shield-Fern: a row of ~~fruit-dots~~ sori on each side of the midrib, each covered by its kidney-shaped indusium. 379 A ~~spore-case~~ sporangium from the latter, just bursting by the partial straightening of the incomplete ring; well magnified. 380 Three of the spores of 379 more magnified. 381 Schizæa pusilla, a very small and simple-leaved Fern, drawn nearly of natural size. 382 One of the lobes of its fruit-bearing portion, magnified, bearing two rows of ~~spore-cases~~ sporangia. 383. ~~Spore-case~~ Sporangium of the latter, detached, opening lengthwise. 384 Adder-tongue, Ophioglossum: ~~spore-cases~~ sporangia in a kind of spike: *a*, a portion of the fruiting part, about natural size; showing two rows of the firm ~~spore-cases~~ Sporangia, which open transversely into two valves.

{Insert in p. 6 of ms.}

Reduce to 1/2

Fig. 385



Reduce to 1/2

Fig. 386

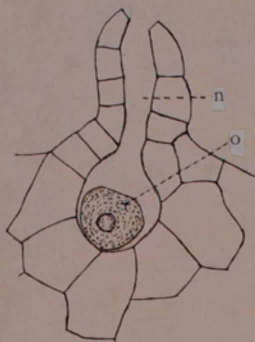
387

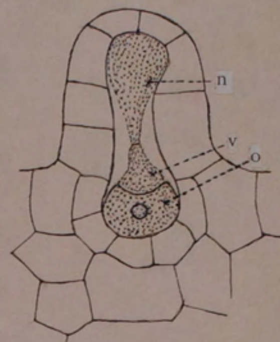
Fig. 385. Prothallium of a Pteris as seen from above, not magnified.

Fig. 386 Under surface of the same prothallium, bearing r, rhizoids; ar, archegonia; an, antheridia. Magnified 3 diameters. 387. Portion of prothallium of a Maiden-hair, showing the same organs as Fig. 386 but more magnified.

{Insert in p. 7 of Ms.}

Fig. ~~916~~ 388





389

Reduce to $\frac{1}{2}$

Fig. 388. Mature archegonium of Pteris, in optical longitudinal section; σ, oosphere; *n*, canal. 389. Young archegonium of Pteris, having remains of the neck canal-cell, *n*, and the ventral canal-cell, *v*; o, the cell becoming the oospore.

{Insert in p. 7 of ms.}

Reduce to ½

Fig. ~~518~~ 390

392

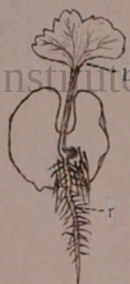
Reduce to ½

Fig. ~~519~~ 391

Fig. 390. Antheridium of Pteris seated on ~~one of the~~ a ~~outermost~~ surface cell of the prothallium; the spermatozoids (s) are in the space of the central mother-cell, from which they have originated. 391. Antheridium from which most of the spermatozoids have escaped. Both figures as seen in optical longitudinal section.

Fig. 392. Spermatozoid of Polypodium in motion. (After Schenck.)

[Insert in p. 8 of ms.]

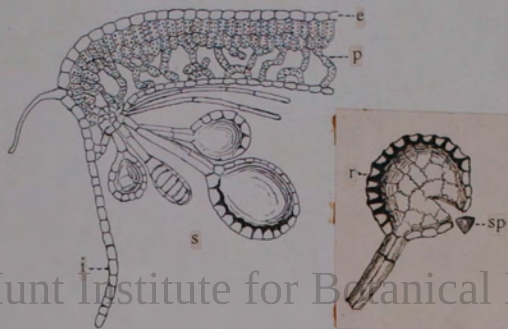


Reduce to $\frac{2}{3}$

Fig. 393

Fig. 393 Prothallium of Pteris with young fern attached to it by its foot; *r*, primary root; *l*, the first leaf.

{Insert in p. 9 of ms.}



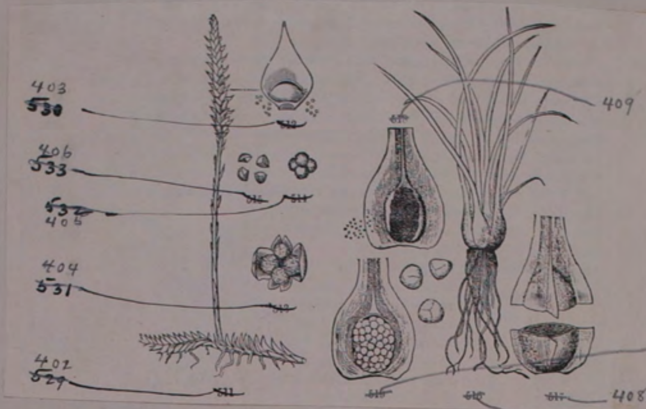
396 397

Reduce to 2/3

Fig. 396. Cross section of leaf of Pteris, showing sorus on lower side; i, marginal indusium; s, sporangia constituting the sorus; p, parenchyma; e, epidermis of upper surface.

Fig. 397 A sporangium of Pteris, just bursting by the partial straightening of the incomplete ring, r; sp, a spore.

[Insert in p. 10 of Ms.]



402 ~~29~~ FIG. ~~511.~~ Lycopodium Carolinianum, of nearly natural size. ~~512.~~ Inside view of one of the bracts and ~~spore-case~~ sporangium, magnified.

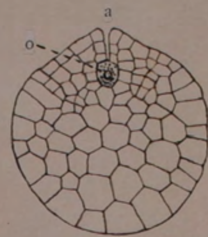
403 ~~30~~ 404 ~~31~~ FIG. ~~513.~~ Open 4-valved ~~spore-case~~ sporangium of a Selaginella, and its four large spores (macrospores), magnified. 405 ~~32~~ ~~514.~~ Macrospores of another Selaginella. 406 ~~33~~ ~~515.~~ Same separated.

407 FIG. ~~516.~~ Plant of Isoetes. 408 ~~517.~~ Base of a leaf (sporophyll) and contained ~~sporocarp~~ sporangium filled with microspores cut across, magnified. 409 ~~518.~~ Same divided lengthwise, equally magnified; some microspores seen at the left. 410 ~~519.~~ Section of a ~~spore-case~~ sporangium containing macrospores, equally magnified; at the right three macrospores more magnified.

{Insert in p. 12 of Ms.}

411

Reduce to $\frac{2}{3}$



412

Fig. 411. Macrospore of Isoetes lacustris, two weeks after its escape from the sporangium, redered transparent by glycerine so that its unicellular structure may be seen through the transparent cell wall. X 60. (After Hofmeister)

Fig. 412. Longitudinal section of prothallium of Isoetes lacustris four weeks after escape of the macrospore, the wall of the macrospore being removed. Germination of the macrospore while enclosed by its wall has given rise to a many-celled prothallium, bearing an imbedded archegonium a at its apex; o, the oosphere. X 40. (After Hofmeister)

[Insert in p. 13 of Ms.]

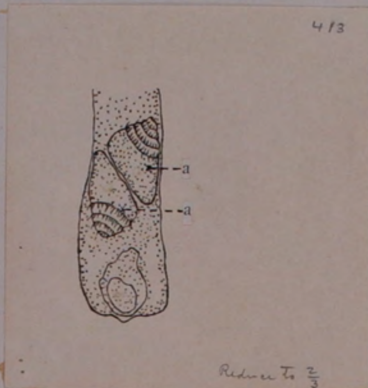


Fig. 413. Lower end of pollen tube of Zamia, a Phanerogam, containing two ciliated generative cells (spermatozoids), a,a.

{Insert in p. 14 of Ms}

414

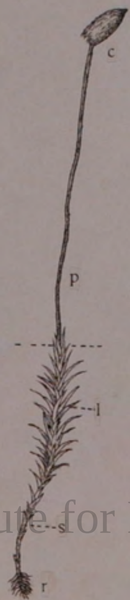


Fig. 414. Polytrichum commune, a common moss on dry banks: s, stem; l, leaf; r, rhizoids; p, pedicel; c, capsule. The portion above the dotted line is the sporophytic generation; the part below it belongs to the gametophyte.

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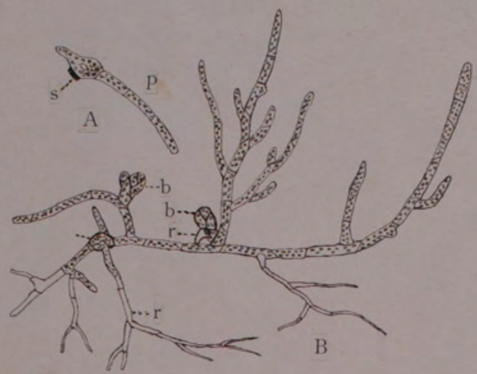


Fig. 415. A. Germinating spore, s, and young protonema, p. ... B. Protonema of moss: s, remains of spore; b, buds of leafy branches; r, r, rhizoids. (After Muller-Thurgau).

Fig. 416. "Moss plant", i.e. erect leaf-bearing branch from protonema, of Bryum bimum: r, rhizoids; s, stem; l, leaf. X 7.

[Insert in p. 15' of Ms.]

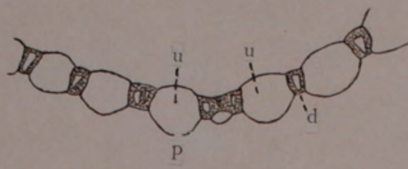
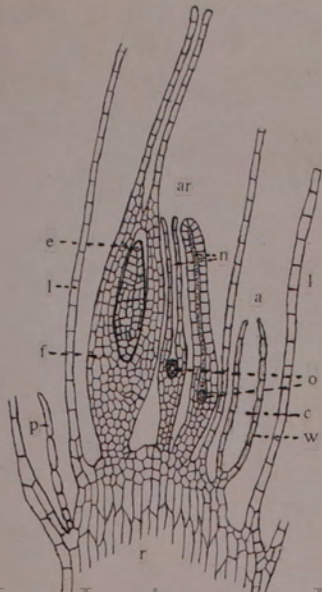


Fig. 417. Part of cross section of a leaf of a bog moss, Sphagnum acutifolium ~~fimbriatum~~ var. rubrum: u, colorless cell for water storage (utricle); p, pore; d, cell containing chlorophyll.

[Insert in p. 16 of Ms.; placing Fig. 418 on the left after reduction to 2/3 and Figs. 419 + 420 on the right after their reduction to 1/3]

418



Reduce to 2/3 418

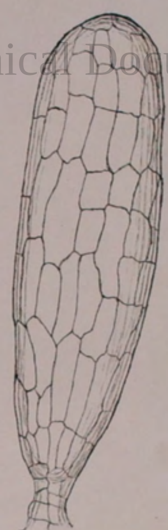
Fig. 418. Longitudinal section through middle of upper end of moss plant of Bryum bimum: r, receptacle (apex of stem); l,l, sections of leaves; a, empty antheridium in section, with (w) its wall and (c) cavity in which the spermatozoids contained; ar, a group of three archegonia in section, ~~of~~ the one on the right being immature and with neck closed, the one in the middle, mature; o, oosphere of each; n, canal through the neck; p, paraphysis. The oosphere of the archegonium (f) at the left has been fertilized and has developed into the embryo (e) of the sporophyte; the wall of the archegonium has also been stimulated to growth.

Fig. 419. Antheridium ~~of~~ before discharge of the spermatozoids, showing arrangement of cells in its wall.

Fig. 420. Spermatozoids of Mnium. (Fig. 420 after Atkinson)

[After the proper reductions, insert the right hand side of Fig 418 in p. 16 of Ms.]

419



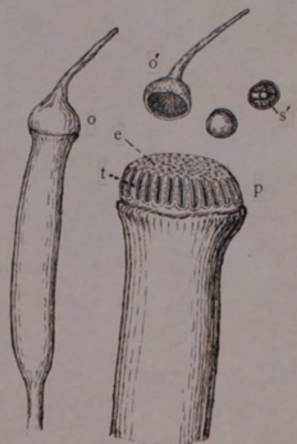
Reduce to $\frac{1}{3}$

420

{Insert in p. 17 of Ms}

Fig. 421. Moss plant of Atrichum angustatum with sporophyte still bearing the calyptra: f, region of insertion of foot of sporophyte into the moss plant; p, pedicel; c, capsule; d, calyptra.

{Insert in p. 18 of Ms.}

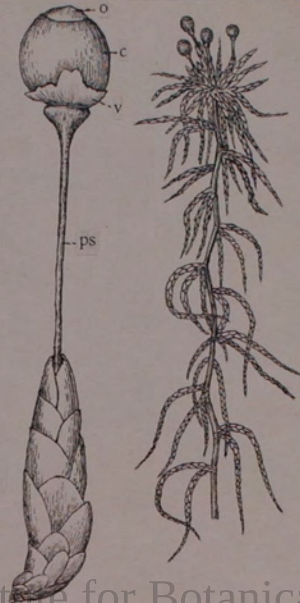


424

Reduce to $\frac{2}{3}$ 422 423

Fig. 422. Capsule of a moss, Atrichum angustatum, without the calyptra: o, operculum; o', operculum removed. 423. Capsule more enlarged, showing the peristome, p; t, a tooth of the peristome; e, epiphragm. 424. Spores of the same moss: s', optical section of spore.

{Insert in p. 19 of Ms.}



Reduce to 2/3

426 425

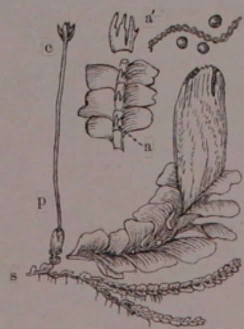
Fig. 425. A shoot of a bog moss, Sphagnum fimbriatum, with four sporophytes. Nat. size.

Fig. 426. A lateral shoot of the same with its terminal sporophyte, magnified: ps, pseudopodium; v, vaginule, i.e. base of the ruptured archegonium; c, capsule; o, operculum. (Figs. 425, 426 after Schimper).

{Insert in p. 21 of Ms.}

430

429 430



427 428

Reduce to $\frac{3}{4}$ — better $\frac{4}{5}$ or not reduced, if likely to print well.

Fig. 427. Leafy shoot of a foliose hepatic, Lophocolea heterophylla, with a sporophyte: s, stem; c, capsule split into four valves; p, pedicel. 428. A branch of the same enlarged, with terminal involucre marking the location of archegonia. 429. Part of shoot as seen from under side, with amphigastria, a, a; a', amphigastrium more enlarged. 430. Three spores and an elater.

{Insert in p. 22 of Ms.}

Fig. 431. Part of male plant of Marchantia polymorpha about natural size: t, thallus; r, rhizoids; b, specialized erect branch bearing antheridial receptacle. 432. Median longitudinal section of anteridial receptacle magnified: a, antheridium containing spermatozoids; a', empty antheridium.

Fig. 433. Female plant of M. polymorpha: t, thallus; r, rhizoids; c, cup containing gemmae; b, specialized branch bearing archegonial receptacle. 434. Median longitudinal section of archegonial receptacle: m, n, o, sporophytes in different stages of growth. In m, half of the perichaetial envelope has been removed and the sporophyte is seen contained in the archegonium, ar. 435. Old sporophyte with capsule, c, burst and discharging spores and elaters: p, pedicel; ar, ruptured wall of archegonium; pe; perianth. 436. Archegonium containing embryo sporophyte in two-celled stage, e.

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437

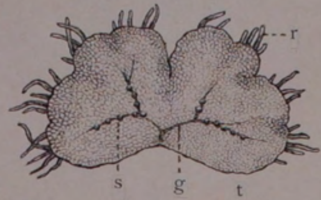

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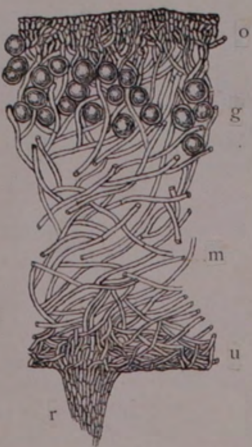
Fig. 437. A floating thalloid hepatic, Riccia natans, natural size: t, thallus; r, rhizoids; g, groove; s, mature sporophyte.

[Insert in p. 28 of Ms.]



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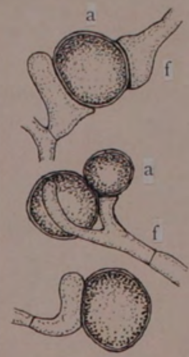
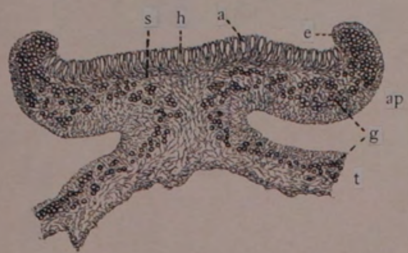
441



442

Fig. 441. Cross section of the thallus of Physcia stellaris: o, cortical layer of upper surface; g, gonidial layer; m, medullary layer; u, cortical layer of under surface; r, part of a rizoid. 442. Algal cells and hyphae from the gonidial layer, showing contact attachment of fungous hyphae, f, f, with algal cells, a, a.

[Insert in p. 29 of Ms.]



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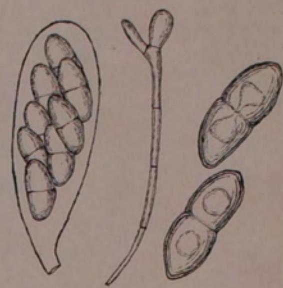
443



444 445 446

Fig. 443. Vertical section of apothecium and thallus of Physcia stellaris: ap, apothecium; t, thallus; h, hymenium; a, ascus; s, subhymenial layer; e, exciple; g, gonidial layer. 444. Ascus containing eight ascospores. 445. Paraphysis. 446. Two ascospores, the upper being immature.

[Insert in p. 36 of ms. these figures Nos. 581 and 582 in Gray's Lessons

Fig. 454. A common edible mushroom, Agaricus campester, less than natural size. The pileus and stem are white; the stem has an annulus but no volva; the lamellae are white when very young, then pinkish, becoming smoky brown and finally almost black.

455. Section of pileus and upper part of stem.

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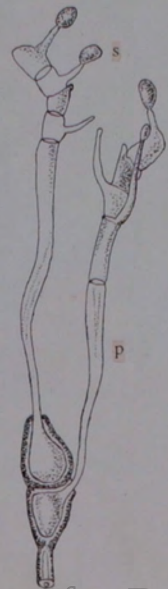

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458

Fig. 458. Germinating teleutospore of grain rust: p, promycelium; s, sporidium. After Tulasne.

[Insert in p. 39 of Ms.]

460

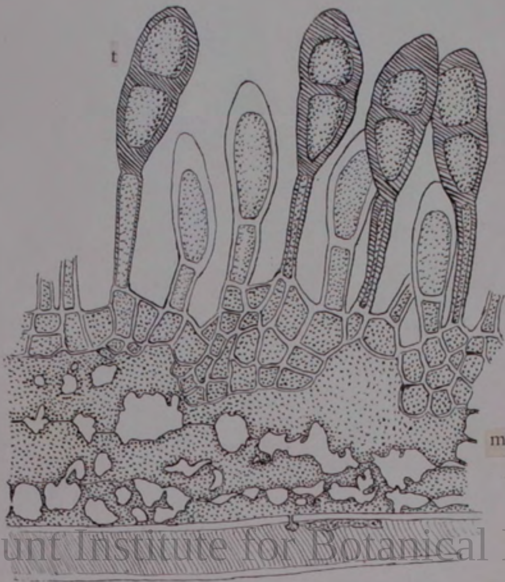

Fig. 460. Longitudinal section of oat stem through a mass of teleutospores: t, teleutospore; m, portion of mycelium very irregular and plasmodium-like in form.

{Insert in p. 40 of Ms}

40a

Fig. 461. Four-celled promycelium of a smut, Ustilago scabiosae: s, sporidium; w, wall of smut spore. After Harper.

Fig. 462. Promycelium of corn smut: s, sporidium; w, germinating smut spore. After Arthur.

[Insert in p. 41 of Ms.]

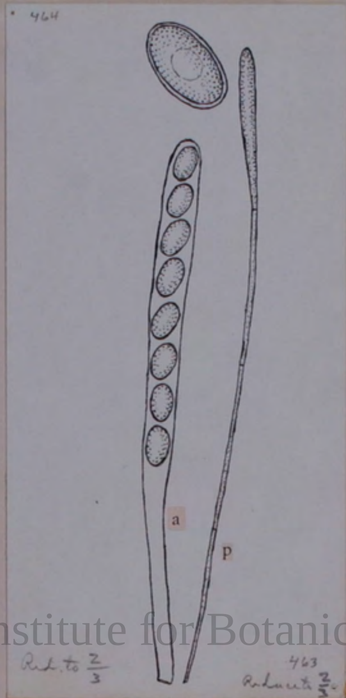

Fig. 463. A, ascus containing eight ascospores, and p, paraphysis of the Ascomycete, Lachnea setosa. 464. One of the ascospores. All highly magnified.

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465

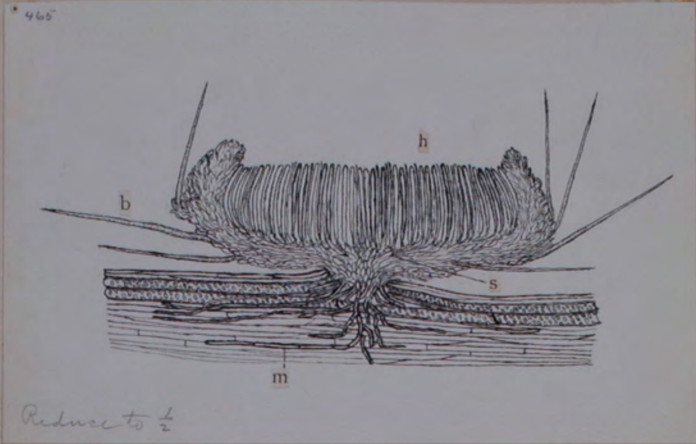

Fig. 465. Vertical section of apothecium (fructification) and the rotting wood from which it springs, of an Ascomycete, Lachnea setosa. The hyphae of the mycelium, m, (drawn very dark to distinguish them from the woody tissue) converge to the base of the apothecium: h, hymenium, consisting of asci and paraphyses; s, subhymenial layer; b, seta.

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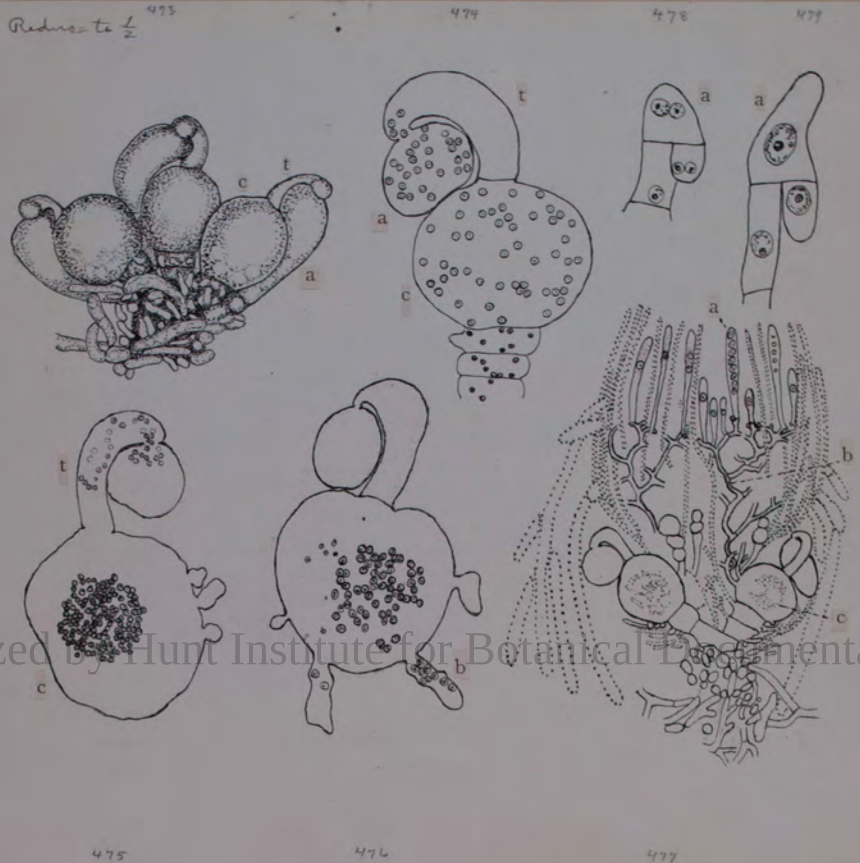
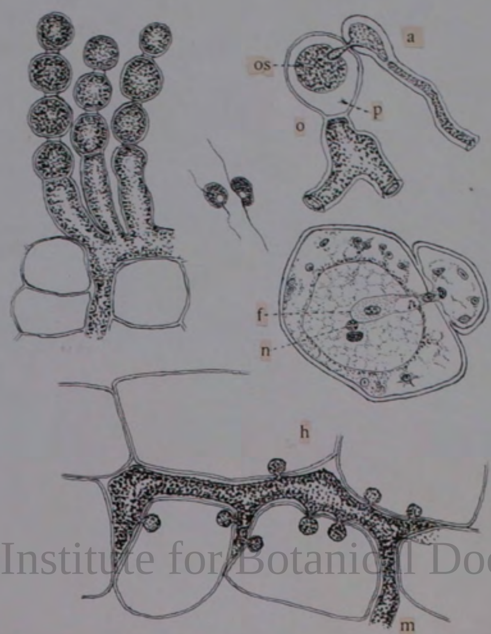


Figs. 473 - 479. Carposporic reproduction of the Discomycete, Pyronema confluens. After Harper. 473. Mycelium bearing three pairs of sexual cells: c, carpogonium; t, trichogyne; a, antheridium. 474. Nuclei beginning to pass from the antheridium, a, into the trichogyne, t. Only the upper end of the antheridium is shown in this and the following figures. 475. Wall between trichogyne and carpogonium has dissolved and antheridial nuclei have passed from the trichogyne into the carpogonium and the nuclei are fusing in pairs. Three ascogenous branches are budding out from the right of ascogonium (former ~~ascogonium~~ carpogonium). 476. Nuclei passing into ascogenous branches after fertilization. A new wall has formed between trichogyne and ascogonium. 477. Vertical section of a young apothecium in which the first asci are ripening. The asci, a, are borne on ascogenous branches, b, which spring from the sides of the ascogonium, c. The paraphyses, p, are drawn with dotted outlines and originate from cells below the ascogonium. 478. Recurved tip of ascogenous branch with dome-shaped young ascus, a, containing two nuclei. 479. Young ascus, a, with single nucleus formed by the fusion of the two nuclei shown in the preceding figure. From this primary nucleus there are formed as many nuclei as the ascus eventually contains ascospores.

[Insert in p. 46 of Ms.]

482 486 484



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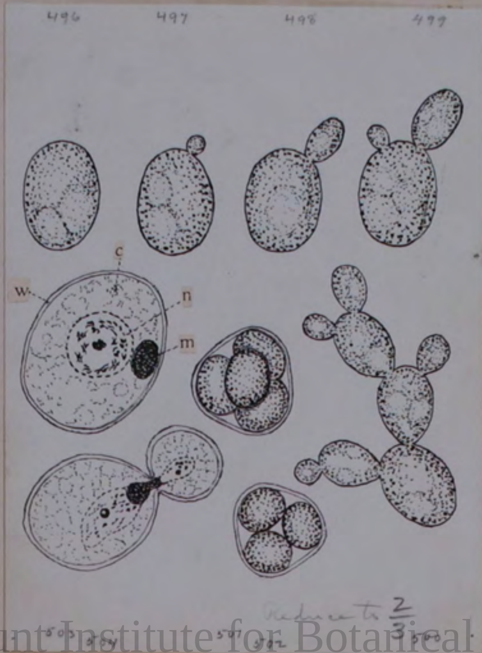
483

Figs, 482, 486. Cystopus (Albugo) candidus on Shepherd's Purse. 482. Conidial fructification at the surface of the stem: the conidia are in bead-like chains. 483. A fragment of the mycelium, m, occupying spaces between the cells of the host plant and penetrating these cells with its globose haustoria, h. 484. ~~Sex~~ Reproductive ~~ual~~ organs borne on the mycelium: a, antheridium; o, oogonium; os, oosphere; p, periplasm. 485. Section of oogonium and antheridium showing fertilization tube, f, about to discharge an antheridial nucleus into the oosphere: n, nucleus of oosphere. (After Davis). 486. Two swarm-spores, such as are produced by germination of either a conidium or an oospore. (After De Bary).

[Insert in p. 50 of Ms]



Figs. 496, 504. Common yeast, Saccharomyces cerevisiae, highly magnified. 496. Single cell (thallus) of yeast. 497, 499. Stages in production of new cells by budding. 500. A colony of connected cells. 501, 502. Cells containing four and three spores respectively – from yeast which had been cultivated for a week on a moist plaster of paris plate in a glass jar. 503. Structure of the yeast cell: w, cell wall; c, cytoplasm; n, nuclear vacuole and network; m, nuclear body (nucleolus). (After Wager). 504. Direct division of the nuclear apparatus in forming a new cell by budding. (After Wager).

[Insert in p. 53 of Ms.]

Reduce to 2/3

505 506 507 508 509 510 511 512 513 514

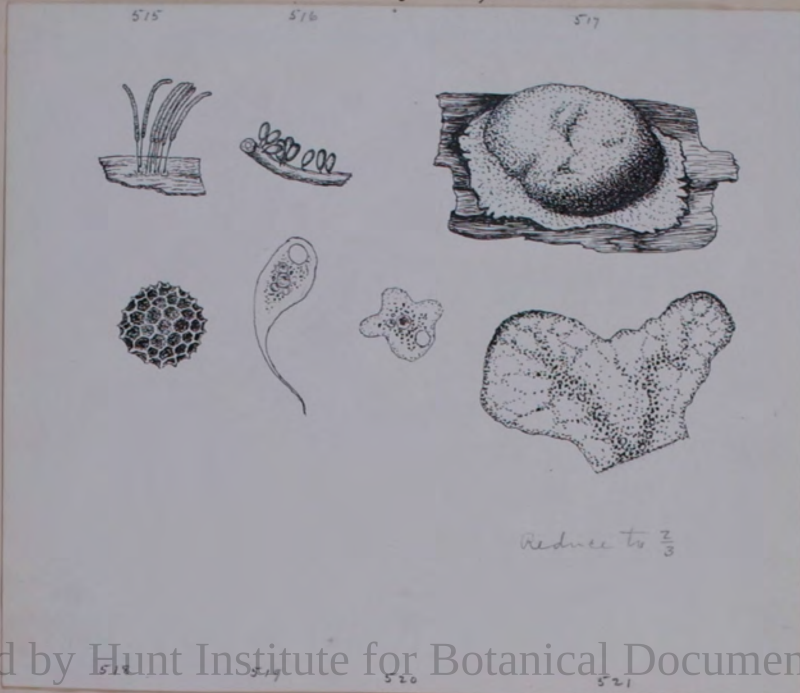
Fig. 505. Bacteria from between the teeth of the human mouth. Magnified about 800 diameters. Figs. 506, . Different kinds of the same as seen in living condition in a preparation in water, but more highly magnified: Fig. 506, Bacillus maximus buccalis, the species forming the long threads of Fig. 505; Fig. 507, Cocci, which appear as mere dots in Fig. 505; Fig. 508, Vibrios, as they appear while moving.

Fig. 509. The structure of the bacterial cell, as shown by plasmolysis of the Bacillus of typhoid fever with a 2 1/2 % solution of common salt: m, cell membrane; the dark masses, p, are the shrunken cell contents.

Fig. 510. Bacillus of typhoid fever, Bacillus typhi abdominalis, prepared and stained to show its cilia, c. Fig. 511. Vibrio buccalis, from the human mouth, prepared to show its cilium. Fig. 512. Spirillum sputigenum, also from the mouth.

Fig. 513. Bacillus subtilis in vegetative condition. Fig. 514. Bacillus subtilis forming spores, s. (Figs. 509 – 514 after A. Fischer).

{Insert in p. 55 of Ms.}



Figs. 515, 521. Myxomycetes. 515. A cluster of sporangia of Stemonitis fusca, natural size. 516. Nine sporangia of Leocarpus fragilis, natural size. 517. Aethalium of Fuligo septica, natural size. 518. Spore, highly magnified, from a sporangium of Stemonitis fusca. 519. Swarm spore, and 520, amoeboid stage, ~~of the same sowing~~ obtained by germinating some of the spores of St. fusca in water. The clear spot marks the position of the contractile vacuole. 521. A plasmodium, natural size.

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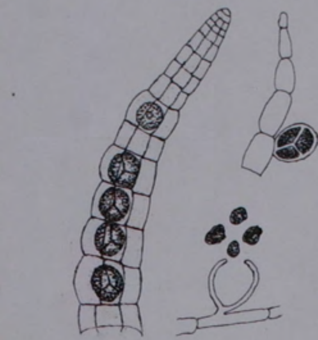


Fig. 526. Branch of Polysiphonia urceolata containing five groups of tetraspores. The fourth spore of each group is hidden by the upper three.

Fig. 527. A branch of Callithamnion Baileyi bearing a sporangium of tetraspores. 528. Tetraspores free from the sporangium. (Figs. 527, 528, after Farlow).

{Insert in p. 59 of Ms.} 531

Figs. 529, 531. Carposporic reproduction of Nemalion multifidum (after Thuret and Bornet). 529. A branch with carpogonium, c, and antheridia, a: t, trichogyne; s, spermatium, produced in the antheridium. 530. Carpogonium dividing after fertilization and giving rise at its sides to carpogenous filaments, b. 531. A nearly mature cystocarp: s, position of a spore in the end of a carpogenous filament.

[Insert in p. 59 of Ms.]

~~533~~ 534

← Fig. 533, Gray's Lessons is to be reduced to 3/4 and its block inserted for printing in the space in lower left hand corner with Figs. 532-535.

Figs. 532-535. Brown Algae. 532. A branch of Sargassum vulgare, natural size: a, air bladder; f, fruiting ~~branch~~ tip. 533. Laminaria saccharina, Devil's Apron, showing the attachment by a "hold fast" to a stone in the bottom of a tide pool; greatly reduced in size. ~~FIG. 533.~~ 534 Agarum Turneri, Sea Colander (so called from the perforations with which the frond, as it grows, becomes riddled); very much reduced in size.

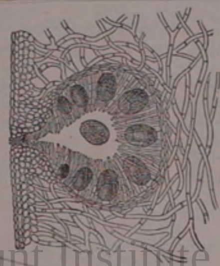
535. A part of the filamentous thallus of Ectocarpus littoralis, magnified: s, a group of ~~four~~ five unilocular sporangia.

[Insert in p. 60 of Ms.]

536

Insert here Figs. 539-541 after reduction as indicated.

Figs. 554-556 of Gray's Lessons may be grouped as indicated here. Then insert in the space in the upper right hand corner Figs. 539-541.



537

538

Figs. 536- 541. Rockweed; all except 539 are Fucus vesiculosus. 536. Upper end of thallus: ~~a, air bladder~~;b, fruiting tip. Three air bladders are located where the thallus forks. 537. Part of cross section of a fruiting tip, showing conceptacle containing large, dark, ellipsoidal oogonia arranged between thread-like paraphyses. The heavy black lines in some oogonia represent fissures between adjacent oospheres. 538. Part of cross section of tip, showing antheridial conceptacle. 539. Branched hair from the male conceptacle of Ascophyllum, bearing four antheridia. The contents of the antheridia have divided and rounded off into spermatozoids. 540. Two spermatozoids. 541. Oosphere surrounded by spermatozoids, as seen during fertilization. (Figs. 536 - 538 after Farlow; 540, 541 after Thuret.)

541

[After reduction insert in group with Figs. 536-538 in p. 60 of Ms.]

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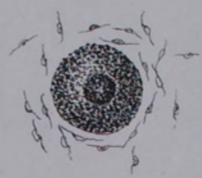
541



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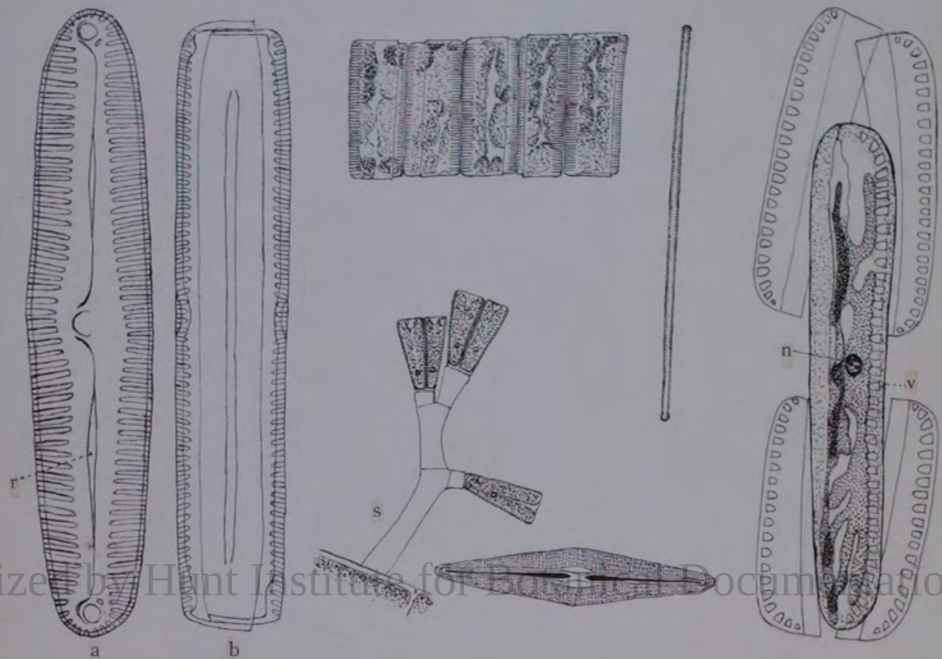
543 544



542 545 546 547

Figs. 542, 547. Diatoms. 542. Pinnularia viridis. a, valve view; b, girdle ~~(side)~~ view, showing the older and larger valve on the left overlapping the smaller valve on the ~~left~~ right like the cover on a pill box; r, raphe. 543. Fragillaria sp., probably. Girdle view of five living Diatoms forming part of a ribbon-shaped colony. The cell contents show through the transparent valves. 544. Synedra. 545. A marine species of Gomphonema. A colony of five individuals attached by a gelatinous stalk, s, to a filament of Ectocarpus. 546. Navicula rhomboides. Valve view. 547. An auxospore of Surirella saxonica, formed by conjugation of the protoplasm of two ~~diatom~~ individuals whose valves still remain on opposite ends of the auxospore: v, valve in course of secretion by the auxospore; n, nucleus. (Fig. 542, after Pfitzer; 547, after G.Karsten.)

[Insert in p. 64 of Ms.]

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Figs. 550, 552 of Gray's Lessons may be used here but in their natural erect position, and with numbers changed as indicated. On their right, in this space, Figs. 551–553 of my drawings may be grouped for printing after the indicated reduction.

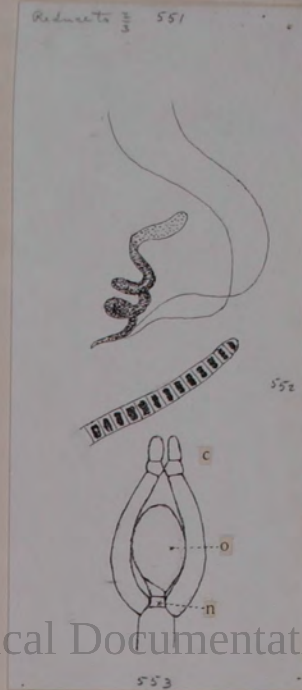

Fig. 548. Branch of a Chara, about natural size. 549. Outlines of a portion of the ~~stem~~ thallus of the same in section, showing the central, internodal cell and the outer or cortical cells. 550. A fruiting portion, magnified, showing structure of the thallus and, at a node, an oogonium directed upward and an antheridium downward. 551. Spermatozoid of Chara fragilis in motion. (After Strasburger.) 552. Part of a filament from an antheridium of Nitella flexilis. The protoplasmic contents of each cell becomes a spermatozoid. 553. Diagram showing position of parts in oogonium of Nitella flexilis: o, oosphere; c, crown cells; n, nodal cell.

{Insert in p. 65 of Ms.}

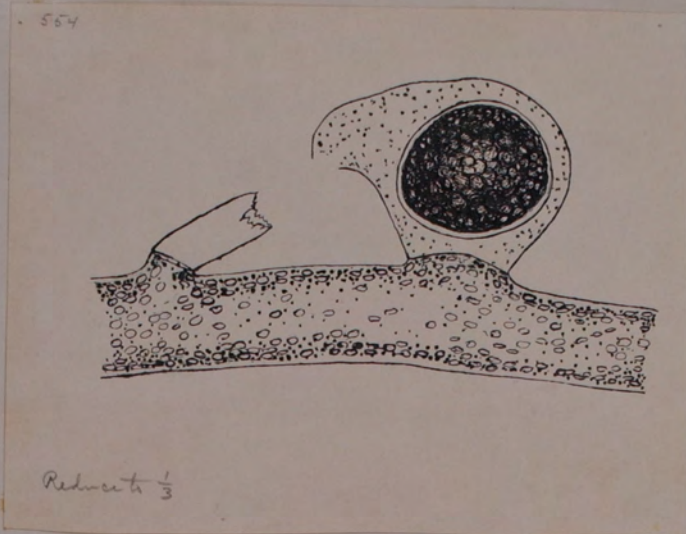

Fig. 554. Part of a filament of Vaucheria bearing an empty antheridium and an oogonium containing an oospore which has already secreted a cell wall.

[Insert in p. 66 of Ms. Figs 568, 571 of Gray's Lessons, but with numbers changed to 555, 558 + explanations as given below.]

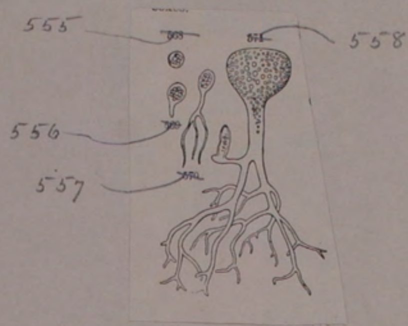

Fig. 555. Early stage of Botrydium granulatum, a globose walled cell such as results from germination of a swarm spore. 556, 557. Stages of growth. 558. Mature plant, highly magnified, with branched rhizoids below, and producing a young plant by budding at the left.

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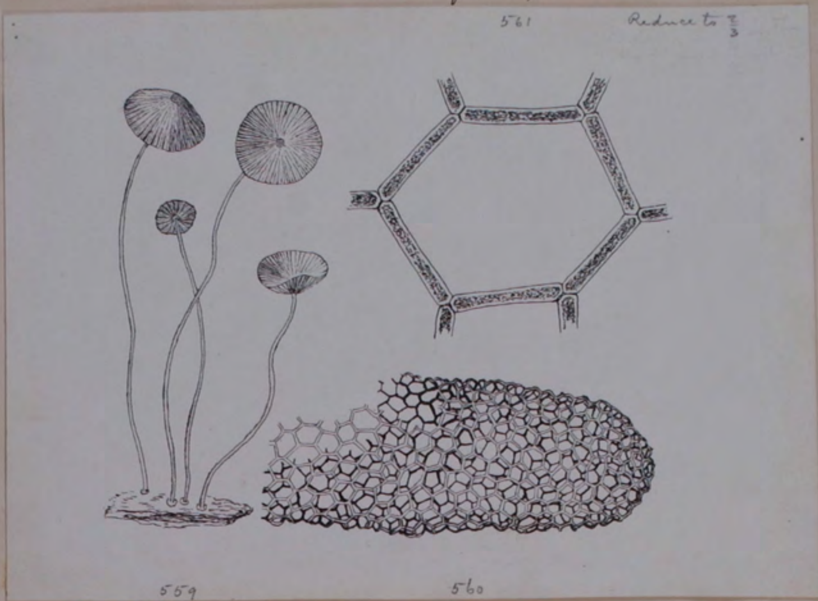
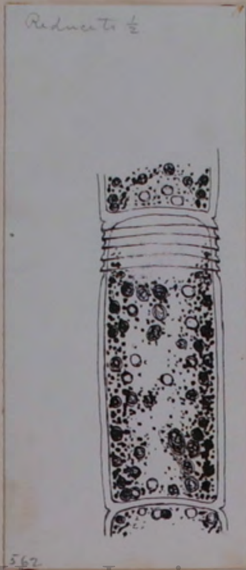


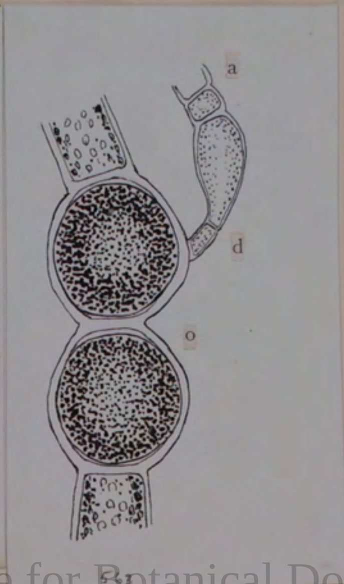
Fig. 559. Acetabularia mediterranea, natural size. (After Schenck.)

Fig. 560. Hydrodicton reticulatum or Water Net, about natural size.

561. A mesh of the net magnified, showing the cylindric unicellular members (individuals) which compose the net or colony.

[Insert in p. 68 of Ms.]





562

Fig. 562. Part of the thallus of Oedogonium sp., highly magnified, showing the characteristic transverse striations near the upper end of a cell. 563. Part of a filament containing two oogonia: o, oosphere; d, "dwarf male", a few-celled parasitic male plant which bears the antheridia in this species; a, empty antheridium.

[Insert in p. 69 of Ms.]

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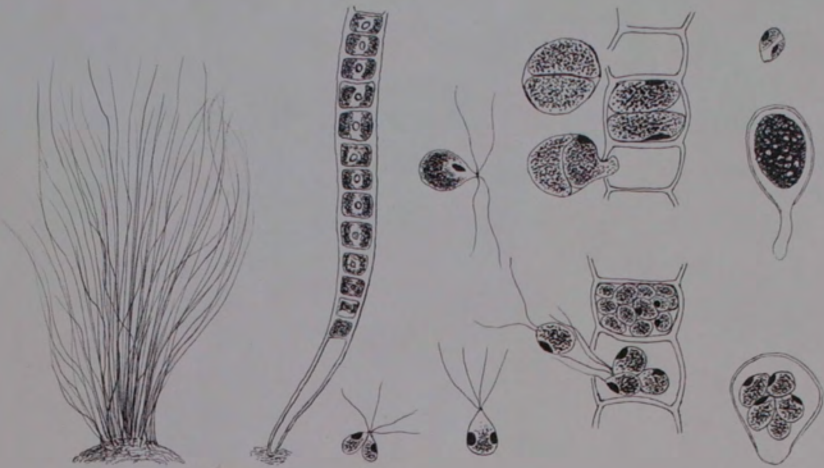


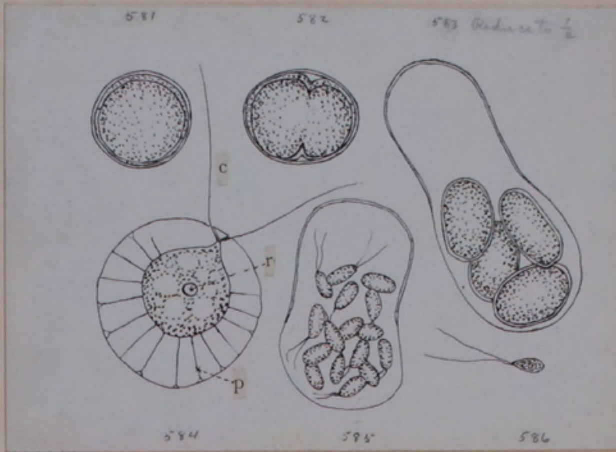
Fig. 564. Ulothrix zonata, natural size. 565. Lower part of a young plant, showing vegetative cells and the rhizoidal cell by which the filament is attached. 566. Cells (sporangia) whose contents have become swarm spores. 567. A swarm spore. 568. Cells (sporangia) whose contents have become planogametes. 569, 570. Stages in conjugation of two planogametes. 571. Young zygospore. 572. Sporophyte produced by germination of zygospore. 573. Sporophyte with contents divided into swarm spores. (Fig.565, after Schenck; 568, 573, after Dodel-Port.)

[Insert in p. 71 of Ms.]

580

Figs. 577, 580. Desmids, highly magnified. 577. Closterium Ralfsii. 578. Cosmarium sp. 579. Xanthidium fasciculatum forming two individuals by fission: a, b, halves of the parent Desmid; a', b', young half-cells being formed by a and b respectively. 580. Closterium strigosum forming zygospore, z, by conjugation of the protoplasmic contents of two cells, each of which has been broken open in the middle region for its escape. ~~of the~~ (Figs. 579, 580, after Wolle.)

[Insert in p. 72 of Ms.]



Figs. 581, 586. Haematococcus (Sphaerella) lacustris, highly magnified. (After Hazen) 581. A resting cell. The whole inner portion of the cell as far out as the inner circle was contained red pigment. 582. Beginning of division of a resting cell. 583. Stage in which the contents of a resting cell have divided into four daughter cells. 584. A mature large swarm spore: c, cilium; p, radiating protoplasmic thread; r, red pigmented region. 585. A mother cell containing many small swarm spores. 586. One of the small swarm spores.

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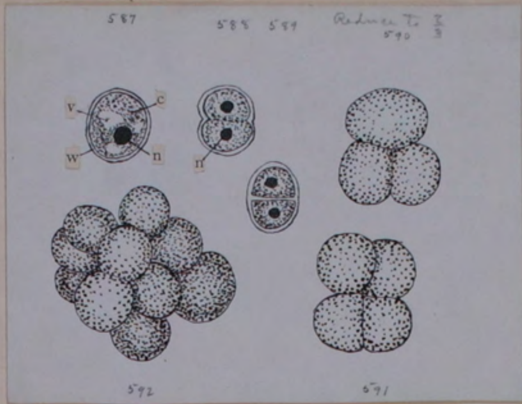

Figs. 587, 592. Pleurococcus vulgaris, highly magnified. 587. The one-celled thallus in optical section: w, cell wall; n, nucleus; c, cytoplasm; v, sap vacuole. 588, 589. Final stages in formation of two cells from a single cell. In 589 the cross wall has formed. 590. Three-celled group in which the lower cells have been formed [illegible] division of the [illegible] cell [illegible]. 591. A four-celled group. 592. A many-celled group.

[Insert in p. 76 of Ms.]

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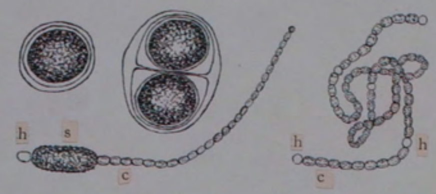

Fig. 596. Gloeocapsa Magma, highly magnified. A single cell before division. 597. After division into two cells.

Fig. 598. Cylindrospermum muscicola, highly magnified: s, spore; h, heterocyst; c, vegetative cells.

Fig. 599. Nostoc, highly magnified: h, heterocyst; c, vegetative cells.