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PROF. G. C. FOSTER, F.R.S. AND PHILIP MAGNUS, B.Sc. B.A.

BOTANY

CLASSIFICATION OF PLANTS

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BOTANY

OUTLINES
of
CLASSIFICATION OF PLANTS

BY

WILLIAM RAMSAY M^{C}NAB, M.D. F.L.S.

PROFESSOR OF BOTANY, ROYAL COLLEGE OF SCIENCE
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EDITORS' PREFACE.

NOTWITHSTANDING the large number of scientific works which have been published within the last few years, it is very generally acknowledged by those who are practically engaged in Education, whether as Teachers or as Examiners, that there is still a want of Books adapted for school purposes upon several important branches of Science. The present SERIES will aim at supplying this deficiency. The works comprised in the SERIES will all be composed with special reference to their use in school-teaching; but, at the same time, particular attention will be given to making the information contained in them trustworthy and accurate, and to presenting it in such a way that it may serve as a basis for more advanced study.

In conformity with the special object of the Series, the attempt will be made in all cases to bring out the educational value which properly belongs to the study of any branch of Science, by not merely treating of its acquired results, but by explaining as fully as possible the nature of the methods of inquiry and reasoning by which these results have been obtained. Consequently, although the treatment of each subject will be strictly elementary, the fundamental facts will be stated and discussed with the fulness needed to place their scientific significance in a clear light, and to show the relation in which they stand to the general conclusions of Science.

In order to ensure the efficient carrying-out of the general scheme indicated above, the Editors have endeavoured to obtain the co-operation, as Authors of the several treatises, of men who combine special knowledge of the subjects on which they write with practical experience in Teaching.

The volumes of the Series will be published, if possible, at a uniform price of 1*s*. 6*d*. It is intended that eventually each of the chief branches of Science shall be represented by one or more volumes.

G. C. F.,
P. M.

PREFACE.

THIS volume on the 'Classification of Plants,' along with the volume on 'Morphology and Physiology' already published in the same Series, is intended to serve as a basis for the botanical teaching in the higher classes of Schools, and also to supply the wants of Medical and other students. For the junior student it will be enough, in the first instance, to study the introductory remarks in each chapter and the description of the 'Classes.' This will enable him to complete the brief outline of the Classes of Plants given in the last chapter of the volume already referred to. In most cases some special example of each 'Class' has been described at considerable length and fully illustrated, the descriptions of the figures often containing additional information, for which there was no room in the text. The more advanced student may proceed to the study of the 'Orders.'

These, for convenience, have been numbered consecutively, from the lowest to the highest; but I must warn the student against supposing that the mutual relationships of these orders can be shown by any lineal arrangement. The 'Orders' have been made to include a number of 'Families,' each usually equivalent to the so-called 'Natural Orders' of many of the older botanical books. The characters of the more important families of the Thallophytes, Bryophytes, Pteridophytes, and Archisperms have been given, but no attempt has been made, from want of space, to treat of the families of Monocotyledons and Dicotyledons.

A brief account of the Geological Distribution of the different groups has been given; but space did not permit of more than occasional notices of the Geographical Distribution.

It cannot be pointed out too often that a sound knowledge of Botany is not to be obtained from the mere study of Text-books, apart from the careful examination and comparison of actual plants. Hence, while the junior student should content himself at the outset with the systematic study of the Classes, he should investigate, with microscope, lens, knife, and needle, such members of the different groups as may be accessible to him. At the same time, he should begin the practical study of individual plants, by taking the first flowering plant he can get, and making as far as possible an exhaustive study of it, ascertaining the name and family to which it belongs. When perhaps a dozen forms have been thus studied, the student can readily use a 'Flora,' and study the plants in his own neighbourhood. I have found such practical work of great value, my Systematic Lectures being always accompanied during the whole session with demonstrations from any flowering plants that can be got for the purpose.

As in the volume on Morphology and Physiology, so in this, I have made ample use of Sachs' 'Text-book of Botany,' of Prantl's 'Lehrbuch der Botanik,' and Luerssen's 'Grundzuege der Botanik,' and have again to tender my most grateful acknowledgments.

Lastly I have to tender my thanks to the Delegates of the Clarendon Press, for consenting to allow the woodcuts from Sachs' 'Text-Book of Botany' to be used in this volume, and also in the preceding one on 'Morphology and Physiology' already published. Better woodcuts could not be obtained. As my two little books will serve as an introduction to the celebrated Text-book of the distinguished German

Botanist, the student after mastering them may well proceed to study the admirable translation of Sachs, published in the Clarendon Press Series. It is a Text-book no teacher can possibly do without, and must be studied by every student who wishes to distinguish himself in Botanical Science.

W. R. McNab.

Royal College of Science, Dublin:
May 3, 1878.

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BOTANY.

SPECIAL MORPHOLOGY AND OUTLINES OF CLASSIFICATION OF PLANTS.

CHAPTER I.

THE THALLOPHYTES.

SUB-KINGDOM I.—*THALLOPHYTA.*

THE plants known familiarly as sea-weeds, funguses, and lichens, belong to the sub-kingdom Thallophyta. The plant-body consists of a thallus, in which the separation into stem and leaf is not observable. Many of the thallophytes consist of a single cell during the greater part of their life, and in the higher forms, whose external construction is still simple, the thallus consists of a series of uniform cells, or at most the external cells differ but slightly from those in the interior. The transition from the Thallophyta to the next sub-kingdom, the Bryophyta, is not an abrupt one, hence in some of the higher thallophytes a separation into stem and leaf may almost be noticed, while in the lower bryophytes the thallus is still to be met with. Indeed it is difficult to give any general characters for thallophytes, and it is only by the study of selected forms that a comprehensive view of the whole can be obtained.

The cells of the thallophytes are often extremely simple, being sometimes masses of protoplasm without a nucleus, and often with no cell-walls. In other cases the simple naked masses of protoplasm are furnished with vibratile cilia. Very often, however, in the thallophytes highly organised cells are to be met with, having a much more complex construction than those of the higher plants.

The modes of sexual reproduction are very varied, and in many a well marked alternation of generations exists. In the lowest forms no sexual reproduction has as yet been discovered. In the higher forms three distinct modes have been described, and by these the higher thallophytes may be divided into three classes. It must be borne in mind, however, that these classes are as yet only provisional, as in many cases our knowledge is defective, and in large groups, the true mushrooms, for example, we have no accurate information regarding the sexual reproduction.

When the two elements necessary for sexual reproduction are indistinguishable in size and appearance, their union is called conjugation. It is the simplest variety, the two elements being still undifferentiated masses of protoplasm, and by their union a zygospore is produced. In some of the plants in which conjugation occurs, slight differences in the appearance of the two conjugating cells may be noticed. In the second group of thallophytes the difference between the two reproductive cells is very great; the one, the oosphere, or germ-cell, being enormously larger than the other, the spermatozoid or sperm-cell. After fertilisation, or the union of one or more minute spermatozoids with the oosphere, the oosphere becomes the oospore. In the third group we have the presence of a structure called the carpogonium, or female element, which supplies the material for the growth of the sporocarp, and may consist of two or more cells. Fertilisation is effected by spermatozoids, or by a kind of conjugation; the spermatozoids being very minute and only stimulating the carpogonium to further development. The sporocarp differs in different groups. It may be very simple or very complex, and even capable of independent growth. The sporocarp consists of two parts—a fertile part, derived from the germ-cell after fertilisation, and producing sooner or later one or many spores, and a case or external covering not developed from the female reproductive organ, but produced as a result of fertilisation and inclosing all the spores developed from it.

The thallophytes may thus be separated into four classes. The Schizophyta or Protophyta, in which no sexual reproduction is as yet known, and including organisms which from their low degree of organisation probably have no such mode of reproduction. The Zygosporeæ include all those forms in which conjugation and the formation of zygospores occurs. The oospore characterises the Oosporeæ; and the production of a complex structure, giving rise to the carpospores, limits the group of the Carposporeæ.

Besides the formation of spores which result either directly or indirectly from a process of sexual reproduction, bud-cells or gonidia are frequently produced, and multiply the plant non-sexually. These non-sexual reproductive cells may be variously produced, as, for example, on minute sterigmata, and hence called *stylogonidia*; or inside an envelope, endogonidia. In other cases four may be developed together inside a cell, tetragonidia; or they may have cilia and be locomotive, the zoogonidia. All these numerous forms are connected with agamogenic reproduction.

The thallophytes, having a soft cellular body, usually without hard parts, and never having any structure resembling fibro-vascular bundles, are not likely to be preserved in a fossil state. Schimper, however, enumerates eighty-two genera, and 353 species of thallophytes. The Schizophyta are represented by a species of Nostoc from the Tertiary. The Zygosporeæ are chiefly represented by the Diatomaceæ, many deposits of a fossil or sub-fossil nature being found among very recent strata. Castracane has, however, detected numerous marine and fresh-water forms in brown coal of Miocene age, nearly all belonging to living genera and species. Coal from the Carboniferous rocks from the neighbourhood of Liverpool, from Newcastle, Scotland, and St. Etienne, yielded several fresh-water forms, all belonging to living genera and species. Forms allied to Conferva occur abundantly in the Tertiary. Of the Oosporeæ, Caulerpites occurs from the Silurian to the Eocene, and

Caulerpa in the Tertiary. Fucoides occurs in pre-carboniferous strata, and Fucus itself in the Eocene. The Carposporeæ are well represented by Florideæ and Characeæ. Thus forty species of Chara are met with from the Triassic to the Tertiary; and the Florideæ are represented by Sphærococcites and Chondrites, from the Lias to the Miocene, Delesseria from the Chalk to the Miocene, and is still living. Corallina occurs from the Silurian up to the present, and the Oldhamia of the Cambrian is probably one of the Florideæ. Colourless Carposporeæ are not unfrequent in the Tertiary, many of the genera being identical with those still living, and belonging chiefly to the Pyrenomycetes (as Sphæria) and Hymenomycetes (as Polyporus). The lichens are represented by ten genera in the Tertiary, all the genera being still living, as Parmelia, Ramalina, Cladonia, Usnea, Lecidea, and Graphis.

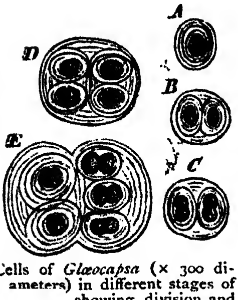
CLASS I.—SCHIZOPHYTA OR PROTOPHYTA.

This class, which is to a great extent provisional, includes the simplest and the smallest plants with which we are acquainted. In some the protoplasm is not separated into coloured and colourless portions; many have the whole tinged with a peculiar blue colouring matter, phycochrome or phycocyan, while a few possess chlorophyll. In many instances no nucleus exists in the cell, and the cells themselves may be so minute as to require the highest magnifying powers for their examination, and even then can scarcely be resolved into wall and granular or homogeneous contents. The wall in many of the higher forms becomes gelatinous. The cells are variously aggregated, or may be altogether separate; when aggregated they form rows, surfaces, or masses of cells, and in many cases colonies are formed in a gelatinous investing case. Often the cells are all similar, but in some of the filaments different forms may be developed. Movements of the cells frequently occur, and in Spirillum one cilium is developed at each end. It is probable that zoogonidia do not occur. No sexual reproduction has as yet been observed, only agamogenesis by division; hence the name Schizophyta, which has been applied to the group by Cohn.

A. *Schizophyta with Green or Blue-Green Colouring Matter.*

Order I. **Cyanophyceæ.**—Blue-green, very rarely purple or red, algæ; cells without a nucleus. Chlorophyll and phycocyan present. The phycocyan or phycochrome is soluble in cold fresh water, the solution being blue by transmitted light and red by reflected.

Family 1. *Chroococcaceæ.*—The rounded cells are either closed in gelatinous matter. Chroococcus and Glœocapsa live in wet places (fig. 1).



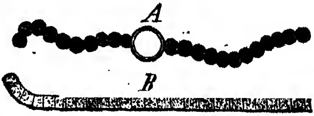
Cells of *Glœocapsa* (× 300 diameters) in different stages of . showing division and the mode in which the daughter cells are surrounded and enclosed by the gelatinous walls of the mother cells; *A*, youngest; *E*, oldest stage. (After Sachs.)

Fam. 2. *Nostocaceæ.*—The

plants are moniliform threads united into masses by gelatinous matter. They are found in water or on wet earth and mosses (fig. 2, A).

Fam. 3. *Oscillatoriaceæ.*—Very narrow filaments with exceedingly fine transverse walls. They occur generally in masses in water or on wet earth, and are distinguished by their remarkable oscillating movements (fig. 2, B).

Fig. 2.



Filament of Nostoc, *A* (× 300 diameters); *B*, end of filament of Oscillatoria (× 300 diameters). (After Prantl.)

Fam. 4. *Rivulariaceæ.*—Whip-like threads arranged in a radiating manner, each thread with a large basal cell, the whole forming a greenish gelatinous mass, either free or attached to water-plants.

Fam. 5. *Scytonemaceæ.*—Branched threads each with a thick dark-brown gelatinous sheath, and bluish green contents.

Order II.—**Chlorophyllophyceæ.** Cells containing chlorophyll only.

Fam. 1. *Palmellaceæ.*—Cells separate or in colonies imbedded in gelatinous matter. No phycochrome present along with the chlorophyll. To a great extent they repeat the forms of the Cyanophyceæ, and are probably the early stages of higher forms, and not separate plants.

Fam. 2. *Eugleneæ.*—Euglena, generally considered one of the Infusoria, may possibly belong to this group of plants.

B. *Schizophyta, without Chlorophyll.*

The peculiar plants usually considered as a special group of fungi, called the Schizomycetes, are to be placed here. They exhibit close affinities to the Oscillatoriaceæ and Nostocaceæ. Related to the Schizomycetes, but differing in many respects, is Saccharomyces, the yeast plant.

Order III. **Schizomycetes.**—Extremely minute plants found in putrefying matters, multiplying by division of the cells in one direction only. The cells are very minute and simple, often exhibiting movements, with one or more cilia, and at other times imbedded in a gelatinous matrix, the zooglœa stage. Bacterium, Vibrio, and Spirillum may be taken as illustrative forms (fig. 3). Sarcina occurs in the contents of the stomach of animals.

Fam. 1. *Bacteriaceæ.*—The Bacteria are divided into the following tribes :—

1. *Sphærobacteria.*—Cells spherical, including the genus Micrococcus.

2. *Microbacteria.*—Cells very small, cylindrical, including the genus Bacterium.

3. *Desmobacteria.*—Cells filiform, including two genera.

(1.) *Bacillus.*—Cells straight.

(2.) *Vibrio.*—Cells curved.

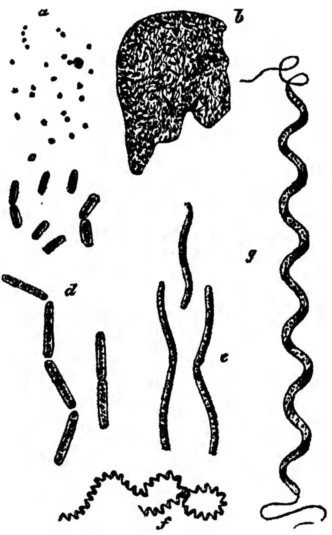
4. *Spirobacteria.*—Cells spirally twisted.

(1.) *Spirochæte.*—Spiral close, of several turns.

(2.) *Spirillum*—Spiral open, of few turns.

Order IV. **Saccharomycetes.**—The yeast plant consists of small oval or rounded cells, either free or united in simple or branching rows. The wall surrounds the protoplasmic contents, which are colourless, slightly granular, with no nucleus but possessing one or more

FIG. 3.



Forms of Schizomycetes × 650 diams.

a, Micrococcus prodigiosus (Monas prodigiosus, Ehr.); *b*, Bacterium Termo (Zoogloea stage); *c*, Bacterium Lineola; *d*, Bacillus Ulna; *e*, Vibrio Rugula; *f*, Spirochæte plicatilis; *g*, Spirillum volutans. (After Cohn.)

vacuoles. During the growth of the plant alcoholic fermentation is set up by it in the saccharine liquid required for its nourishment. Under certain conditions, as when grown on a slice of a boiled carrot or on a slab of plaster of Paris, four cells develope in the interior of the yeast cell. These germinate and again give rise to rows of cells (fig. 4). The cells also multiply by division, a small daughter cell being produced at the side of the mother cell, division occurring in any direction. Saccharomyces cerevisiæ and Saccharomyces mycoderma (Mycoderma vini), are the best known species of the group. The temperature at which the fermentation of beer wort takes place modifies the form of the cells. Thus in strong English ale and porter the cells are oval, and come to the top of the vat. In German beer, such as Bavarian, the yeast remains at the bottom of the vat, and the cells are rounded. In the formation of 'top yeast' the temperature required is from 14° to 18° Cent., while 'bottom yeast' is produced at a temperature of from 4° to 10° Cent.

FIG. 4.

The Yeast-plant, *Saccharomyces cerevisiæ*.

a, rounded cells from 'bottom yeast,' 50 hours after sowing in beer wort; *b*, row of oval cells from 'top yeast' (× 400 diams.); *c*, 'bottom yeast' after cultivation on a piece of carrot, four cells forming in the interior of the parent cell; *d*, the four cells (× 750 diams.) (After Reess.)

CLASS II.—ZYGOSPOREÆ.

The simplest form of sexual reproduction, namely that known as conjugation, is here to be met with. The essential feature of the process is, that the two elements, whose union is necessary in all sexual reproduction, are not distinguishable one from the other by any external characters, so that we cannot affirm which is the male and which the female. In some cases a slight difference is to be noticed, but the difference is never very great. The conjugating cells are either stationary or locomotive. When locomotive they are ciliated zoospores. Two, three, or many cells may unite. The result of conjugation is the production of a zygospore, or in the Myxomycetes the production of the plasmodium by the union of many masses of protoplasm.

Dodel has pointed out that in Ulothrix, ciliated zoospores of various sizes are produced, from two to fourteen in a cell. The large ones are non-sexual and develop a new plant at once. The small ones are sexual and conjugate, but according to Dodel the small ones may, under certain circumstances, also grow directly into new plants if they have by any chance failed to conjugate.

The conformation of the thallus is very different in different groups of the Zygosporeæ. In many cases we have separate cells, or cells which become detached from each other (eremoblasts of Sachs); in other cases cell rows or cell surfaces. In one of the divisions the cells are united to form a colony or cœnobium.

In the Zygosporeæ forms both with and without chlorophyll occur, but no phycochrome is to be met with.

The Zygosporeæ may be divided into two groups according as the conjugating cells are stationary or locomotive.

A. Conjugating Cells locomotive.

Many green algæ produce zygospores which are the result of the conjugation of two zoospores. In general two kinds of zoospores are produced. The larger ones, Macrozoogonidia, are concerned in non-sexual reproduction only, one or more being produced by division of the protoplasm of a vegetative cell. After a period of activity they come to rest, germinate, and produce a new plant. The microzoospores are produced in cells by segmentation, like the larger ones, but frequently on different plants or on different parts of the same plant. The microzoospores are sexual, as they conjugate and produce a zygospore, which, after a period of rest, germinates and produces a new plant.

The Zygosporeæ with locomotive conjugating cells include forms both with and without chlorophyll. The Confervaceæ and Ulvaceæ may be taken as examples of the former, while the remarkable funguses known as the Myxomycetes belong to the latter.

1. *With Chlorophyll.*

Order V. **Zoosporeæ.**

Fam. 1. *Pandorineæ.*—Pandorina is a remarkable unicellular alga united into colonies which swim freely about in water. The colony consists of sixteen zoogonidia, united into a spherical mass by a gelatinous investment, from which the cilia project. Each of the sixteen zoogonidia breaks itself up into sixteen new zoogonidia, thus forming sixteen new colonies or cœnobia. This is the non-sexual reproduction. The sexual reproduction begins in the same way, the new colonies separating into zoospores which vary in size, and when conjugation occurs it is between a large and a small zoospore (fig. 5, pp. 14, 15.)

Fam. 2. *Hydrodictyeæ.*—The Hydrodictyon consists of numerous cylindrical cells, united to form a wide meshed sac-like net, several inches in length. The contents of the individual cells break up into macrozoogonidia and microzoospores. The macrozoogonidia unite to form a 'net' which is set free by the rupture of the mother cell. The microzoospores are set free, and probably conjugate, as united zoospores were observed twenty years ago by Cohn (fig. 6, A, B, C, p. 16).

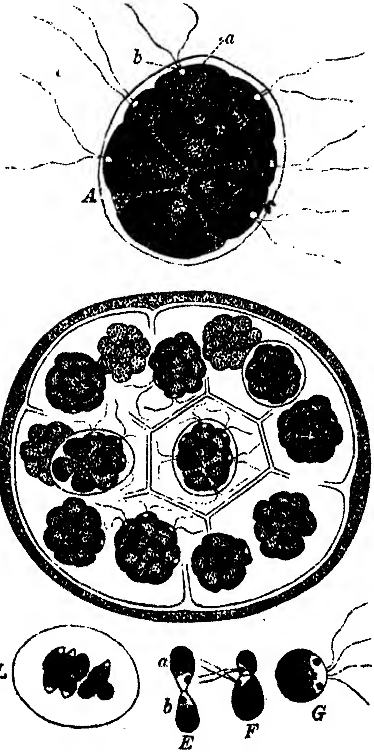
Fam. 3. *Confervaceæ.*—Filamentous algæ, living in salt or fresh water. The filaments may be simple, as in Conferva; or branched as in Cladophora. Microzoospores and macrozoogonidia are produced, probably by different plants, and conjugation has been observed to take place between the microzoospores of Cladophora (fig. 7 and 8, p. 17).

Fam. 4. *Ulvaceæ.*—Ulva consists of polyhedral cells united to form a flat cell-surface. They are marine algæ, often of some size, and either simple or branched, or sometimes tubular, Enteromorpha. Both macrozoogonidia and microzoospores exist, and conjugation has been observed to take place between the latter (fig. 9, p. 18).

2. *Without Chlorophyll.*

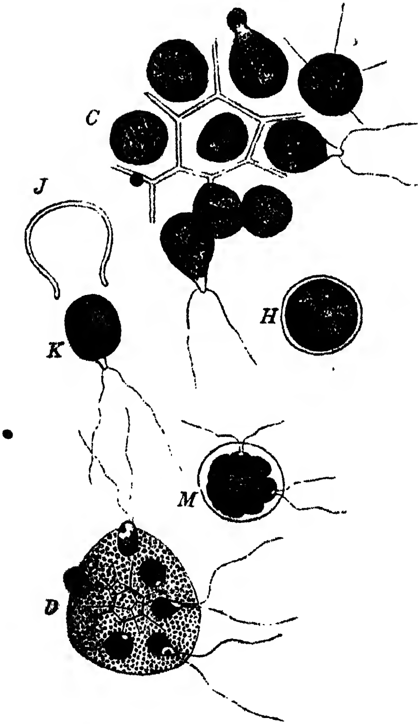
Order VI. **Myxomycetes.**—Sachs places the Myxomycetes in the group of the Zygosporeæ. The spores of the Myxomycetes rupture, and the protoplasm

FIG. 5.



Pandorina Morum.

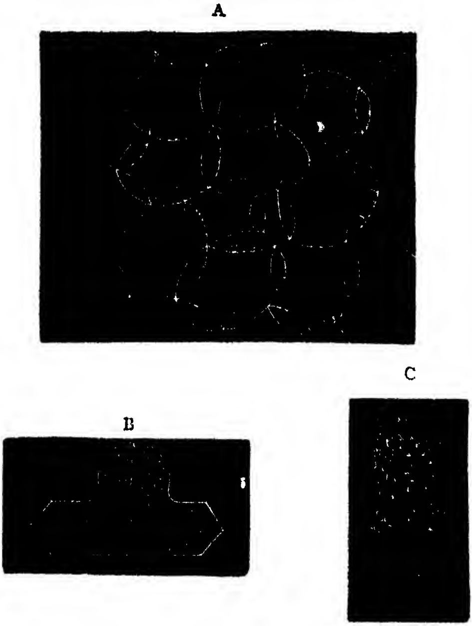
A, non-sexual colony or cœnobium of 16 zoogonidia; *a*, red spot; *b*, transparent anterior end of zoogonidium to which the two cilia are attached; *B*, sixteen young sexual colonies about to leave the gelatinous wall; *C*, a colony of large (female) zoospores, the cells escaping; *D*, colony of



small (male) zoospores; *E*, *F*, *G*, conjugating zoospores (*a*, female; *b*, male); *H*, zygospore in resting stage (red); *J*, *K*, germinating zygospore, the contents escaping as a large red ciliated zoospore; *L*, new colony formed by division of *K*, very young stage; *M*, same colony as *L* in a further stage of development. (After Oersted.)

escapes, forming uniciliate zoospores which soon lose the cilia and become amœboid. (Fig. 11, p. 21). The amœ-

Fig. 6.

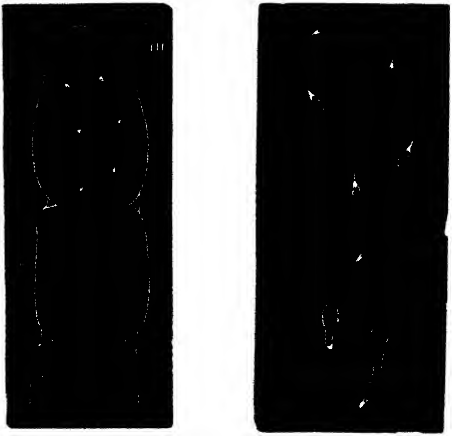


Hydrodictyon utriculatum.

A, cells of the net (× 200); *a*, the individual cells: *B*, one of the cells opening and permitting the escape of many small zoospores; *C*, cell with contents breaking up into new cells, macrozoogonidia; these arrange themselves to form a new net, which escapes by rupturing the wall of the parent cell. (After Oersted.)

boid particles of protoplasm run together and produce a *plasmodium*, or compound zygospore, by a sort of wholesale conjugation. The plasmodium or compound zygospore ultimately developes spores by a more or less complicated process. The plasmodium does not consist of cells, but is a living moving mass of proto-plasm, often of some size, and exhibiting movements

FIG. 8.



Apex of thallus of *Cladophora glomerata*. Zoogonidia escaping by opening (*m*) from upper cell. The two lower cells still filled with young zoogonidia. (After Oersted.)

Zoogonidia of *Cladophora glomerata* free and ciliated above, germinating below. (After Oersted.)

in its interior (fig. 10, p. 19). The whole plasmodium generally becomes converted into the club-shaped or spherical sporangium, in the interior of which the spores are developed, generally in the meshes of a special structure, the Capillitium (fig. 10 *a*, p. 20). The spores when liberated, rupture, and the contents escape as the uniciliate zoospores above described.

B. *Conjugating Cells Stationary.*

1. *Forms containing Chlorophyll.*

These include the group of Algæ, known as the Conjugatæ, to which belong the Zygnemaceæ, Desmidiaceæ, and Diatomaceæ.

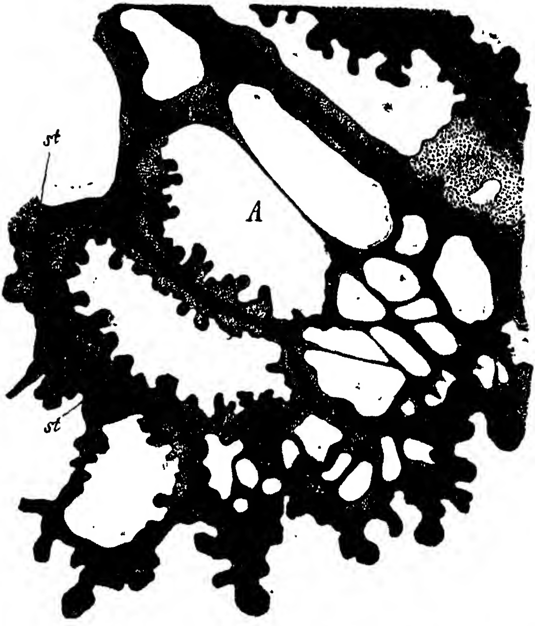
Portion of the thallus of Ulva.

Cells *a*, filled with young zoogonidia; *b*, opening by which the zoogonidia escape from the cells; *c*, free ciliated zoogonidia. (After Oersted.)

Order VII. **Conjugatæ.**

Fam. 1. *Zygnemaceæ.*—The Zygnemaceæ consist of cell-rows, forming long filaments. They live in floating masses in fresh water. The chlorophyll is generally arranged in a characteristic manner, being spiral in Spirogyra (fig. 12, p. 22), and in stars in Zygnema. No zoospores are formed, non-sexual reproduction of the cells taking place by division, the sexual reproduction by conjugation. Generally the zygospore is formed in one of the cells of the filament (fig. 13, p. 23.)

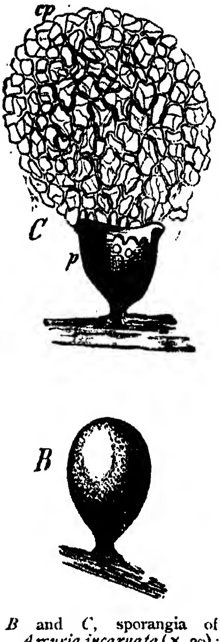
FIG. 10.



A, portion of the plasmodium of *Didymium leucopus*; *st*, the more granular central part of the threads (× 350). (After Sachs.)

Fam. 2. *Mesocarpeæ.*—Like the Zygnemaceæ, but the zygospore forms in the tube between the conjugating cells. In Mesocarpus the chlorophyll assumes the form of plates.

10 *a*.



B and *C*, sporangia of *Arcyria incarnata* (× 20): *B* unopened; *C*, opened, by rupture of the wall (*p*); *cp*, the capillitium. (After Sachs.)

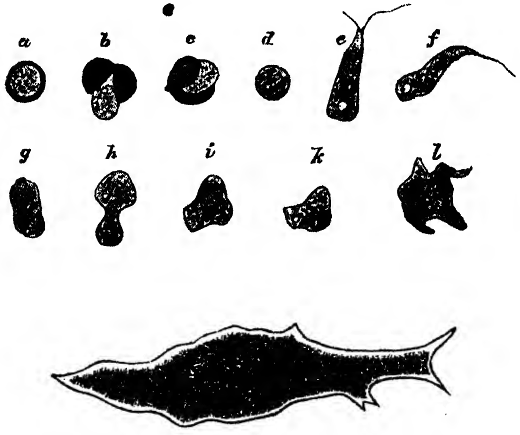
Fam. 3. *Desmidiaceæ.*—Unicellular algæ or rarely filamentous, the cells often assuming very beautiful forms. They multiply by division, and sexual reproduction takes place by conjugation. Closterium, Cosmarium (fig. 14, p. 24), and Euastrum may be taken as examples.

Fam. 4. *Diatomaceæ.*—The Diatomaceæ are unicellular plants, with silicious cell walls, the green colour of the chlorophyll is obscured by the presence of a brownish-yellow colouring matter. The cell consists generally of two flat portions which are silicious, each with a girdle band of cellulose, one enclosing the other like the bottom or lid of a pill-box (fig. 15, p. 25). The cells divide, each half of the cell forming a new silicious valve and girdle band. Sexual reproduction is by means of conjugation. The individuals, when they have reached their minimum size by division, conjugate, and the zygospore gives rise to full-sized individuals; hence these spores have been called Auxospores (fig. 16, p. 26).

2. *Forms without Chlorophyll.*

Order VIII. **Zygomycetes.**—Many of the commoner forms of mould belonging to the genus Mucor, and growing on fruit, bread, or dung may be taken as

Fig. 11.

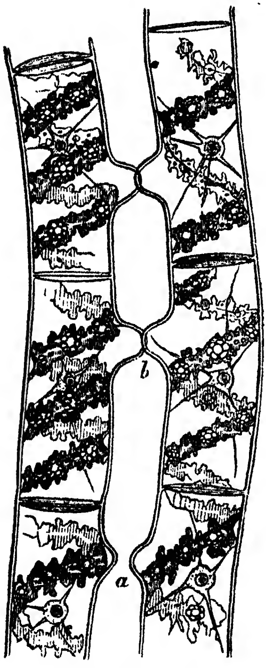


Æthalium septicum.

a, spore ; *b*, *c*, spore-case rupturing and permitting the protoplasmic contents to escape ; *d*, rounded mass, which becomes ciliated, *e*, *f* ; *g*, *h*, *i*, *k*, *l*, *m*, amœboid state after loss of cilia. (After Oersted.)

examples of this division. The spore developes a much branched mycelium, which consists of a single cell, spreading over or through the nutrient matter in which the fungus grows (fig. 17, p. 27). The mycelium sends

FIG. 12.



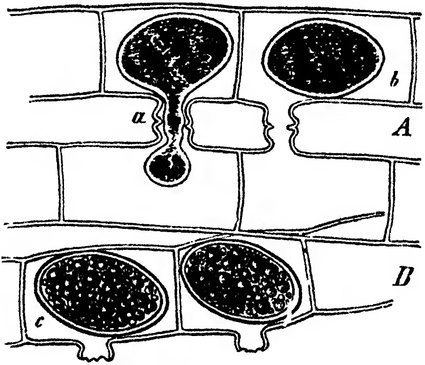
Spirogyra longata (× 550).

Two filaments about to conjugate. The cells contain chlorophyll in spiral bands, with starch and oil globules. In the centre of each cell is the nucleus, surrounded by protoplasm, sending narrow filaments to the wall of the cell. *a, b, c*, formation of the tube by which conjugation takes place. (After Sachs.)

up branches into the air which develope sporangia. The end is rounded and enlarged, and separated by a wall from the rest of the mycelium. The spores or endogonidia are produced within the sporangia. Each spore will develope new mycelium. Sexual reproduction takes place by conjugation (fig. 19, p. 29.) Small branches of the mycelium approach each other, then unite, a wall forms at each side, and the central structure developes into a zygospore (fig. 18, p. 28). After a period of rest the zygospore germinates, and developes a sporangia, with endogonidia, but with no mycelium. These endogonidia again reproduce mycelium with sporangium (fig. 17, p. 27). Three families belong to this order, Mucorinæ, Piptocephalidæ, and Chætocladiaceæ, the two latter being remarkable moulds parasitic on Mucor.

Class III.—OOSPOREÆ.

In this group there is developed a peculiar large cell, readily distinguished by it appearance and size from those in its neighbourhood. This cell is the oogonium. The contents of the oogonium either contract into a single round mass, the oosphere, or

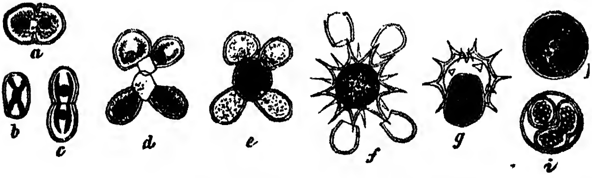


Spirogyra longata (× 550).

A, cells conjugating, the protoplasm passing from one cell to the other at *a*; the contracted and rounded united mass shown at *b*; *B*, young zygóspores, *c*, surrounded by a wall, and containing numerous drops of oil, each zygospore still contained in the interior of the parent cell. (After Sachs.)

two or more oospheres are formed. The antheridia are also single cells, much smaller than the oogonia. The contents of the antheridia either become one or more spermatozoids very much smaller than the oosphere, or a kind of conjugation takes place between the antheridium and the oogonium. The oosphere is always non-locomotive, the spermatozoids moving towards it. After fertilisation the oosphere becomes the oospore, which is invested by a firm wall and remains in a state of rest for some time, before germinating. In most cases the oospore does not develope directly into young plants, but divides and may form zoospores. The oosphere may be compared to the germinal cell in the archegonium of a moss, and the oospore to the moss fruit.

FIG. 14.



Cosmarium Meneghinii, one of the *Desmidiaceæ*.

a, *b*, *c*, different views of the mature cells; *a*, front; *b*, end; *c*, side view; *d*, two cells conjugating; *e*, young zoospore formed; *f*, ripe zygospore with spiny outer wall, the walls of the parent cells empty; *g*, the zygospore germinating after a period of rest; *h*, the young cell escaped from zygospore; *i*, young cell dividing, showing two new desmids similar to (*a*) placed crosswise in the interior of the parent cell. (After Oersted.)

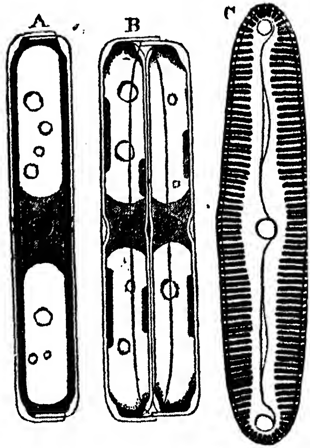
Order IX. **Cœnobieæ.**—Unicellular plants, living in colonies.

Fam. 1. *Volvocineæ.*—Volvox consists of a rounded colony or cœnobium, furnished with cilia externally, and repeating to a great extent the structure exhibited by Pandorina, among the Zygosporeæ. The sexual reproduction is by antheridia and oogonia. Only a small number of the cells of a colony are sexual. The oospheres are large and surrounded by a gelatinous cell-wall, the oogonium. The spermatozoids are developed in smaller cells, the antheridia, and fertilise the oosphere by penetrating the gelatinous wall.

Order X. **Sphæropleaceæ.**—Vegetative and reproductive cells similar.

Fam. 1. *Sphæropleaceæ.*—Sphæroplea consists of

FIG. 15.

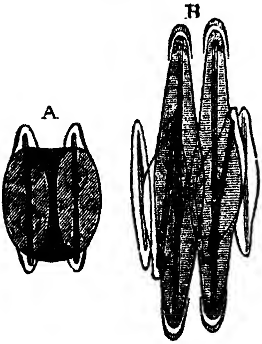


Navicula (Pinnularia) viridis.

A, girdle-band view before division. The silicious wall at each side, the markings not seen. At each end the girdle-band is visible, the one part overlapping the other; B, same view after division. The girdle-bands have separated considerably, and two new silicious walls have formed in the centre; two new girdle-bands will form, one from each new silicious wall; C, front view of the silicious wall showing the markings. (After Oersted.)

long, slender, free, unbranched filaments, and resembles a Conferva, except in its mode of reproduction. The reproductive cells differ from the vegetative in having a small opening or pore. The contents of the cells of one filament develope oospheres, while another forms ciliated spermatozoids; these escape by the pore, and entering the pore in another filament, fertilise the oospheres (fig. 20, p. 30).

Fig. 16.



Frustulia saxonica, showing conjugation and formation of auxospores.

A, conjugation of two cells; B, formation of two auxospores. (After Oersted.)

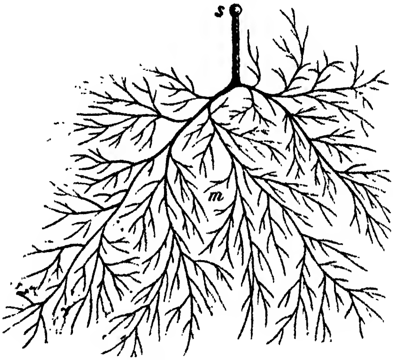
Order XI. **Cœloblasteæ.**—Unicellular plants consisting of large or small, often branched and variously shaped cells, having the protoplasmic contents continuous throughout the whole. The reproductive cells only are separated from the common tube-like thallus during their growth. The group includes forms both with and without chlorophyll. Some of the members of the group are extremely simple in their construction, forming a remarkable series of parasites, with or without chlorophyll.

1. *With Chlorophyll.*

Fam. 1. *Vaucheriaceæ.*—Vaucheria is a filamentous alga occurring in water or on damp earth, and forming coarse dark-green tufts. Zoogonidia are formed at the ends of the branches (V. sessilis), the whole surface being covered with cilia. The sexual reproduction takes places by means of antheridia and oogonia (fig. 21, p. 31).

Fam. 2. *Caulerpaceæ.*—Caulerpa, one of the most remarkable marine algæ, belongs to this group. It consists of a large branched cell, forming the whole thallus, with differentiated parts somewhat resembling root, stem, and leaf. The reproduction of Caulerpa is unknown. Many other forms must be referred

Fig. 17.



Mucor Mucedo.

The mycelium (*m*) developed from a single spore. The aerial erect hypha thread bearing a young sporangium, *s*. (After Prantl.)

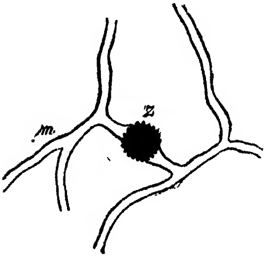
doubtfully to the Cœloblasteæ, forming separate families; but as in all the reproduction is unknown, their exact position is unsettled (fig. 22, p. 32).

Fam. 3. *Chlorochytridiaceæ.*—Parasitic green algæ. The thallus is unicellular, the contents breaking up into zoogonidia. Sexual reproduction has not been observed. Chlorochytrium Lemnæ, the best known example, was discovered and described by Cohn. It lives in the parenchyma of the duckweed, Lemna trisulca.

2. *Without Chlorophyll.*

Fam. 4. *Chytridiaceæ.*—Colourless parasitic fungi of very simple construction, having zoogonidia furnished with only a single cilium. They are closely related to Saprolegnia.

Fig. 18.



Zygospore z, in mycelium threads, m, of Mucor. (After Prantl.)

Fam. 5. *Saprolegniaceæ.* — Colourless saprophytes or parasitic fungi, generally living in water on dead flies and other animals, or on plants or vegetable matter. The thallus is tubular, branched, and unicellular. A portion of the thallus is often separated by a wall, and gives rise to numerous ciliated zoogonidia. Other plants develope antheridia and oogonia. The oogonia are formed at the apex of the thallus as a rounded swelling; the antheridia arising as two branches, one on each side from below the oogonium, and ultimately uniting with the oogonium by a process of conjugation. Pythium, Saprolegnia and Achlya are examples of this family.

Fam. 6. *Peronosporeæ.*—This family includes a number of funguses superficially resembling forms of mildew or mould, living as parasites, and often exceedingly destructive. They have a tubular thallus, and develope stylogonidia in special aerial branches of the mycelium. The stylogonidia develope (usually six) zoogonidia, which rapidly spread the plant. The sexual reproduction is by antheridia and oogonia, like that of Saprolegnia. Cystopus candidus, common on Cruciferæ, especially shepherd's purse (Capsella Bursa pastoris) is a good example. In it the ripe oospore gives rise, on germinating, to a number of ciliated

FIG. 19.

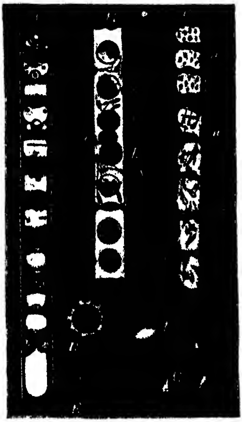
Conjugation of *Mucor stolonifer.*

a, small projections forming on neighbouring portions of mycelium; *b*, union of these projections, the apex of each becoming enlarged and club-shaped, while the whole projection is much elongated; *c*, projection still further enlarged, a new wall forming in each, cutting off two cells, α and β, the female α, being larger than the male β; *d*, the wall separating α and β disappears, and the contents unite to form the zygospore, with a thick granulated outer wall. (After Oersted.)

zoospores. The potato-disease fungus, Phytophthora infestans, and the species of Peronospora, all belong to this family (figs. 23, 24, pp. 33 and 34).

Order XII. **Œdogoniaceæ.** — Filamentous algæ, which reproduce, non-sexually by zoogonidia, and sexually by antheridia and oogonia. The large round oospore, after a period of rest, produces four zoospores, which develope non-sexual plants. Many zoogonidia are formed by rejuvenescence by the cells of the filament. Other zoospores are separated, and afterwards attach themselves to the side of the oogonia, forming the peculiar dwarf-males, the antheridium being the larger part of the minute male plant. In Œdogonium the filaments are simple; they are branched in Bulbochaete (fig. 25, p. 35).

FIG. 20.



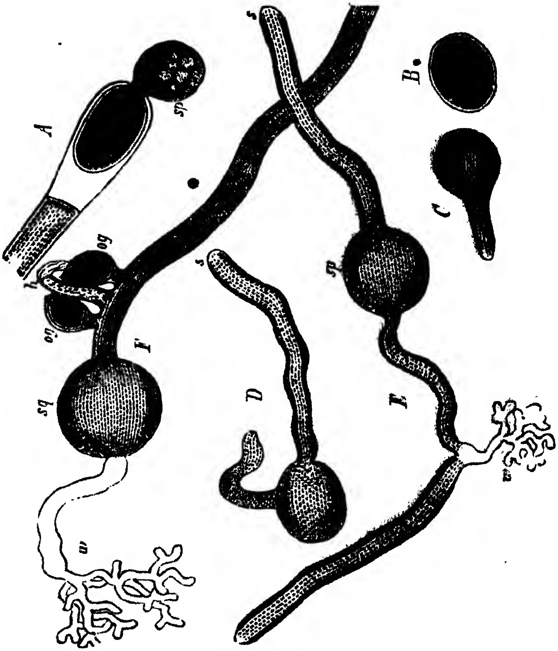
Sphaeroplea annulina.

A, ordinary filament: *B*, filament consisting of oogonia, the contents breaking up into oospheres: *C*, filament consisting of antheridia with ciliated spermatozoids: *D*, *E*, vegetative zoogoni- ...., . . , oospore in act of being fertilised by a spermatozoid, *s*; *G*, spermatozoids: *m*, *n*, oospheres and antheridia in different stages of development; *o*, opening for entrance or escape of spermatozoids; *r*, chlorophyll masses in vegetative filament.

(After Oersted.)

Order XIII. **Fucaceæ.**—Brown algæ, the green colour of the chlorophyll being obscured by the presence a of brown colouring matter (phycophæin or melanophyll). The thallus is often large and dichotomously branched, the forms being very varied. The parts of the thallus often resemble roots (rhizoids) and a stem and leaves. The structure is simple, consisting of a mass of cell-tissue, resembling protomeristem, the outer layers of cells being smaller than the inner, and forming a kind of limitary tissue. These algæ are marine. In Fucus the sexual reproduction is effected by antheridia and

Fig. 21



Vaucheria sessilis (× 30).

A, a zoogonidium (*sp*) escaping; *B*, zoogonidium in its resting-stage, after having lost its cilia; *C*, zoogonidium germinating; *D*, further stage in the germination; *E*, germination still further advanced; *sp*, the zoogonidium; *s*, apex of the tubular green thallus; *w*, rhizoids, root-like colourless portion of thallus; *F*, thallus with reproductive organs; *u*, antheridium; *og*, oogonia. (After Sachs.)

oogonia developed in peculiar cavities, conceptacles, clustered together at the swollen apex of the branches of the thallus (figs. 26 and 26 *a*, pp. 36 and 37). The spermatozoids are furnished with two cilia. The oospheres are liberated before being fertilised by the spermatozoids. After a short resting stage the oospore develops a new plant (fig. 27 and 27 *a*, pp. 38 and 39).

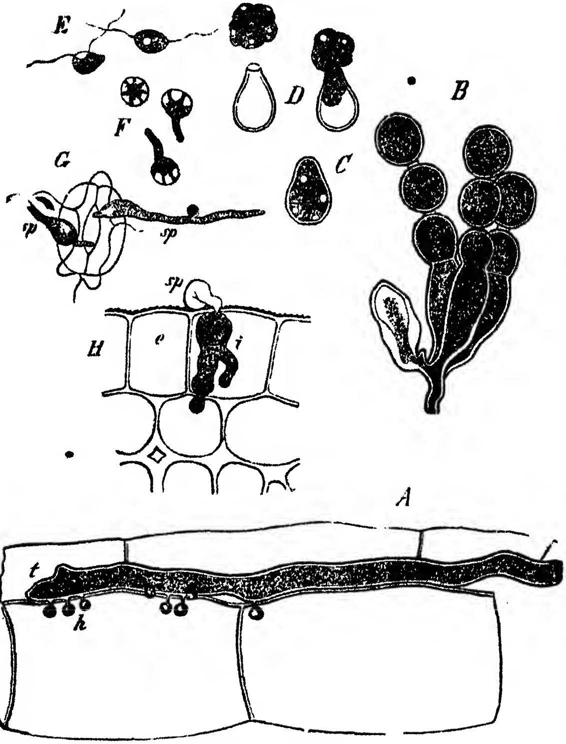
Caulerpa prolifera (nat. size).

Portion of thallus showing, *r* root-like, *s*, stem-like, and *b*, leaf-like parts of the same cell. (After Oersted.)

Order XIV. **Phæosporeæ.** — The Phæosporeæ agree in the structure of their thallus with the Fucaceæ; and in being brown-coloured marine algæ. The reproduction is, however, imperfectly known. Antheridia and zoogonidia are known in some of the genera, but no structure resembling the oogonium has as yet been discovered.

The Phæosporeæ and Fucaceæ include the largest known thallophytes. To the former belong Laminaria, Nereocystis, Lessonia, and Macrocystis. Macrocystis pyrifera, in the oceans of the southern hemisphere, attains a length of from 300 to 500 feet. Lessonia, also from the southern seas, resembles a graceful willow tree having a large

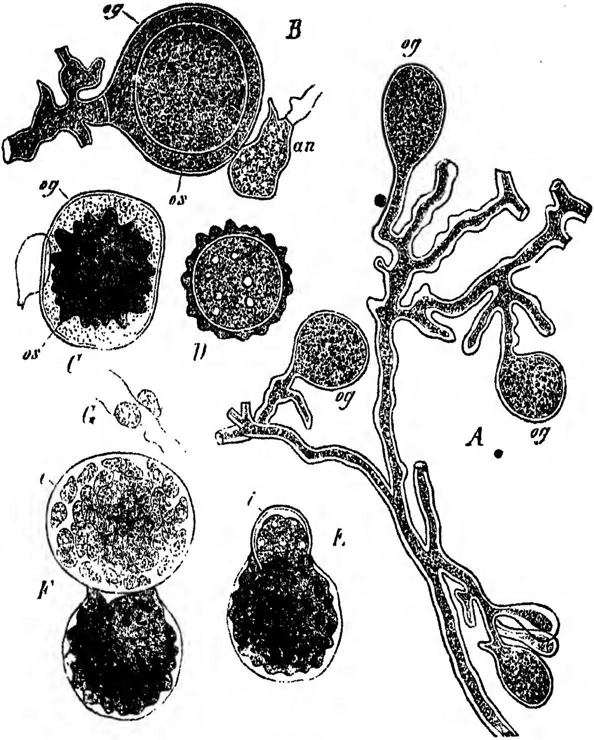
FIG. 23.



Cystopus candidus (× 400).

A, branch of mycelium, *f*, growing at the apex, *t*, and giving off haustoria, *h*, into the cells of the pith of *Lepidium sativum*. *B*, aerial portion of the mycelium bearing the stylogonidia. *C*, stylogonidium, showing division of its contents. *D*, contents of stylogonidium escaping as zoo gonidia. *E*, zoogonidia with cilia. *F*, germinating zoogonidia. *G*, zoogonidia germinating on a stoma, forming mycelium, *sp*. *H*, germinating zoogonidium of the potato disease (Phytophthora infestans) penetrating the epidermis of the potato-stem. (After De Bary.)

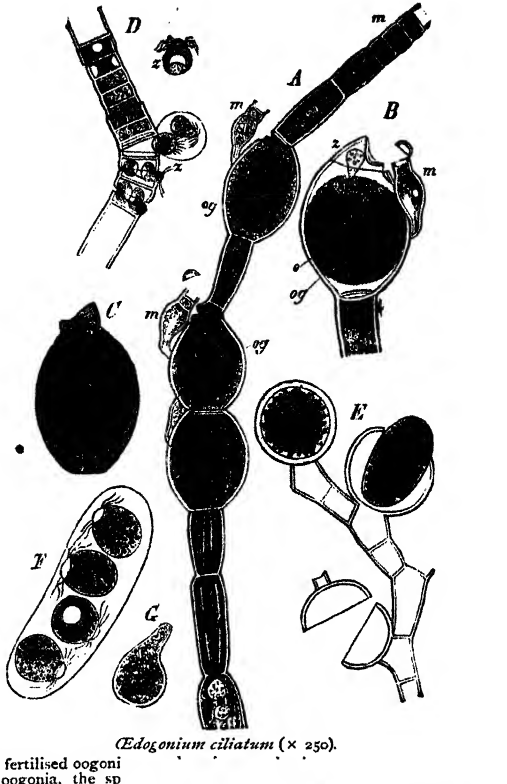
Fig. 24.



Cystopus candidus (× 400).

A, mycelium with young oogonia. *B*, oogonium, *og*; young oospore, *os*; antheridium, *an*. *C*, mature oogonium with oospore. *D*, mature oospore. *E*, *F*, *G*, formation of zoogonidia from oospores; *i*, protruded endosporium. (After De Bary.)

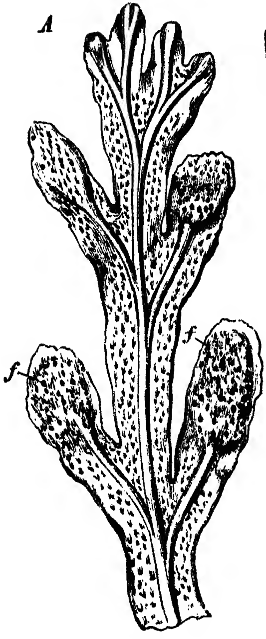
FIG. 25.



Œdogonium ciliatum (× 250).

A, *og*, fertilised oogoni
the oogonia, the sp
develope from zoospores produced by rejuvenescence from the cells (*m*) at the upper end of the filament. *B*, oogonium at moment of fertilisation; *o*, the oosphere; *z*, the spermatozoid. *C*, ripe oospore. *D*, *Œdogonium gemelliparum*, spermatozoids (*z*) produced directly from cells of the male filament. *E*, part of branch of *Bulbochæte* with oogonia, one with an oospore, the other with the spore escaping, the third empty. *F*, four zoospores resulting from an oospore. *G*, zoospore come to rest, and germinating. (After Pringsheim.)

Fig. 26.



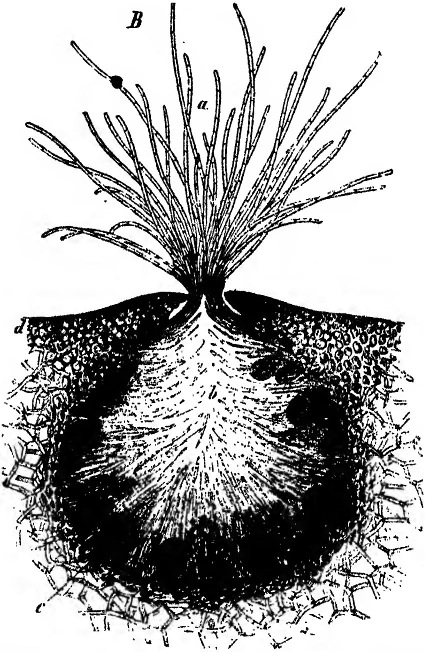
Fucus platycarpus.

A, end of portion of thallus (nat. size) *f, f*, fertile branchlets. (After Thuret.)

trunk. Nereocystis is a gigantic alga from the northern seas, and Laminaria saccharina sometimes attains a length of from eight to twelve feet on our own coasts. The latter includes Sargassum forming the Sargasso sea, and Durvillæa, a gigantic sea-weed from the southern ocean.

Class IV.—Carposporeæ.

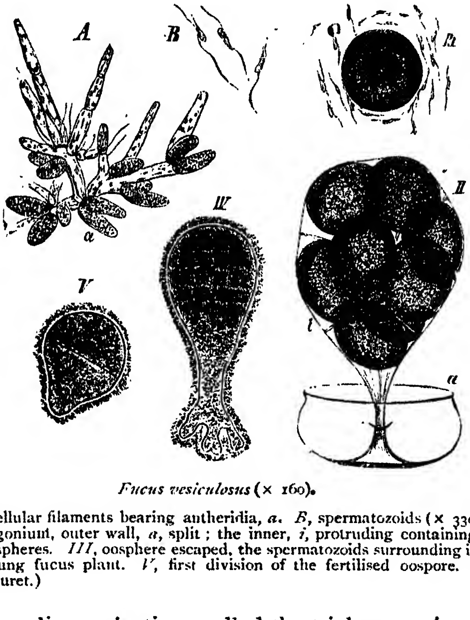
This class includes a number of the higher forms of Algæ and Fungi, differing very much from each other in habit and mode of growth. They are distinguished by the production of a spore-fruit or sporocarp, which is the product of the fertilised female reproductive organ. The sporocarp consists of two parts: 1. the fertile part, developed directly from the female reproductive organ, the carpogonium, and producing, sooner or later, one or many spores; 2. the sterile part or case, not developed from the carpogonium but developing as a consequence of fertilisation, and enclosing all the spores. The sporocarp may be either large or small. In Coleochæteæ, Characeæ, and Florideæ, the forms which possess chlorophyll, the



B, transverse section of a conceptacle ; *a*, hairs projecting rom the mouth ; *b*, hairs in the interior ; *c*, oogonia ; *e*, antheridia ; *d*, limitary tissue of thallus. (After Thuret.)

sporocarp is small. In the forms not containing chlorophyll, as the Ascomycetes and Basidiomycetes, the sporocarp is very large and conspicuous, and may live after the plant which bore the reproductive organs has died. The sporocarp developes from the carpogonium, which in its simplest state is a single cell (Coleochæte) but in others consists of several cells before fertilisation.

FIG. 27.



Fucus vesiculosus (× 160).

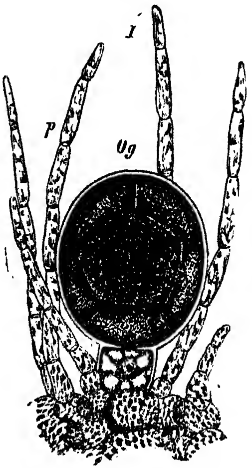
A, cellular filaments bearing antheridia, *a*. *B*, spermatozoids (× 330). *II*, oogonium, outer wall, *a*, split; the inner, *i*, protruding containing eight oospheres. *III*, oosphere escaped, the spermatozoids surrounding it. *IV*, young fucus plant. *V*, first division of the fertilised oospore. (After Thuret.)

A peculiar projection, called the trichogyne, is generally found both on one-celled and many-celled carpogonia, resembling the style of higher plants. It is absent in Podosphæra, feebly developed in Peziza, and well-developed in Coleochæte and in the Florideæ. The male organs differ very much. Some have antheridia with spermatozoids, the spermatozoids being active, as in Coleochæteæ and Characeæ, or passive in the Florideæ. In fungi special sac-like structures or pollinodia are produced, which fertilise the carpogonia by a kind of conjugation.

1. *Carposporeæ with Chlorophyll.*

Order XV. **Coleochæteæ.**—Coleochæte is a disc-like alga of a beautiful green colour, living attached to stones or submerged water-plants. The carpogonium consists of a single cell, wide below, and tapering above into a long slender canal, the trichogyne, open at the apex. Fertilisation is effected by moving spermatozoids from the antheridia. After fertilisation a covering forms round the central cell, which developes into a small mass of tissue, each cell forming a zoospore. A new plant like the parent, arises from each of the zoospores (fig. 28 p. 40).

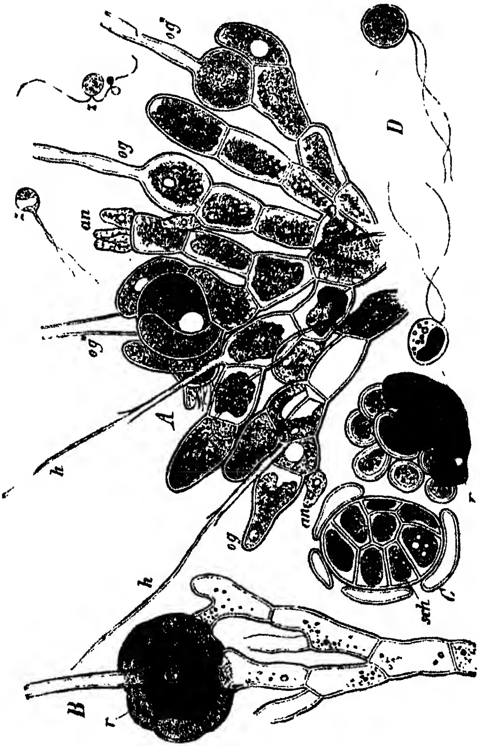
Fig. 27 *a.*



I, oogonium *Og*, with hairs (paraphyses) surrounding it. (After Thuret.)

Order XVI. **Florideæ** or **Red Algæ.**—They are mostly marine, and are distinguished by their fine red

FIG. 28.

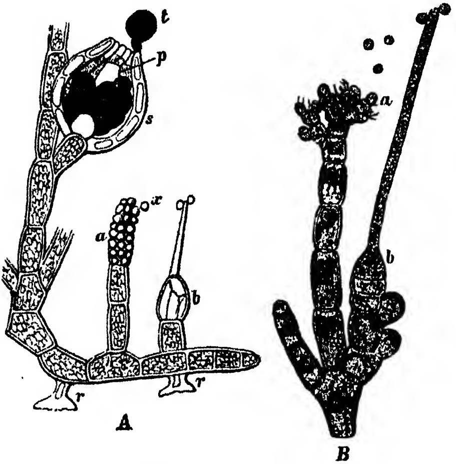


Coleochæte pulvinata (× 350).

A, portion of thallus of fertile plant; *an*, antheridia; *og*, carpogonia, with trichogyne; *z*, *z*, spermatozoids; *h*, hairs with sheathing base; *B*, carpogonium surrounded by covering, *r*, of sterile tissue, forming the ripe sporocarp; *C*, tissue from interior of sporocarp, each cell of which developes a zoospore; *D*, zoospores from *C*. (After Pringsheim.)

or violet colour, due to the presence of phycoerythrin. Batrachospermum, which is not brightly coloured, lives in fresh water. The thallus varies very much in structure and construction, being often very much branched. Reproduction is both non-sexual and

FIG. 29.



A. Lejolisia mediterranea (× 150).

r, rhizoids; *a*, antheridium; *x*, spermatozoids; *b*, carpogonium, with trichogyne, two spermatozoids attached to the apex; *s*, section of ripe sporocarp; *t*, ripe spore escaping. (After Bornet.)

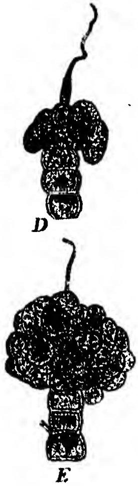
B. Helminthora multifida.

B, branch with antheridia and spermatozoids, *a*; *b*, trichogyne with spermatozoids. (After Bornet.)

sexual. Non-sexual reproduction is generally effected by tetragonidia, bud-like cells without cilia developed in fours in certain cells of the thallus. Fertilisation is effected by the spermatozoids, minute rounded bodies, destitute of cilia, attaching themselves to the trichogyne, the carpogonium then developing into the sporocarp. The carpogonium is simple in Nemalion, or consists of many cells in Lejolisia. In the latter the trichogyne is supported by a special row of cells, the trichophore (fig. 29, A.)

The most important sub-orders of the Florideæ are, 1. Gymnosporeæ, spores naked (Helminthora, fig. 29 *a*); 2. Sporocarpeæ, spores in a case (Lejolisia, fig. 29, A); 3. Corallineæ, with carbonate of lime in the tissues. The Irish moss, Sphærococcus crispus, belongs to the Gymnosporeæ.

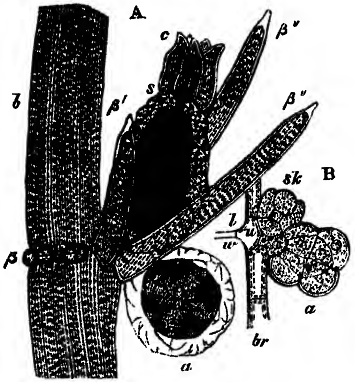
FIG. 29 *a*.



Helminthora multifida. *D*, *E*, development of spores. (After Bornet.)

Order XVII. **Characeæ.**—Plants living in masses in fresh or brackish water. They differ from the other thallophytes in having lateral appendages to the axis, structures probably to be looked on as leaves. The stem of Nitella consists of a long cell forming the internode, the branches or leaves developing in whorls at the nodes. Chara has the stem and leaves covered by a peculiar cortical arrangement of cells, surrounding the long central cell. The cells contain chlorophyll and show rotation of the protoplasm. Sexual reproduction is effected by antheridia and sporocarps, the former often called the globule, from its shape, the latter the nucule. The antheridium has a red-coloured wall, consisting of eight flat cells, each developing a central cell bearing numerous whip-like filaments. Every cell of the filament contains a ciliated spermatozoid. The carpogonium consists of a central cell, supported on a slender stalk, the rudiment of the trichophore, the whole is surrounded by a case formed before fertilisation. The sporocarp contains a single spore, which germinates after a period of rest. The wall of the sporocarp consists of spirally twisted cells, which become dark in colour. The top is crowned by a series of five teeth, unicellular in Chara, and two-celled in Nitella (fig. 30).

FIG. 30



Chara fragilis (magnified).

A, central portion of a leaf (*b*), with an antheridium, *a*, and a carpogonium, *s*; *c*, crown of five cells at apex; *β*, sterile lateral leaflets; *β′* large lateral leaflet near the fruit; *β″*, bracteoles springing from the basal node of the reproductive organs; B, a young antheridium, *a*, and a young carpogonium, *sk*; *w*, nodal cell of leaf: *u*, intermediate cell between *w* and the basal node cell of the antheridium; *l*, cavity of the internode of the leaf; *br*, cortical cells of the leaf. (After Sachs.)

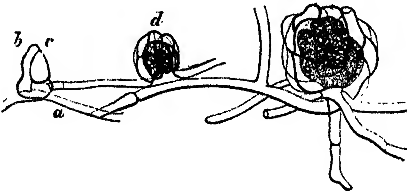
2. *Carposporeæ without Chlorophyll.*

The sporocarps of these Carposporeæ are commonly known as the Fungi belonging to the Ascomycetes, Æcidiomycetes, and Basidiomycetes. The sexual reproduction is not known in all the forms, so that the group must be considered as to a certain extent provisional. The mycelium is developed from the true spores or carpospores, and spreads over or through the nutrient matter on which the fungus grows. It consists of hyphæ threads, rows of very narrow cells branched and interlaced, forming a false tissue. The mycelium is either composed of one or many hyphæ threads, and may be of long or short duration, sometimes living for many years. The mycelium often produces non-sexual reproductive organs, gonidia or conidia, which germinate and form new mycelium. In many forms the gonidia-bearing mycelium is the only known stage of the fungus. Where the life-history is better known the mycelium has been observed to produce sexual reproductive organs, differing in the different groups. After fertilisation a more or less complex sporocarp is produced. In the sporocarp the two sorts of tissue, the fertile and sterile, may be observed. In some the sporocarp forms secondary mycelium from which new plants may arise. The sporocarp developes spores, either on the surface or in the interior. The former are gymnocarpic, the surface developing the spores, the hymenium being exposed. The latter are angiocarpic, the spores being formed in an internal mass of tissue, the gleba, surrounded by a case, the peridium. When the spores are ripe, the peridium ruptures and the spores are scattered. The sporocarp consists of modified hyphæ threads, often forming a pseudo-parenchyma, that is, a cell-tissue not formed by division of an apical cell, but having the walls of neighbouring rows of the hyphæ cohering more or less intimately. The walls are not in general coloured blue by the action of sulphuric acid and iodine, and consist of a modification of cellulose. In a few cases, as in the asci or spore-sacs of lichens, the wall of the ascus is coloured blue by the action of iodine alone. Starch and chlorophyll are never met with in the group now under consideration, all being either parasites feeding on living animal or vegetable matter, or saprophytes, obtaining their nourishment from similar matter in a state of decay.

Order XVIII. **Ascomycetes.**—The Ascomycetes are distinguished by the production of their spores in sacs or asci, elongated or club-shaped bodies in which generally eight spores are formed by free-cell formation. The sacs are generally arranged so as to form a kind of hymenium, either superficial or in the interior of the sporocarp. The sexual reproductive organs are developed on the mycelium, and the sporocarp with the ascospores is the result of fertilisation. The carpogonium (formerly called the ascogonium), is often spirally twisted and thicker than the straighter antheridium (formerly called the pollinodium). A kind of conjugation takes place between the carpogonium and the antheridium, spermatozoids not being produced. Many ascomycetes multiply non-sexually by means of gonidia, which develope on certain threads of the mycelium.

The plants belonging to this group may be divided into subordinate divisions, such as the Mildews, Discomycetes, Truffles, Pyrenomycetes, and Lichens.

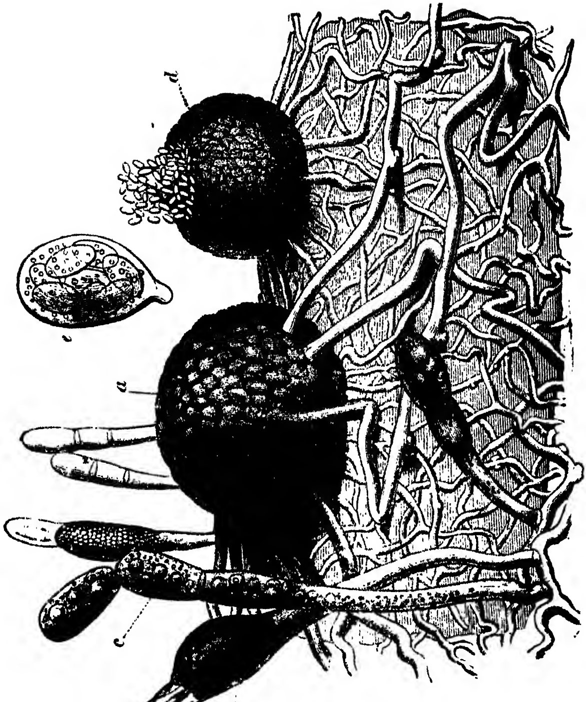
Fam. 1. *Erysiphaceæ.*—The mildews represented by such genera as Erysiphe and Podosphæra belong to this group. They form a white web-like mycelium spreading over the leaves and stems of plants. Podosphæra has a very simple carpogonium and antheridium, both being unicellular. After fertilisation the carpogonium divides into two cells, the upper forming a single



Erysiphe Cichoriacearum (magnified).
a, mycelium threads; *b*, antheridium; *c*, carpogonium; *d*, young sporocarp; *e*, older sporocarp. (After Oersted.)

ascus with eight ascospores. Erysiphe forms antheridia and carpogonia, and also gives rise to peculiar non-sexual reproductive organs, probably analogous to buds, known as pycnides. (Figs. 31 and 32.) The common mould called Aspergillus glaucus belongs to this group. The sporocarps were described as Eurotium herbarorum, while the gonidial stage was Aspergillus. The plant is now known as Eurotium Aspergillus-glaucus (figs. 33,and 33 *a.*)

FIG. 32.

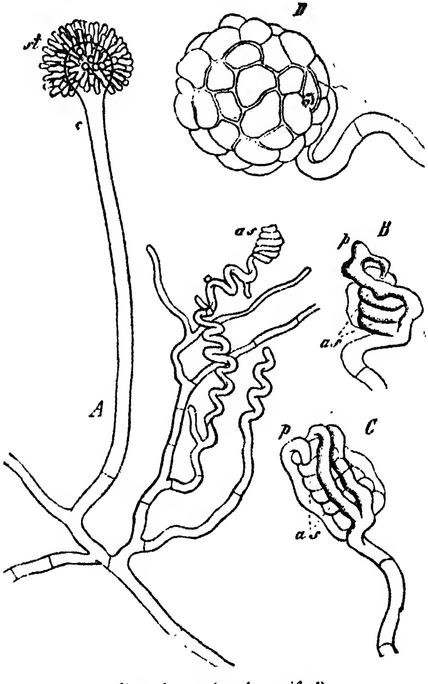


Portion of a leaf covered with *Erysiphe communis* (magnified), the mycelium covers the whole under-surface.

a, sporocarp; *b*, structure called a pycnide of doubtful function; *c*, stylogonidia; *d*, second form of pycnide; *e*, ascus with eight ascospores removed from the sporocarp. (After Oersted.)

Fam. 2. *Discomycetes.*—In the disc-like fungi of which Peziza forms a good example, the hymenium is superficial and spread over the whole upper part of

FIG. 33.



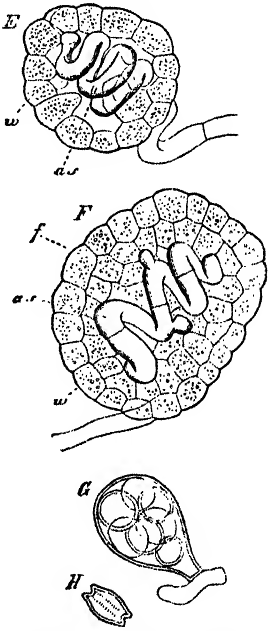
Eurotium repens (magnified).

A, portion of mycelium, with erect hypha-thread, *c*, bearing sterigmata, *st*, from which the stylogonidia have fallen; young ascogonium, *as*. *B*, spiral ascogonium, and the pollinodium or antheridium (*p*). *C*, the same beginning to be surrounded by the sterile filaments, two shown in the front. *D*, sporocarp. (After De Bary.)

the sporocarp. The plants live among mosses or on decaying wood, and much resemble the lichens. Ascobolus has a carpogonium consisting of a row of cells, and a branching antheridium. After fertilisation, the central cell of the carpogonium developes numerous filaments, which form asci as secondary branches, the whole invested by a mass of sterile tissue (figs. 34 and 35.)

Fam. 3. *Tuberaceæ*. The truffle is a good example of the peculiar underground sporocarp produced by this group. The common blue mould, Penicillum glaucum, also belongs to the Tuberaceæ, as shown by the recent researches of Brefeld. The Penicillum developes stylo gonidia which have been long known, but the sporocarp has only been recently discovered. It arises from an antheridium and carpogonium and forms

FIG. 33 *a*.

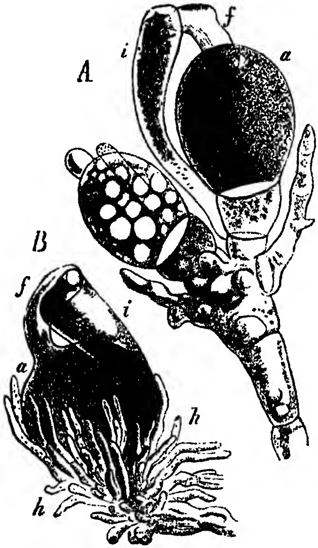


Eurotium repens (magnified).
E, *F*, sections of unripe sporocarps, *w*, outer wall, *f*, inner cells of sterile tissue, *as*, filaments developed by the ascogonium giving rise to the asci, *G*, each containing eight ascospores. *H*, ripe ascospore. (After De Bary.)

a minute structure like a grain of sand. In its interior the asci and ascospores are developed.

Fam. 4. *Pyrenomycetes.* These fungi have the asci contained in peculiar flask-shaped cavities; the peri-

FIG. 34.

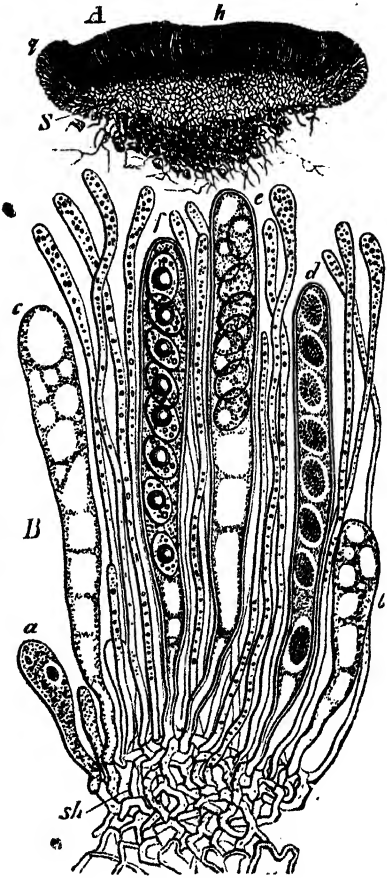


Peziza confluens (highly magnified).

A, showing the reproductive organs at the time of fertilisation; *a*, carpogonium; *f*, trichogyne; *i*, antheridium or pollinodium; *B*, hyphæ of sterile tissue of the sporocarp developing as a result of fertilisation. (After Tulasne.)

thecia. In Sphæria each perithecium is the result of a process of fertilisation. Claviceps, the ergot, belongs to this group. The young ovary of rye becomes

FIG. 35.

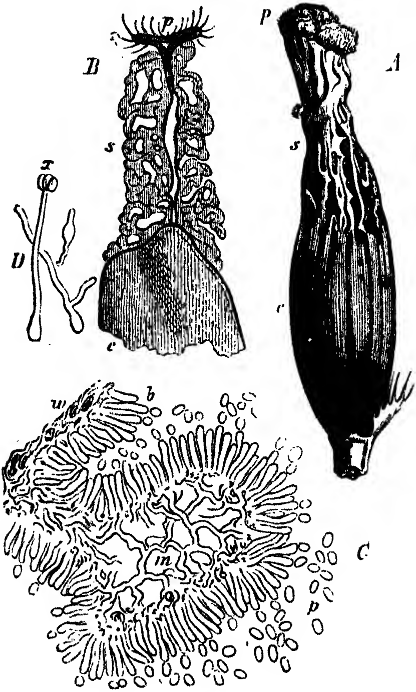


A, vertical section of whole plant (× 20); *h*, hymenium or layer with spore-forming asci; *S*, sterile tissue forming a margin (*g*) to the cup-like fungus, and giving off fine hyphæ into the soil. *B*, section of the hymenium (× 550); *a–f*, asci, with ascospores in various stages of development intermixed with slender paraphyses; *sh*, sub-hymenial layer of hyphæ. (After Sachs.)

Peziza convexula.

enveloped by a soft mycelium, which develops gonidia. These are accompanied by a honey-like secretion, the

Fig. 36.

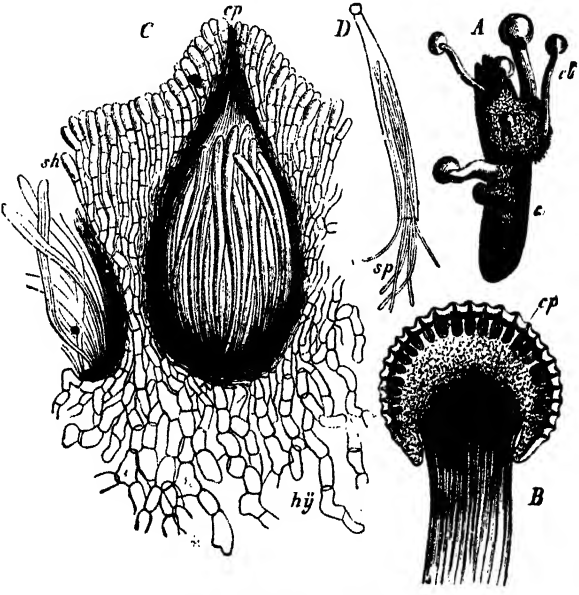


Claviceps purpurea (magnified).

A, young sclerotium (*c*), with old sphacelia (*s*); *p*, the apex of the dead ovary of rye. *B*, upper part of *A*, in longitudinal section. *C*, transverse section through the sphacelia, *m*, the mycelium with the hyphæ bearing stylogonidia, *b*; *w*, portion of the wall of the ovary. *D*, germinating stylogonidia, with promycelium and sporidia. (After Sachs.)

sphacelia stage. In a short time the mycelium permeates the whole ovary, and converts it into a hard mass, the sclerotium stage or ergot. The sclerotium, after a

FIG. 37.



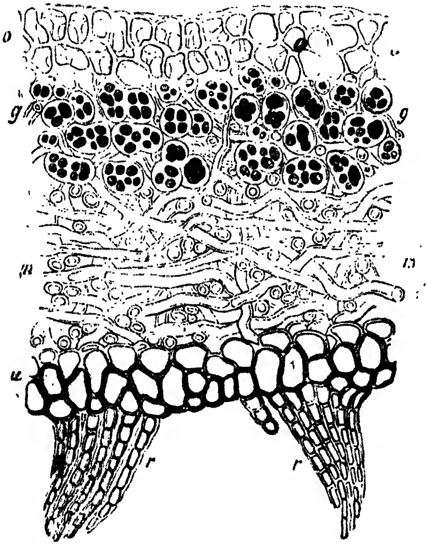
Claviceps purpurea (magnified).

A, a sclerotium (Ergot) *c*, forming sporocarps, *cl*. *B*, longitudinal section of a sporocarp, showing the perithecia (*cp*). *C*, perithecia (highly magnified), showing the asci; *hy*, hyphæ of sporocarp, *sh*, outer layer of sporocarp. *D*, single ascus, ruptured, permitting the elongated narrow spores, *sp*, to escape. (After Tulasne.)

period of rest and when placed on the ground, develops small stalks, with a rounded head, in which are developed numerous perithecia with asci and ascospores (figs. 36 and 37).

Fam. 5. *Lichenes.*—Lichens were formerly considered to be a special class of thallophytes, but recent

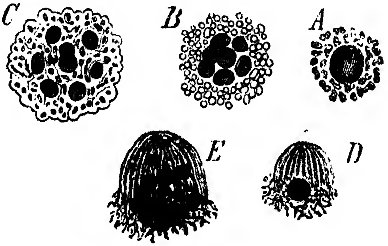
FIG. 38.



Transverse section of the thallus of *Sticta fuliginosa* (× 550).
o, limitary cells of upper side : *u*, of under side, with rhizoids, *r* : *m*, hyphæ threads of interior of thallus ; *g*, green gonidia. (After Sachs.)

researches show that they must be considered as ascomycetous fungi, parasitic on algæ. The algæ were formerly known as the green gonidia of the lichen thallus, and belong chiefly to the Palmellaceæ, with chlorophyll, or to the Nostocs and other Cyanophyceæ. The algæ are either scattered irregularly throughout the whole thallus or form a definite layer. The thallus contains in addition the hyphæ of the fungus, and thus consists of two elements, the fungal and the algal (fig. 38). The thallus bears peculiar spore-bearing structures, closed or open, with the asci, each with eight ascospores. When the sporocarp is open, like the Discomycetes, it is called the apothecium, when closed it

FIG.



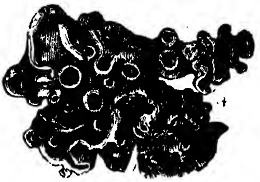
Soredia of *Usnea barbata* × 500).

A, soredium consisting of one green gonidium covered with hyphæ. *B*, many green gonidia formed by division. *C*, the green gonidia separated by hyphæ. *D*, *E*, germinating soredia, growing apex formed of hyphæ developing into a new lichen-plant, the green gonidia multiplying by division. (After Schwendener.)

resembles the Pyrenomycetes and developes perithecia. Peculiar structures, called spermogones and pycnides are also found, as also in other Ascomycetes and their allies. A non-sexual mode of reproduction by means of soredia occurs. The soredia consist of one or more algal cells surrounded by hyphæ. They detach themselves from the thallus, and form new plants (fig. 39).

Lichens are widely distributed, and live on rocks, stones, stems of trees, or on the ground. They may be dried up without losing their vitality. The thallus varies much in form and structure, and from characters derived from the nature of the thallus, lichens have been divided into gelatinous lichens (Collema), crustaceous (Graphis), foliaceous (Sticta), and fruticose (Usnea) (figs. 38, 39, 40, 41 and 42.)

Fig. 40.



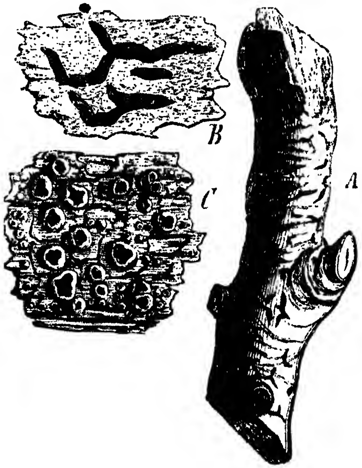
Collema pulposum (slightly magnified).

One of the gelatinous lichens, the thallus bearing apothecia. (After Sachs.)

Order XIX. **Æcidiomycetes.**—Parasites with their mycelium running through the tissues of living plants, many of the forms being well known pests, such as Rust, &c. The sexual reproduction of the Æcidiomycetes is unknown, and their position is at present uncertain. The mycelium gives rise to small fruit-like bodies, the Æcidia, which may, perhaps, be the result of some sexual reproductive process. The are cup-like bodies, having at the base a series of elongated cells or basidia, which develope rows of spores or stylogonidia. In addition, two other kinds of spores are sometimes formed, but not in cups. These break through the epidermis of the host plant. One of the best known forms belonging to this group, and having three kinds of spores, is the rust in wheat, Puccinia graminis. During the summer the stems, leaves and glumes of the wheat become covered with reddish-brown patches of spores. These are one-celled, rounded, and are now known as the uredospores, from having been formerly placed in a special genus, Uredo.

After a time a few two-celled spores appear among the uredospores, and gradually patches consisting exclusively of these teleutospores are formed. The teleutospore germinates in spring on the leaves of the barberry, and develops a small pro-mycelium, on which appear another set of germinating bodies, the

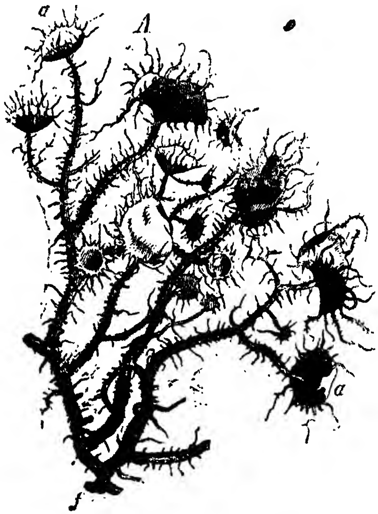
FIG. 41.



Crustaceous Lichens.
A, B, Graphis elegans on bark of the holly. *C, Pertusaria Wulfeni.* (*B, C,* slightly magnified). (After Sachs.)

sporidia. These sporidia germinate, and form the mycelium in the tissues of the barberry, from which arises the Æcidium of the barberry. The Æcidium is produced on the under side of the leaf, and on the upper side smaller flask-like bodies, called spermogones of unknown functions are developed. The spores formed in the Æcidium germinate on the wheat, but not on the Barberry. This fungus affords a good example of what De Bary calls Heterœcism, or changing from host to host during different stages of development (figs. 43 and 44, pp. 60 and 61.)

FIG. 42.

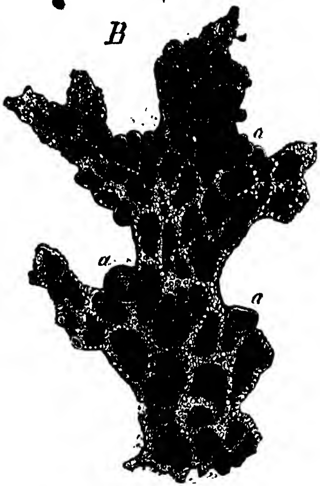


A. Usnea barbata (nat. size).
A fruticose lichen, with apothecia, *a*; *f*, disc by which it is attached to the bark of a tree. (After Sachs.)

Order XX. **Ustilagineæ.**—Related :
mycetes in their parasitic habit, but differing in their having only one kind of spore, are the Ustilagineæ, the Bunt and Smuts. The spores are very numerous and in the case of the smut of oats, Ustilago carbo,

fill the whole diseased grain with black powder. Another fungus belonging to the group is the brand, Tilletia caries. When the spores germinate, a promycelium is produced, the branches of which undergo a kind of conjugation before sporidia are formed. The sexual reproduction of these plants is unknown (fig. 45), p. 62.

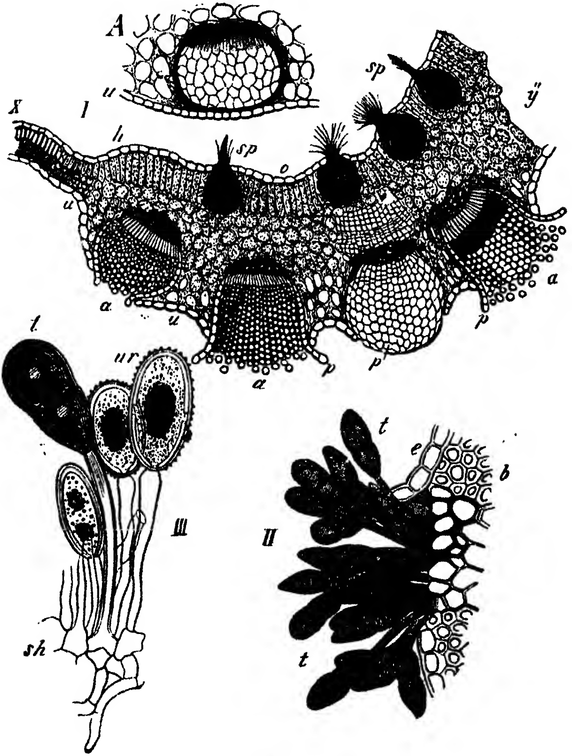
Fig. 42 *a*.



B. Sticta pulmonacea (nat. size).
A foliaceous lichen (under side); *a*, apothecia. (After Sachs.)

Order XXI. **Basidiomycetes.**—To this group belong the funguses commonly known as mushrooms and toadstools. The mycelium forms a white mass of threads ramifying in the nutrient substratum, and the part known as the fungus is the fruit-bearer, or sporocarp. The sporocarp produces the spores, either

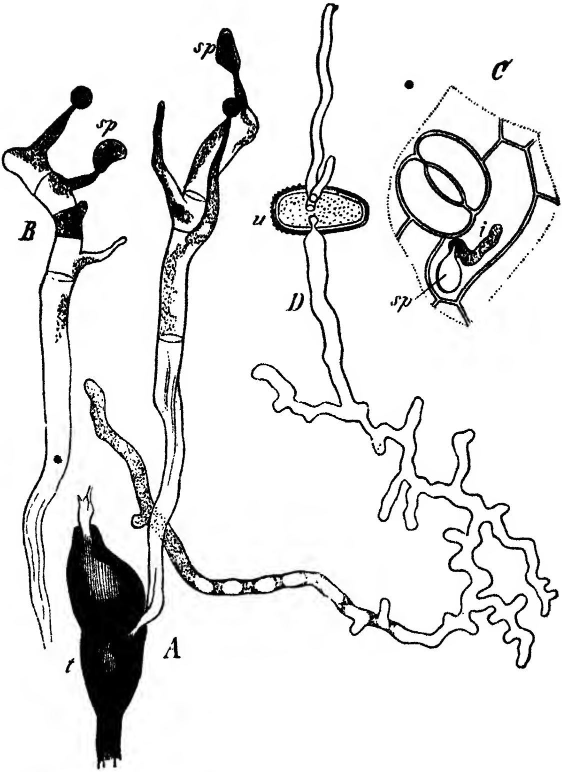
Fig. 43.



Puccinia graminis (highly magnified).

A, transverse section of leaf of Barberry (*Berberis vulgaris*), with young æcidium-fruit still unopened. *I*, similar section, with æcidium-fruits (*a*) in various stages of development; *p*, peridium or wall of æcidium-fruit; *o*, epidermis of upper side, *u*, of under side of leaf; *x*, normal blade of leaf, but greatly thickened at *y*; *sp*, spermogones, peculiar structures of unknown function. *II*, teleutospores, *t*, on couch-grass, *Triticum repens*; *e*, epidermis; *b*, sub-epidermal cells. *III*, Uredo-spores, *ur*, with one teleutospore, *t*, from couch-grass; *sh*, the hyphæ threads. (After Sachs.)

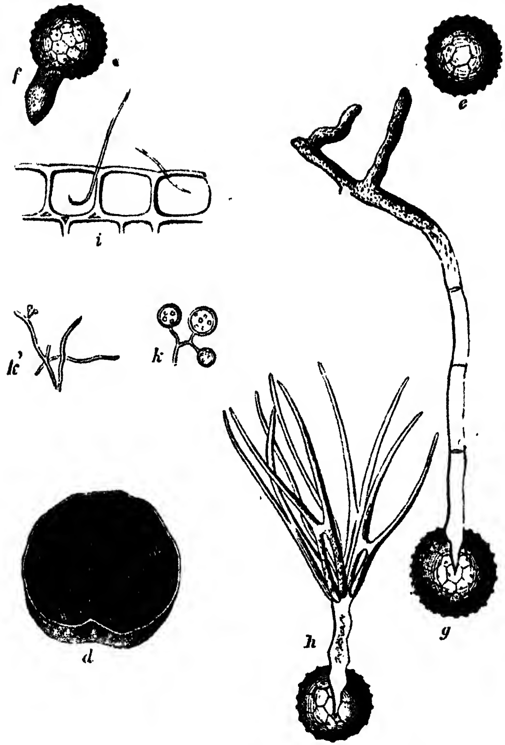
FIG. 44.



Puccinia graminis (highly magnified).

A, germinating teleutospore, *t*, with promycelium forming the sporidia, *sp*. *B*, similar promycelium, with sporidia. *C*, sporidium, *sp*, germinating on under side of leaf of Barberry, the mycelium, *i*, penetrating the epidermis. *D*, germinating Uredo-spore (*u*) fourteen hours after being placed on the leaf of a grass, forming a branched mycelium. (After Sachs.)

FIG. 45.



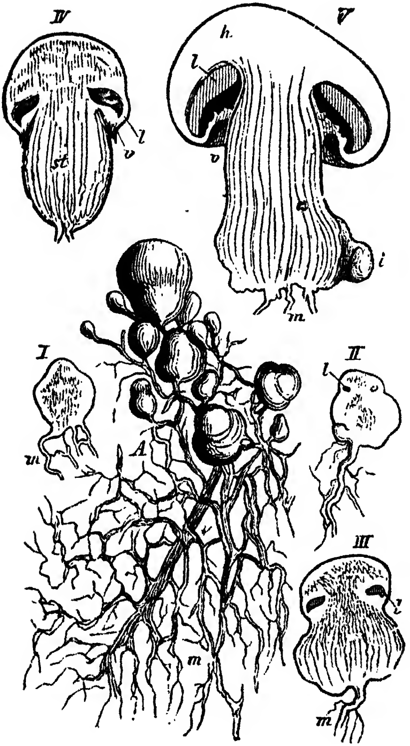
Tilletia caries (the Bunt). *d*, transverse section of infected wheat-grain; *e*, spore; *f*, *g*, *h*, spores germinating; *g*, formation of branching promycelium, with granular protoplasm; *h*, spore germinating and forming the narrow branches which unite by a kind of conjugation, the ends of the filament afterwards forming remarkable spores, which give rise to mycelium, *i*, penetrating the epidermis; *k'*, mycelium, with formation of young spores (stylogonidia?); *k*, the same, with spores further developed. (*d*, after Oersted; *e–h*, after Tulasne, × 460; *i–k*, after Kuhn, × 300.)

superficial or concealed; and developed on basidia, enlarged cells forming a special layer called the hymenium. The basidia bear at their apex four small projections, the sterigmata, on each of which a spore forms by cell-division. The Basidiomycetes include among other groups the two large divisions of Hymenomycetes and Gasteromycetes. In both of these the life-history is very imperfectly known.

Sub-order 1. HYMENOMYCETES.—The sporocarp, which is variously shaped, has a superficial hymenium. The common mushroom may be taken as a good example. The sporocarp of the mushroom arises from underground mycelium threads, and consists of a rounded rather cylindrical stalk bearing on its summit the cap or pileus. It is convex above and bears on its undersurface a series of radiating plates or lamellæ running from the stalk to the margin. These lamellæ, or gills, are covered by the closely-placed elongated cells, the basidia; the whole layer being known as the hymenium. Each of the basidia developes four sterigmata with spores. When ripe the coloured spores fall off, and, when they germinate, give rise to the mycelium, from which the young sporocarps are developed, probably as a result of some sexual reproductive process. Polyporus and Boletus belong to the same group; the underside of the pileus is however covered with tubes, in the inside of each of which the hymenium is developed. Some of the Hymenomycetes are edible, many are poisonous. (Figs. 46, 47, pp. 64 and 65.)

Sub-order 2. GASTEROMYCETES.—The spores are here developed on basidia, but the hymenium is in the interior of the more or less spherical sporocarp, and not on the surface, as in the Hymenomycetes. When

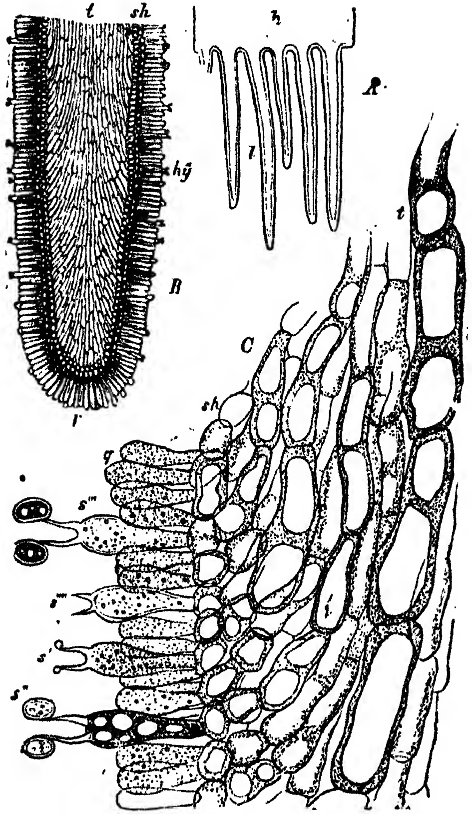
FIG. 46.



Agaricus campestris (nat. size).

m, underground mycelium, with very young sporocarps at *A* ; *I-V*, different stages of development of the sporocarp ; *m*, mycelium, *st*, stalk, *l*, in *II* and *III*, annular air space, the gills (lamellæ) subsequently forming at upper part, *V*, *l* ; *v*, tissue of lower part of air space, *l*, forming the volva, which ultimately ruptures, and forms a ring round the stem. (After Sachs.)

FIG. 47.



Agaricus campestris.

A, section of the cap or pileus, *h*, showing the lamellæ or gills, *l* (sligh magnified). *B*, section of one of the lamellæ (more highly magnified), the central tissue of the gill called the trama, *sh*, short rounded cells forming the sub-hymeneal layer, *hy*, the hymenium the spores are ripe the outer covering (the peridium) ruptures, and the spores escape. Sometimes a capillitium is formed, with the spores placed between the meshes as in the Myxomycetes. The puff-ball, Lycoperdon, and Phallus, the stink-horn, are the best known examples. The earth star, Geaster, and the cup-like Nitidularias belong to this division. Our knowledge of the life history is still very imperfect (fig. 48).

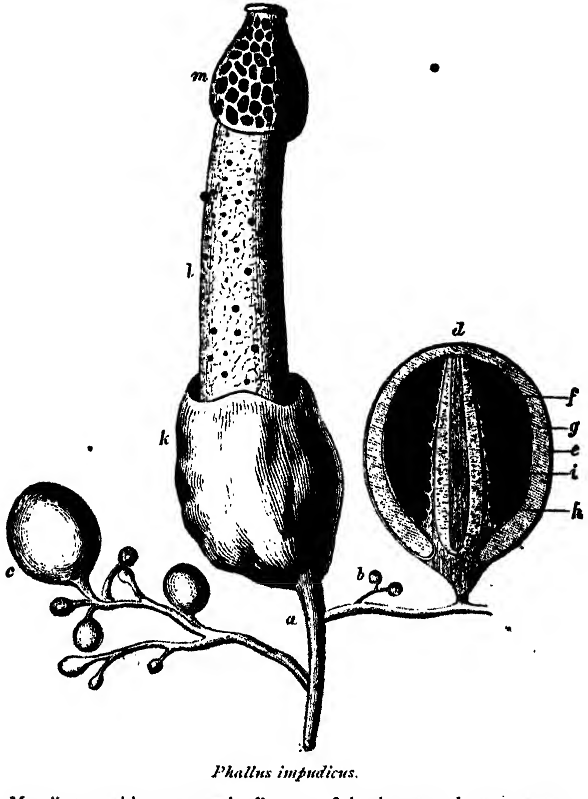
CHAPTER II.

THE BRYOPHYTES.

SUB-KINGDOM II.—*BRYOPHYTA or MUSCINEÆ.*

THE Bryophyta are distinguished by their sharply defined alternation of generations. The first generation is sexual and may be either a thallus or a leafy-axis, bearing the antheridia and archegonia. From the central cells of the archegonium after fertilisation, arises the second or non-sexual generation, the sporocarp, a case with or without a stalk, and containing the spores. From the spores the sexual stage arises either directly or indirectly. When the spore germinates there is either produced the protonema, a series of conferva-like threads, from which the leafy axes of the moss arise by budding ; or a thallus is developed directly from the germinating spore. In the lowest groups the thallus is developed, while in the higher there is an axis with leaves. Roots are never formed, their functions being performed by root hairs. The thallus, or leafy axis, may repeatedly develope sexual

Fig. 48.



Phallus impudicus.

Mycelium *a*, with sporocarps in all stages of development; *b*, very young; *c*, much older; *d*, longitudinal section of sporocarp before rupture of the peridium; *e*, *f*, *g*, the three layers of the peridium; *h*, undeveloped stem; *i*, gleba, an inner mass of tissue covered by the spore-bearing hymenium; *k*, *l*, *m*, the fully-developed sporocarp, *k*, peridium, *l*, stem, *m*, remains of gleba. (After Oersted.)

reproductive organs, and in addition, non-sexual reproduction by buds, &c., may take place. The seta of the moss also gives rise to a protonema and buds, under certain conditions.

The reproductive organs are of two kinds, produced either together or separately, on the same or different plants. The male reproductive organs are the antheridia, the female the archegonia.

Fig. 49.

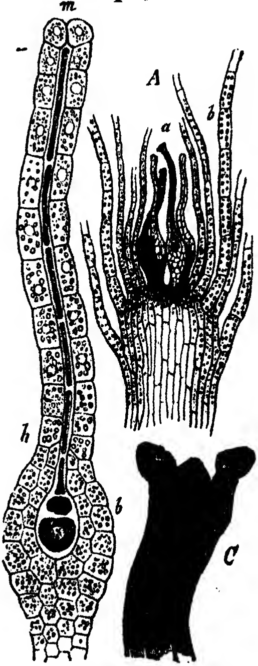
Funaria hygrometrica.

A, antheridium open, and permitting the spermatozoids, *a*, to escape (× 350). *B*, Polytrichum, sperm-cell, *b*, with enclosed spermatozoid; *c*, free spermatozoid, with two cilia at pointed end (× 800). (After Sachs.)

The antheridia are stalked bodies, spherical or club-shaped in form (fig. 49). The sac-like wall consists of a single layer of cells, and it encloses a number of small closely crowded cells, the sperm-cells, each one of which develops a single spermatozoid. When the antheridium is ripe the wall ruptures when wet, the sperm-cells escape at the apex, and then each of the sperm-cells liberates its spermatozoid. The spermatozoids are spirally coiled threads, thick at one end and tapering to a fine point at the anterior end, which is furnished with two long vibratile cilia, whose action causes the movement of the spermatozoid.

The archegonia are flask-shaped bodies enlarged below from a narrow base, and prolonged above into a long narrow neck (fig. 50). The wall consists of a single layer of cells. The neck and base contain a central row of cells, the lower one forming the germ-cell, the upper ones forming a special series, which becomes gelatinous when the archegonium is ripe, and thus forms a canal for the passage of the spermatozoid. After fertilisation the germ-cell becomes surrounded by a wall, and then begins to divide. The reproductive organs are developed in groups or singly. The groups are often surrounded by a special investing covering, the involucre or perianth. Among the reproductive organs peculiar hairs are met with, called paraphyses.

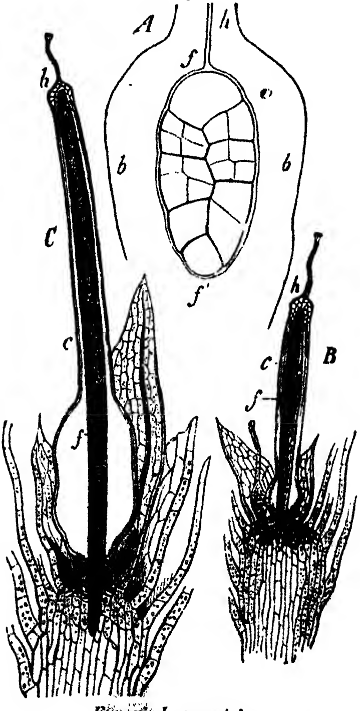
FIG. 50.



Funaria hygrometrica.
A, apex of stem of a fe[ ]le plant (× 100), *a*, archegonia, . , ... *B*, an archegonium (× 550), *b*, base with central cell, *h*, neck, *m*, mouth, the axial row of cells becoming gelatinous. *C*, mouth of fertilised archegonium, with dark-walled cells. (After Sachs.)

From the fertilised germinal cell there is developed directly the second non-sexual generation, the sporogonium. As the sporogonium grows the lower end penetrates deeper and deeper into the tissues of the first generation, and is entirely nourished by it; but the cells are not in organic connection (fig. 51). The wall of the arche-

FIG. 51.



Funaria hygrometrica.

A, longitudinal section of archegonium (× 500), *b, b*; neck, *h*; young sporogonium, *f, f'*. *B, C*, different stages in the development of the sporogonium, *f*; calyptra, *c*; neck of archegonium, *h*. The lower end of sporogonium is shown penetrating downwards into the tissues of the end of the leafy axis. (After Sachs.)

gonium grows as the germinal cell developes into the sporogonium, and becomes a special covering, the calyptra. The calyptra gives way ultimately, and remains either at the base or apex of the sporogonium.

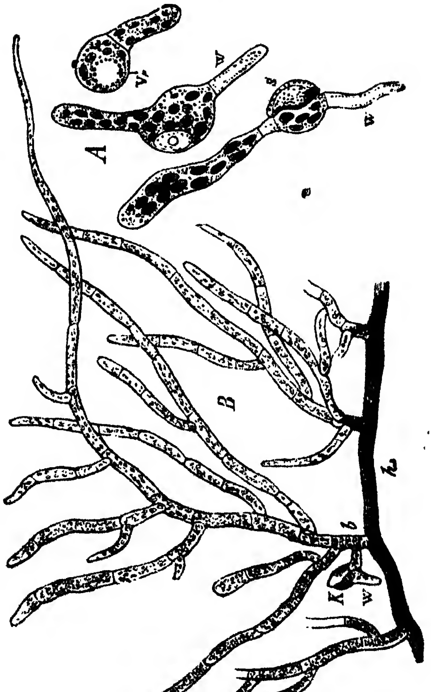
The form of the mature sporogonium differs in the different groups. In general it consists of an urn-case, or theca, supported externally on a long or short slender stalk, or seta. In the urn-case the spores arise from definite layers of tissue, the mother-cells dividing into fours. In some a central mass of tissue remains, called the columella. In all the mosses the spores are produced alone, but in most of the liverworts peculiar spiral cells, called elaters, are developed along with the spores. When the spores are ripe the urn-case opens in different ways, and the spores are scattered.

The spores are rounded, and when ripe possess two coverings, the exosporium or outer cuticular layer, generally marked with small excrescences, and ruptured during germination by the protrusion of the inner coat or endosporium. The spore contains protoplasm, and in addition chlorophyll grains, starch, and oil. When the endosporium protrudes, cell-division takes place, and the branching cell-rows of the protonema develop in the mosses (fig. 52).

The tissues of the mosses are well developed, but fibro-vascular bundles do not exist. The plant-body is either a thallome, or a caulome with phyllomes. The branching is often dichotomous, never axillary.

The bryophytes can be divided into two classes, the Liverworts and the Mosses.

FIG. 52.



Funaria hygrometrica.

A, germinating spores (× 350), *s*, exosporium, *w*, root-hair, *v*, vacuole. *B*, part of protonema three weeks after germination (× 90), *h*, main branch, with brown walls, *b*, side branch, *k*, formation of bud from which the leafy-axis of the moss arises, *w*, root-hair. (After Sachs.)

Class V. *Hepaticæ.*—The urn-case or capsule does not open by a special lid, but by four or two valves, or irregularly, or does not open at all (Riccia). Elaters are nearly always present in the sporogonium along with the spores. The columella is not developed, except in the Anthocerotæ. The ripening of the spores takes place during the time the capsule is enclosed in the calyptra. The calyptra is torn when the spores are ripe, and it remains below at the base of the capsule. The plant-body of the first generation is a thallus, or thallus-like stem with scale-like leaves (amphigastria), or a leafy axis, the leaves consisting of one layer of cells (a cell-surface) without a midrib or vein. The stem is bilateral. Root hairs are developed largely, and all of them are unicellular.

Class VI. *Musci.*—The urn-case or capsule generally opens by means of a special lid, which is thrown off when the spores are ripe. Elaters are never formed with the spores. The columella is always present, at least at the early stage of development. The calyptra is generally torn when the sporangium is young, and the upper part is carried up on the urn-case like a cap; the lower part remains below as the vaginula. The plant-body of the first generation is always a leafy axis; the leaves generally have a prominent central midrib or vein, two or more cells thick. The stem is very rarely bilateral. The root hairs are cell-rows.

Schimper enumerates seventeen genera and forty-six species of Bryophyta, all from the Tertiary. There are seven genera of Hepaticæ, all still living, including three species of Marchantia and seven of Jungermannia. There are ten genera of mosses in the Terriary, nine still living, and including one species of Sphagnum, one Phascum, twenty of Polytrichum, and thirteen of Hypnum.

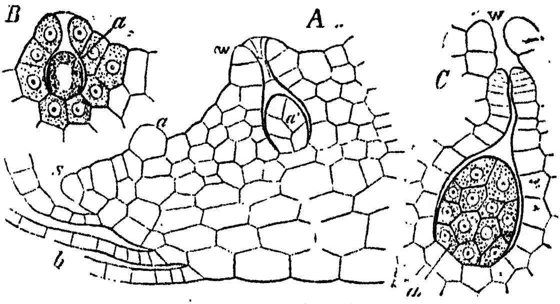
Class V.—Hepaticæ, Liverworts.

The plant-body of the lower forms of this class is a thallus, with no distinction between stem and leaf. In others a thallus-like stem is produced with minute scale-like leaves on one side, while in others there is a stem with numerous small leaves. The latter are distinguished as the foliose liverworts; the former as the thallose. The thallose liverworts are closely appressed to the ground, with two entirely different sides; the upper having a well-developed epidermis generally with remarkable stomata, and having abundance of chlorophyll-bearing cells beneath it. The under side developes but little chlorophyll, and the epidermis forms numerous root-hairs. The foliose liverworts are also bilateral, the upper and under sides being different. The leaves typically stand in three rows, the row on the under side being either entirely wanting or consisting of small scale-like leaves called amphigastria. The form and lobing of the other leaves always has some relation to the bilateral growth. The forms with erect stems also exhibit marked signs of bilaterality.

The class Hepaticæ includes four orders.

Order XXII. **Ricciaceæ.**—The antheridia and archegonia are placed singly on the upper side of the thallus-like stem. The sporogonia are immersed in the thallus, spherical in form, not stalked, containing no elaters, and not opening to scatter the spores. The thallus-like stem is dichotomously branched, and bears a row of scale-like leaves on the under side (figs. 53, 54).

FIG. 53.



Riccia glauca (× 500)

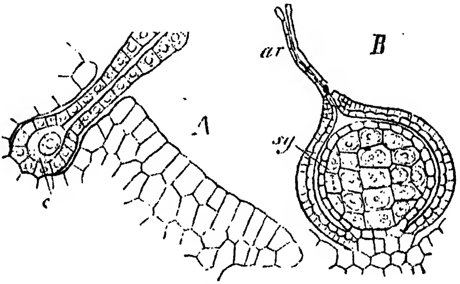
A, longitudinal section through apex of thallus, *s*, apical cell, *b*, scale-like leaves or amphigastria, *a*, very young antheridium, *a'*, older antheridium surrounded by a swollen wall of the thallus, *w*. *B*, young antheridium, *a*, surrounded by the wall. *C*, older antheridium in longitudinal section. (After Hofmeister.)

Order XXIII. **Anthoceroteæ.**—The thallus is irregularly branched, and creeps over the surface of the soil. The archegonia are imbedded in the upper side of the thallus. The sporogonium is long and narrow, breaking into two long valves from above downwards. It possesses a columella and elaters, but the elaters have no spiral threads in their interior (figs. 55, 56).

Order XXIV. **Marchantiaceæ.**—The thallus-like stem is thick, creeping, and dichotomously branched;

above with an epidermis and well-developed stomata communicating with lozenge-shaped cavities containing chlorophyll-bearing cells in branching rows; below

FIG. 54.

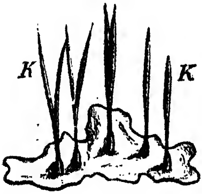


Riccia glauca.

A, longitudinal section of apex of thallus; *ar*, archegonium, *c*, central cell (× 560). *B*, unripe sporogonium, *sg*; neck of archegonium, *ar* (× 300). (After Hofmeister.)

with scale-like amphigastria and numerous root-hairs. The antheridia and archegonia are developed on special erect branches. The antheridia occur in numbers on the upper surface of the expanded umbrella-like branch. The archegonia are found on the under side of the star-like branches. The sporogonium contains both spores and elaters, and opens either irregularly or by four valves or by an opening at the apex. Marchantia polymorpha forms cup-like structures on the upper side of the

FIG. 55.

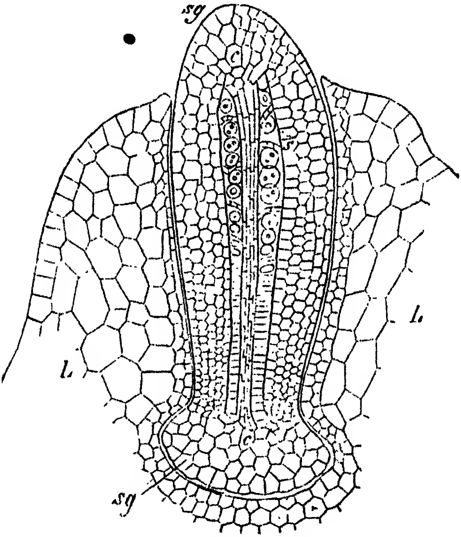


Anthoceros lævis (nat. size). *K*, *K*, the sporogonia, both open and unopened. (After Prantl.)

stem, gemmæ cups, containing numerous buds or gemmæ (figs. 57, 58, 59, 60, 61, 62).

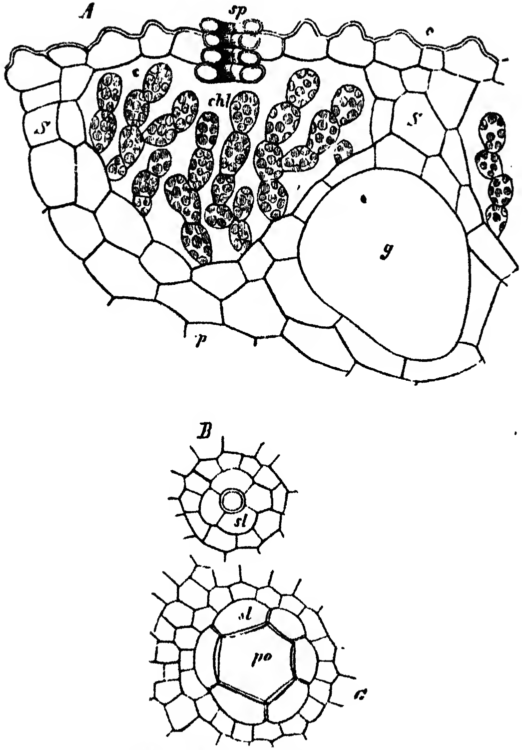
Order XXV. **Jungermanniaceæ.**—The sporogonium opens by four valves from the apex to the base, and contains both spores and elaters. The Jungermanniaceæ include two sub-orders; *a.* Thallosæ, with the plant-body, a flat thallus or thallus-like stem (Aneura), and *b.* Foliosæ, the plant-body an axis with leaves (Jungermannia), (fig. 63).

FIG. 56.



Anthoceros lævis (× 150).
The young sporogonium, *sg*, surrounded by the involucre, *L*; *c*, *c*, the columella; *s*, spores. (After Hofmeister.)

FIG 57.



Marchantia polymorpha (× 550).

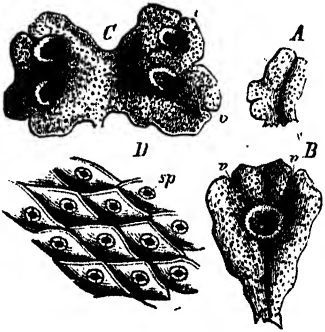
A, longitudinal section of erect portion of thallus, *o*, epidermis, *s*, walls between the air-spaces, the latter filled with rows of chlorophyll-bearing cells, *sp*, stoma, *g*, large cell. *B*, *C*, young stomata seen from above, pore or opening, *po*; *sl*, the guard cells. (After Sachs.)

CLASS VI.—MUSCI, MOSSES.

The plant-body is always a leafy axis, seldom bilateral. The plants generally live in tufts on the soil, stones or stems of trees. The class contains four orders.

Order XXVI. **Sphagnaceæ.** The spherical sporo-

FIG. 58.

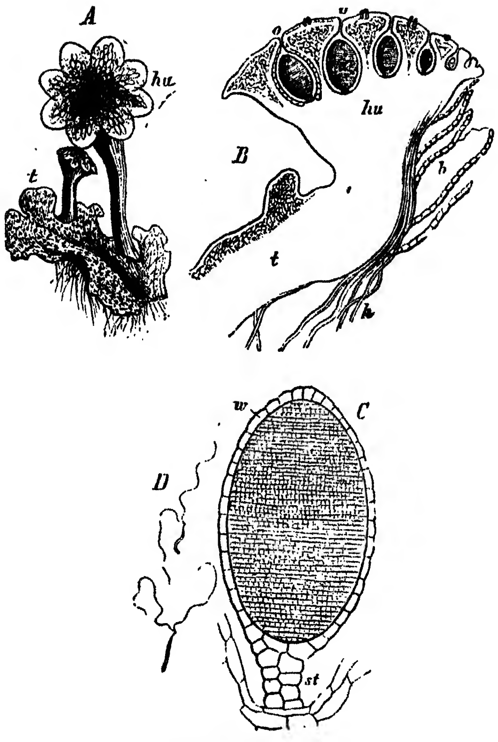


Marchantia polymorpha (slightly magnified).

A, *B*, young branches of thallus; *C*, two branches right and left developed from a gemma; *B* and *C*, with gemmæ cups on upper surface, *v*, *v*, emarginate apical region. *D*, portion of upper side of thallus, showing the lozenge-shaped spaces, each with a central stoma, *sp* (more highly magnified). (After Sachs.)

gonium contains a hemispherical columella, and opens by a lid at the apex. The seta is very short and supported on a pseudopodium, the calyptra remaining at the base of the sporogonium (fig. 64). The bog-mosses or sphagna live in large tufts in bogs and moist places. The leaves and outer part of the stem have large cells with openings in the walls which

FIG. 59.

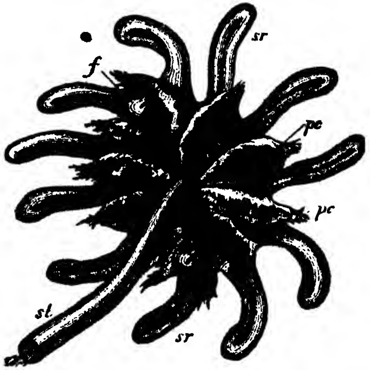


Marchantia polymorpha.

A, portion of horizontal thallus, *t* (nat. size), with two erect branches (*hu* bearing the antheridia on the upper surface. *B*, magnified longitudinal section of the same, *b*, amphigastria, *h*, root-hairs, *a*, antheridia in cavities, each opening above at *o*. *C*, almost ripe antheridium (highly magnified), *st*, stalk, wall, *w*. *D*, spermatozoids (× 800), each with two cilia. (After Sachs.)

admit water into the interior of the cell. The protonema developed from the spore is of two kinds. When germinating in water it is filamentous and branched with lateral buds, but on a solid substratum a flat-lobed proembryo is produced.

FIG. 60.



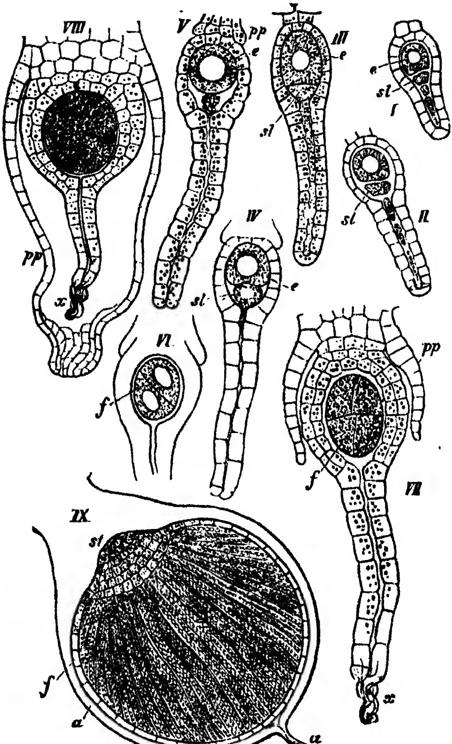
Marchantia polymorph (× 6). Upper portion or stellate disc of erect branch of thallus, bearing sporogonia.

st, its stalk with two grooves ; *sr*, star-like division of upper end of branch ; *f*, sporogonia surrounded by a common covering, the perichætium, *pc*. (After Sachs.)

Order XXVII. **Schizocarpæ.**—The columella is cylindrical, free above. The sporogonia open by four valves, which remain attached above and below. The calyptra forms a cap-like structure on the sporogonium. The Andreæas, belonging to the family Andreæaceæ, live on rocks in alpine districts.

Order XXVIII. **Cleistocarpæ.** The sporocarp does not open ; the columella is connected above and below with the wall. The calyptra remains attached at the

FIG. 61.



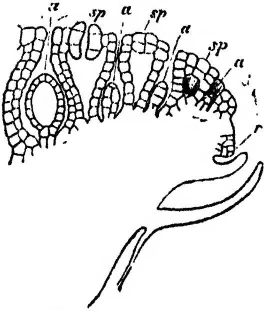
Marchantia polymorpha (× 300).

Development of sporogonium. *I*, *II*, young archegonia. *III*, *IV*, same after formation of the central canal of the neck. *V*, mature, and ready for fertilisation. *VI*–*VIII*, fertilised archegonia, the central cell, *f*, begins to divide; *x*, withered cells at apex of neck; *e*, central cell of archegonium; *sl*, lowest cell of axial row that becomes gelatinous; *pp*, the perianth in different stages of development. *IX*, the unripe sporogonium (× 30) enclosed in the calyptra (*a*), with its neck, *a'*; *f*, wall of the capsule; *st*, the undeveloped stalk. The interior of the capsule, filled with spores and fibres, the undeveloped elaters. (After Sachs.)

base of the sporogonium. The Phascums are all minute mosses, generally living on the soil and having the protonema remaining until the spores are ripe.

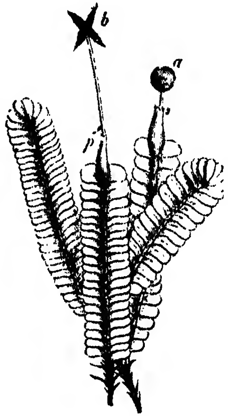
Order XXIX. **Stegocarpæ.**—The columella is connected above and below with the wall of the sporogonium, and is surrounded by the tissue from which the

FIG. 62.



Marchantia polymorpha (× 300).
Anterior margin of young antheridial (circular disc) branch of thallus. *r*, the apical cell; *a*, *a*, antheridia in different stages of development; *sp*, the stomata opening into the air-cavities between the antheridial cavities. (After Hofmeister.)

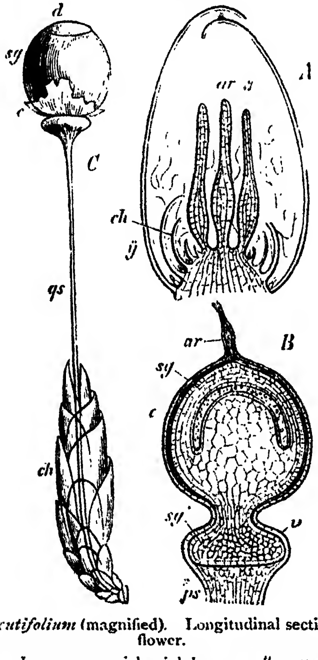
FIG. 63.



Bilateral leafy axis. *p*, the perianth; *a*, unripe capsule; *b*, ripe open capsule. (After Prantl.)

spores are developed. External to the spores are air-bearing cavities separated by rows of cells containing chlorophyll. The epidermis is provided with stomata especially near the base. The sporogonium opens by a lid, the operculum. Below the operculum is a specially developed part of the wall of the sporogonium, called the peristome. It generally consists of separate teeth, which may be 4, 8, 16, 32, or 64, in number, and in one or two rows. The peristome is absent in Gym-

FIG. 64.



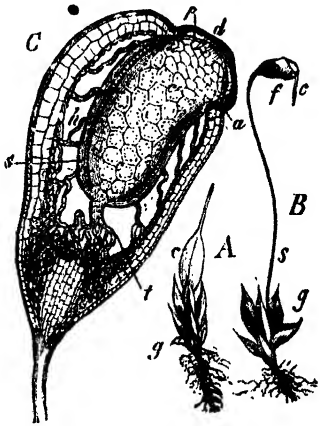
Sphagnum acutifolium (magnified). Longitudinal section of a female flower.

ar, archegonia; *ch*, young perichætial leaves; *y'*, upper leaves of the shoot, forming the perianth. *B*, longitudinal section of the sporogonium; *sg*, foot of sporogonium, *sg'*, covered by the vaginula, *v*, the capsule being covered by the calyptra, *c*; the neck of the archegonia shown at *ar*; *ps*, the pseudopodium; in the centre of the capsule, is the columella and the curved row of spore-mother cells. *C*, ripe sporogonium of *Sphagnum squarrosum* (*sg*); operculum, *d*; torn calyptra, *c*; the elongated pseudopodium, *gs*, surrounded by the perichætial leaves, *ch*. (After Schimper.)

nostomum. The sporogonium is generally elongated and bears the calyptra like a cap at its apex (fig. 65).

The archegonia, and later, the sporogonia, are developed either at the end of the main axis or on special lateral branches; from this character the Stegocarpæ are divided into two sub-orders. 1. Acrocarpæ; arche-

FIG. 65.



Funaria hygrometrica.

A, leafy-axis, with root-hairs, and young sporogonium enclosed in the calyptra, *c*. *B*, nearly mature sporogonium; *s*, seta, *f*, urn-case or capsule, *c*, calyptra. *C*, longitudinal section of capsule (magnified), *a* columella, *d*, operculum, *p*, peristome, *s*, layer in which the spores are developed, consisting of the spore-mother cells, *h*, air-cavities, *t*, filamentous tissue of the columella. (After Sachs.)

gonia at the apex of the stem, the sporogonia terminal, unless they are pushed to one side by the late development of a lateral branch near the apex of the stem; Funaria, Polytrichum. 2. Pleurocarpæ; the archegonia and sporogonia developed on special short lateral branches; Hypnum.

CHAPTER III.

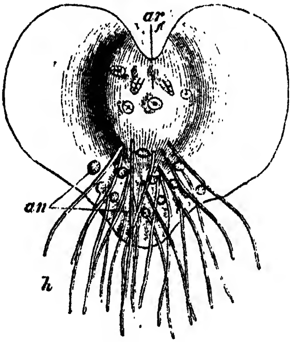
THE PTERIDOPHYTES.

SUB-KINGDOM III.—*PTERIDOPHYTA or VASCULAR CRYPTOGAMS.*

The Pteridophyta of Cohn include a number of plants commonly known as equisetums, adders-tongues, ferns rhizocarps, lycopods and selaginellas. The life-history is divided into two stages; the first is the sexual stage, or oophore; the second, the non-sexual stage, or sporophore. When the spore germinates it gives rise directly to the oophore, a peculiar thallus-like body of simple construction, called the prothallus or prothallium. The prothallium bears the reproductive organs, the antheridia and archegonia. After the central cell of the archegonium has been fertilised, the young embryo plant begins to develope while the prothallium dies and disappears. The embryo plant developes into the second stage or sporophore, a highly organised plant, with roots, stem, and leaves, all permeated by well developed fibro-vascular bundles. The sporophore produces no sexual reproductive organs, but numerous sporangia with spores. The spores are either all of one kind, or two kinds, large and small, may be produced in different sporangia. By the nature of the oophore and sporophore, the Pteridophyta are sharply separated from the Bryophyta, the prothallium corresponding to the leafy axis of the moss, and the fully developed spore-bearing fern-plant to the urn case.

The Prothallium (fig. 66) is a small structure resembling the thallus of the simplest liverworts. It is in many cases capable of independent existence, and is furnished with chlorophyll and numerous root hairs. At certain parts of its surface it developes the sexual reproductive organs, which are like those of the moss, and receive the same names, antheridia and archegonia.

FIG. 66.



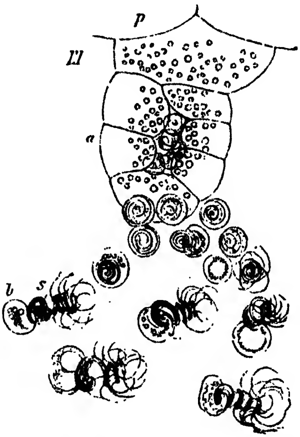
Prothallium of fern (× 10).

View of the under side, showing the root-hairs, *h*, with the antheridia, *an*, scattered among them; the archegonia, *ar*, are situated near the emarginate apex. (After Prantl.)

The antheridia (fig. 67), are placed on the surface of the prothallium, or partially embedded in its tissue. When superficial they consist of a hemispherical or cylindrical mass of cells. The wall is formed by a single series of cells, and in the centre the mother-cells of the spermatozoids, the sperm-cells, are developed. When ripe the spermatozoids are liberated as spiral threads, with a number of cilia at the anterior end.

The archegonia (fig. 68), resemble those of the mosses, consisting of a lower expanded part which is embedded in the tissue of the prothallium, and not free like that of the Bryophyta. The upper part forms a short neck with a central canal formed by gelatinous degeneration. Below is the germ-cell, the central cell

FIG. 67.



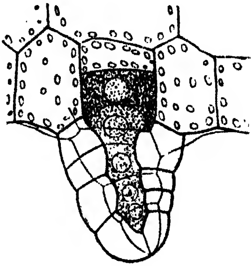
Antheridium of *Adiantum Capillus-Veneris* (× 550).

p, cells of prothallus; *a*, wall of antheridium, the sperm-cells are seen escaping; *s*, spermatozoid, with the central protoplasm of the sperm-cells remaining attached as a vesicular swelling at *b*. (After Sachs.)

of the archegonium, from which, after fertilisation, the embryo plant is developed.

The structure of the prothallus differs in different groups. Thus in the ferns it is a flat green expansion appearing above ground, and capable of independent growth. In Ophioglossum and Lycopodium the prothallus is a mass of tissue, developed underground, and forming no chlorophyll. In the Rhizocarps, Selaginella, and Isoetes, the prothallium is exceedingly small and remains always partially enclosed by the large spore, and it developes only the archegonia. The male often reduced to a single cell, forms the antheridium, with the spermatozoids in the microspores or small spores.

FIG. 68.



Archegonium of *Pteris serrulata* (strongly magnified).

The axial row of cells of the neck, and the germ-cell or central cell of the archegonium, are represented, with protoplasm and nuclei. (After Sachs.)

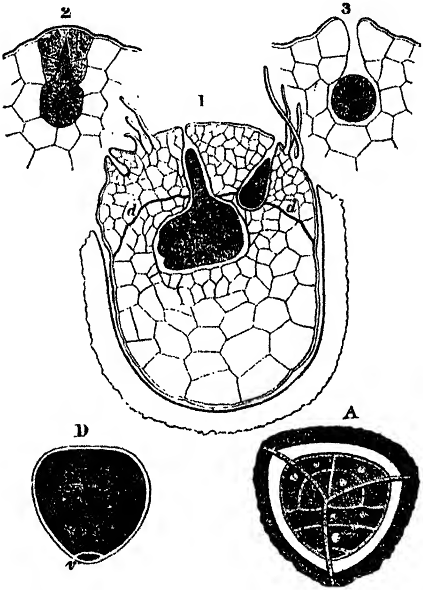
The Macrospore (fig. 69), forms the female prothallus, the apex only projecting from the macrospore after germination, and it developes only one or a few archegonia.

The microspore developes a rudimentary prothallus and antheridium, the spermatozoids being produced at once as a result of germination.

The second stage or sporophore is developed from the central cell of the archegonium, after fertilisation, and is a highly developed plant, with roots, stems and leaves. The structure differs in the different groups, and spores are formed non-sexually in all.

The spores are formed in the sporangia by division into four of the mother-cells in the interior of the sporangium. When the spores are of two kinds, macrospores and microspores, there are two kinds of sporangia, the macrospores forming in the macrosporangia,

FIG. 69.



Germination of macrospore of *Selaginella Martensii.*

1, longitudinal section of a macrospore, with prothallium and endosperm separated by the diaphragm, *d*; two embryos seen in prothallium, *e'*, *e'*; *a*, young archegonium, near which are root-hairs. 2, young archegonium not yet open. 3, archegonium, with fertilised germinal cell divided into two.

Germination of microspore of *S. caulescens.*

A, microspore rendered transparent, showing the division of the endosporium. D, microspore, showing the antheridium filled with the mother-cells of the spermatozoids; *v*, the vegetative cell, or rudimentary prothallium. (After Pfeffer.)

the microspores in the microsporangia. The sporangia are small structures often developed in considerable numbers, sometimes on the surface of the leaf, or enclosed in peculiar folded leaves, or they develope in the ground tissue of the leaf itself. When superficial the sporangia are generally modified hairs.

The Pteridophyta can be divided into three classes.

Class VII. *Filicinæ.*—The leaves are usually large and branched, the stem small and unbranched. The sporangia are developed in numbers on the underside, margin, or in the mesophyll of ordinary or modified leaves or portions of leaves, and not limited to any special region of the stem. The spores are either of one kind or both microspores and macrospores are developed.

Class VIII. *Equisetinæ.*—The leaves united form small sheaths with toothed margins surrounding the much branched stem. The sporangia on the margin of flat shield-like metamorphosed leaves, placed in whorls, and forming a cone-like structure at the end of ordinary or modified stems. Spores of one kind surrounded by peculiar elaters formed by splitting of an external extra coat.

Class IX. *Lycopodinæ.*—The leaves are small and numerous, the stem generally elongated and slender, dichotomously branched. The sporangia placed singly on the base, or in the axil of ordinary or metamorphosed leaves usually forming a cone-like structure at the ends of the branches. Spores of only one kind, or both microspores and macrospores are developed.

The Pteridophyta are largely represented in a fossil state. Schimper enumerates 190 genera, and 1,265 species. The Filicinæ are represented by 154 genera, and 914 species. Five families of the order Filices are extinct, viz. the Sphenopteridæ (Sphenopteris, Devonian to Tertiary); Neuropteridæ (Palæopteris, Devonian and Carboniferous, Adiantites, Carboniferous to Miocene); Pecopteridæ (Pecopteris, Carboniferous to Tertiary); Tæniopteridæ and Dictyopteridæ. The Sphenopteridæ are probably related to the Hymenophyllaceæ. Thirteen genera of Polypodiaceæ, all belonging to living genera, occur in the Tertiary. Three genera of Cyathæaceæ in the Tertiary. Gleichenia occurs in the Oolite and Chalk, as well as living; Lygodium (Schizæaceæ) in the Chalk and Tertiary, and Osmunda in the Tertiary. The Marattiaceæ occur from the Permian (Scolecopteris) to the Tertiary; Schimper, however, including Marattiopsis (Tertiary) and Angiopteridium (Triassic to Miocene) in the Tæniopteridæ. One Ophioglossum is met with in the Tertiary. Of the Rhizocarpeæ four genera and eight species occur in a fossil state, from the Wealden to Tertiary, viz. Marsilidium in the Wealden, Marsilia in the Tertiary, along with Salvinia and Pilularia. In addition there are about 140 forms of Filicinæ not completely identified, not included in the above. The Equisetinæ are represented by thirteen genera and 93 species; four genera belong to the family Equisetaceæ, and nine to the extinct family of the Calamariæ, the latter family being limited to the Devonian, Carboniferous, and Permian. The Equisetaceæ extend down to the Palæozoic (Equisetites in Carboniferous), and Equisetum from the Triassic, now the only living genus. Twenty-seven genera and 266 species of Lycopodinæ are met with in a fossil state. Lycopodites in Devonian and Carboniferous, Lycopodium from the Carboniferous. Two species of Isoetes occur in the Miocene; but Selaginella has not yet been described as fossil. Closely related to Selaginella and Isoetes were the families of the Lepidodendræ (Lepidodendron, 65 species in Carboniferous) and the Sigillariæ (Sigillaria, 83 species chiefly from the Carboniferous). Both these families, like the Calamariæ, were limited to the Palæozoic epoch.

Class VII.—FILICINÆ.

Spores, generally of one kind only, producing a green monœcious prothallium capable of independent existence. The Rhizocarps have macrospores and microspores; the prothallium is never independent of the spore.

The sporophore is a leafy axis, the stem well-developed, rarely branched, producing large, generally dichotomously branched leaves. The roots are developed in numbers by the stem and branch monopodially. The sporangia are developed on ordinary or modified leaves, and are usually grouped in small clusters called sori. The sporangia in the Polypodiaceæ are trichomes, the mother-cells of the spores developing from the central cell of the sporangium. In the Ophioglossaceæ the spores are developed in the tissue of the leaf, and no central cell is formed.

The apex of the stem and root does not always form an apical cell. When it does so, it produces either two or three rows of segments in the stem, and always three rows in the root. The fibro-vascular bundles are largely developed. The xylem contains the scalariform vessels, and is surrounded by soft phloem.

The Filicinæ may be divided into two groups, I. Isosporeæ, with only one kind of spore, and II. Heterosporeæ, with both macro- and microspores. The former group includes three orders, the latter only one.

I. Isosporeæ.—Spores of one kind.

Order XXX. **Filices.**—Sporangia of modified trichomes, each developed from a single epidermal cell, produced in clusters on the surface of ordinary or slightly modified leaves. No stipules.

Order XXXI. **Marattiaceæ.**—Sporangia produced from a group of epidermal cells; the ring either rudimentary or wanting. The large, much branched leaves with stipules.

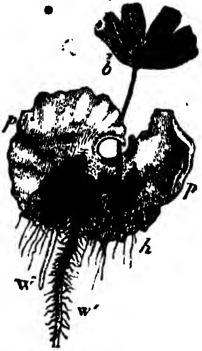
Order XXXII. **Ophioglossaceæ.** — Sporangia formed by groups of cells in the interior of a modified branch of the sheathing leaf. The ring is absent.

II. Heterosporeæ.—Spores of two kinds; the microsporangium, with numerous microspores; the macrosporangium, usually with one macrospore. The sporangia are enclosed in modified leaves or 'fruits.'

Order XXXIII. **Rhizocarpeæ.**

Order XXX. **Filices.**—Ferns. The spores are of one kind and develope green monœcious prothalli. The prothallus, as it developes from the spore, is at first a row of cells; but ultimately it becomes a flat broad rounded expansion (fig. 70), with a portion cut out of the anterior margin. On the underside, close to the emargination, the archegonia are developed. At this spot the prothallium is several cells thick, so that a cushion-like structure, bearing the reproductive organs, is produced. All the rest of the prothallus consists of a single layer of chlorophyll-bearing cells. Rarely the prothallus produces buds, thus multiplying by a process of agamogenesis. Root-hairs are abundant behind the archegonia. The antheridia are developed among the root-hairs, or on the margin of the prothallus.

FIG. 70.



Prothallium (p) of *Adiantum Capillus-Veneris* seen from below, showing the young plant developed from the fertilised central cell of the archegonium.

b, first leaf; *w′*, *w″*, roots; *h*, root-hairs of prothallium (× 3.) (After Sachs.)

The sporophore, or fern-plant, has in the tree-ferns a tall erect tree-like stem, with a crown of large leaves at the top. Other ferns generally have a bilateral stem, either more or less erect, or prostrate and creeping underground. Branching is rare; it is never axillary, but always dichotomous. Frequently buds are formed adventitiously from the petioles, and on the leaves; the buds on the petioles simulating lateral branches. The leaves are placed singly along the stem with well developed internodes, or the internodes may be suppressed and a crown of large leaves formed at the apex of the stem. In the ferns the marks of the bases of the petioles may be distinctly seen covering the stem. The leaves are often very large, and are generally branched; stipules are never developed. The development of the leaf is slow. The petiole forms during the first year; the minute lamina the second, and the whole unrolls in the circinate manner in the third year. Some of the leaves have a periodic growth, as Gleichenia, which continues year by year for a long time. Others, as Lygodium, resemble a climbing stem, growing long at the apex. The leaves are often covered with dry scaly hairs, but they are generally most developed at the base of the petiole. The whole stem, and often the petioles, develope roots; hence in the tree-ferns the covering of roots may be thicker than the stem itself. The stems and roots possess an apical cell; the ground tissue of the stem generally developes much brown sclerenchyma.

FIG. 71.

Leaflet of *Aspidium Filix-mas*, under side. *i*, indusium covering the sorus. (After Sachs.)

The sporangia are formed on the leaves in clusters, called the sori (fig. 71). In most cases the sori are developed on the under side of the ordinary leaves, and are either naked, or covered by a scale-like structure, the indusium. In the Hymenophyllaceæ the sori are on the margin, the indusium being cup-like. In others, as in the Osmundaceæ, a modified part of the leaf bears the sporangia. The form and position of the sori differ in the various genera, and the sori are either naked, or covered by a variously formed indusium. Along with the sporangia, paraphyses sometimes occur in the sori. The sporangium is a stalked capsule, rarely sessile (fig. 72). It consists of a wall, composed of a single layer of cells surrounding the spores, which arise by division of the central cell. The central cell developes sixteen spore mother-cells. A special part of the wall of the sporangium becomes the ring or annulus which causes the case to open and scatter the spores. The position of the annulus varies, and it may be either complete or incomplete.

The ferns may be divided into the following families :

A. Sori on a columella projecting from the margin of the leaf, surrounded by a cup-like indusium.

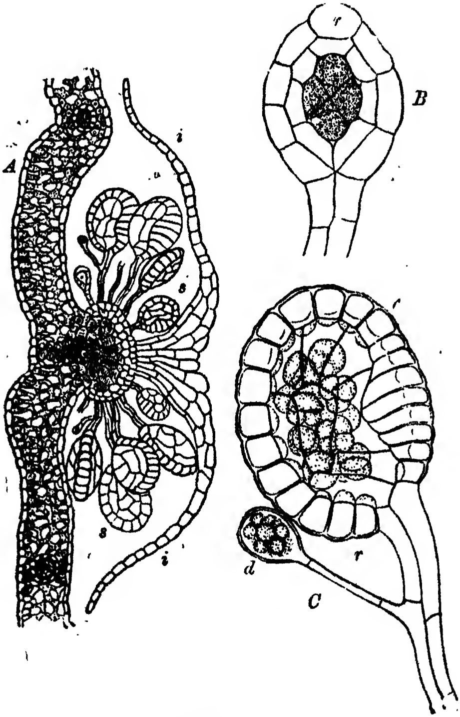
Fam. 1. *Hymenophyllaceæ.*—Small plants, often moss-like in appearance, and without true roots, living chiefly in the antarctic regions. Three forms are British. The sporangium has a complete ring, placed transversely, or slightly inclined ; the opening of the case longitudinal.

B. Sporangia with long, rarely with short stalks, and arising from single epidermal cells.

Fam. 2. *Polypodiaceæ.*—The most widely distributed and largest group of ferns, varying much in appearance. The sporangia have an incomplete longitudinal ring and open transversely to scatter the spores. The Polypodiaceæ are divisible into a number of sub-families, the most important being the Pterideæ, Aspidieæ, Asplenieæ, and Polypodieæ.

Fam. 3. *Cyathæaceæ.*—Sporangia with short stalks on a projecting base. The ring is complete and longitudinal; the sporangium ruptures transversely.

FIG. 72.



Aspidium i

A, section of leaf, with sorus, showing the sporangia *s*, *s*, and covered by the indusium, *i*. *B*, young sporangium, the central cell divided into four, *r*, the ring. *C*, mature sporangium, with spores in the interior; *d*, a glandular hair (highly magnified). (After Sachs.)

C. Sporangia sessile or on very short stalks.

Fam. 4. *Gleicheniaceæ.*—Exotic ferns from the southern hemisphere, with large leaves, generally showing interrupted periodic growth. Sporangia with a complete ring running transversely and causing the case to open longitudinally to scatter the spores.

Fam. 5. *Schizæaceæ.*—Exotic ferns chiefly inhabiting the warm regions of Asia and America. The leaves often resemble a climbing stem in their mode of growth. The sporangia have a complete ring forming a cap-like structure at the apex of the case. The sporangia open longitudinally.

Fam. 6. *Osmundaceæ.*—Ferns from temperate regions in Europe and America; the Royal fern, Osmunda regalis, inhabiting the British Islands. The sporangia are developed on modified portions of the leaf, destitute of parenchyma, and possess no ring, but only a peculiar group of cells below the apex, which causes the case to open longitudinally on the side opposite the special cells.

Order XXXI. **Marattiaceæ.**—The prothallus is produced above ground, and is thick, fleshy, and dark green in colour. The antheridia are developed as depressions in the thick prothallus, and appear equally on the upper and under side. The spermatozoids resemble those of the ferns. The archegonia have a very short neck, only the two end cells projecting from the surface of the prothallium. In structure they resemble the archegonia of the rhizocarps (Salvinia), more than the ferns.

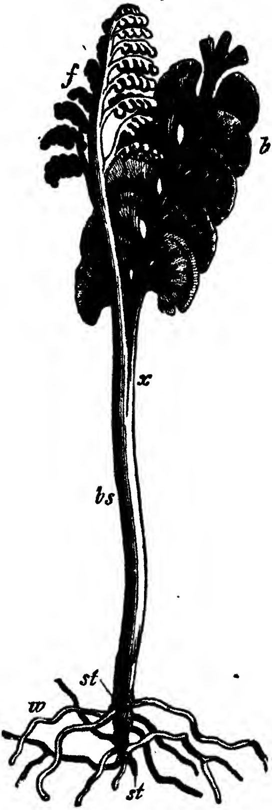
The stem, like that of the Ophioglossaceæ, is unbranched, and has no internodes. It developes roots in an acropetal manner, and never contains strings of sclerenchyma. The stem has a large apical cell, but the root has a series of small cells instead of one at the apex. The Marattias are very large, fern-like plants, from the tropics, distinguished from the ferns by their remarkable sori and by their stipules. The leaves of the genus Angiopteris are remarkable for their large size, being sometimes ten feet long.

The sporangia are formed on the under side of the leaf, from a group of epidermal cells. The wall is very thick and has sometimes a group of cells at the apex, forming a rudimentary ring, somewhat like that in Osmunda.

Order XXXII. **Ophioglossaceæ.**—The prothallium (when known), is formed underground, and is a thick mass of tissue having the antheridia and archegonia imbedded in its upper surface. The stem of the sporophore is always very short, unbranched, and remains underground. It does not develope any strings of sclerenchyma. The British forms send up only one leaf at a time, two others being observable in a young condition at the apex of the stem, and enclosed by the sheathing base of the mature leaf. The leaf branches, one half being fertile, the other half sterile and so placed that the fertile branch (or rarely branches), project from the anterior side of the sterile half (fig. 73). The roots are developed from all parts of the stem in acropetal order. The roots do not possess an apical cell. The chief genera belonging to this order are Ophioglossum and Botrychium. The former has the fertile and sterile parts of the leaf simple; in the latter both are divided. The sporangia are formed by groups of cells in the interior of the leaf, and never possess a ring.

Order XXXIII. **Rhizocarpeæ.** The spores are of two kinds, microspores forming in microsporangia, macrospores in macrosporangia, both enclosed in peculiar modified leaves or fruits. The macrospores form a minute prothallus with the archegonium projecting from the spore. The microspores either have a very rudimentary prothallus, or at once form the mother-cells of the spermatozoids. The sporophore is a leafy axis with roots, rarely as in Salvinia, rootless. The stem is bilateral and horizontal, developing two or more rows of leaves on the upper side, and roots on the lower. The leaves are often rolled up in a circinate manner. The sporangia are developed in peculiar fruits with one or more cavities. The

FIG. 73.



Botrychium Lunaria (nat. size). *st*, stem; *w*, roots; *bs*, sheath of leaf. Leaf dividing at *x* into a fertile part *f*, and a sterile part *b*. (After Sachs.)

fruits are modified leaves or parts of leaves. Each cavity developes a sorus, the sporangia arising from superficial cells. The sporangia each develope a central cell from which sixteen spore mother-cells arise. Numerous microspores are formed in each microsporangium, while only one macrospore arrives at maturity in each macrosporangium. The stem has an apical cell which forms either two or three rows of segments. The root has an apical cell forming three rows of segments. The order contains two families, —the Salviniaceæ, having the macro- and microsporangia in different 'fruits;' the Marsileaceæ having them both in the same fruit.

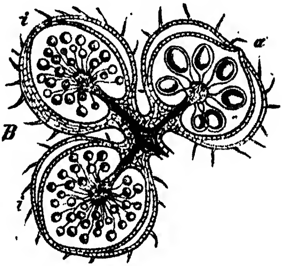
Fam. 1. *Salviniaceæ.* Salvinia natans occurs in Central Europe floating in fresh water. The microspores develope a minute male prothallus, which projects from the spore like a short sac. The apex of the sac divides into two small cells, the rudimentary antheridium in which the spermatozoids are formed. The female prothallus forms inside the spore, and appears at the apex of the macrospore bearing several archegonia.

The sporophore is a floating water-plant having a horizontal stem with two rows of flat, simple, green leaves on the upper side, and one row of divided, submersed water-leaves on the under side, resembling roots at first sight. The roots are absent. The sporangial fruits are formed by the branches of the modified water-leaves, and are globular, one containing a sorus of macrosporangia, the other a sorus of microsporangia covered by an indusium. (Fig. 74.)

Azolla belongs to the same family. It differs from Salvinia in possessing roots.

• Fam. 2. *Marsileaceæ.* Includes two genera, Marsilea to which the Nardoo plant of Australia belongs, and Pilularia. The latter is British. The male prothallus is wanting, the contents of the microspore breaking up into the sperm-cells from which the spermatozoids are developed. The female prothallus, which projects slightly from the spore, developes a single archegonium. •

FIG. 74.

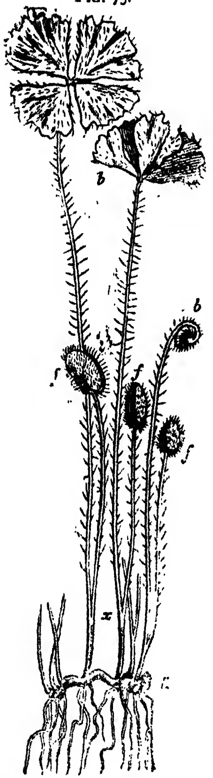


Salvinia natans (× 10). Longitudinal section through three fertile apices of a water-leaf.

i, i, two fruits, with microsporangia; *a*, one with macrosporangia. (After Sachs.)

The sporophore of Marsilea (Fig. 75) consists of a creeping stem running along the soil at the bottom of shallow water. It produces two rows of long-petioled leaves, each with four leaflets. The under side of the stem developes numerous roots. The leaves branch near the base, the fertile part being a small oval fruit in the interior of which are many sori enclosed in indusia. The sporangial fruit is a modified leaf; the sporangia spring from the superficial cells of the inner surface, and are therefore modified

FIG. 75.



Marsilea salvatrix (½ nat. size).

K, apex of stem ; *b*, leaves ; *f*, the fruits springing from the petioles at *x*. (After Sachs.)

trichomes. Each sorus contains both macroporangia and microsporangia. The venation of the leaves is circinate. Pilularia differs from Marsilea in having linear leaves without the terminal leaflets. The sporangial fruit has four cavities containing micro- and macrosporangia.

CLASS VIII.—EQUISETINÆ.

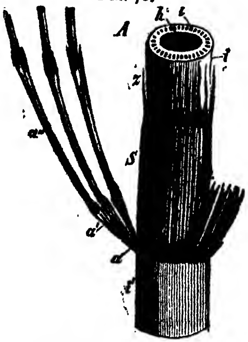
Order XXXIV. **Equisetinæ.**—This class contains only one living genus, Equisetum, but numerous fossil forms, as Calamites, &c., can be referred to a second family of the same class.

Spores are all similar, but generally developing two kinds of prothallus. The prothallus is much branched, somewhat like an endive leaf, and developes the archegonia in the angles between the lobes. The antheridia are formed at the ends of the lobes of the small male prothallus. The prothallus is developed above ground, is green, and capable of independent existence.

The sporophore developes

numerous underground stems which branch frequently, give off numerous roots, and send up yearly annual green-coloured aerial stems. The aerial stem is jointed, and bears the leaves as ring-like toothed sheaths (fig. 76), each fine tooth representing a leaf. The surface of the aerial stem is marked with ridges and furrows, the ridges correspond in position to the apices of the sheath leaves. The branches, which were formerly considered as arising endogenously, have recently been shown to be axillary. They resemble the main axis in structure.

FIG. 76.



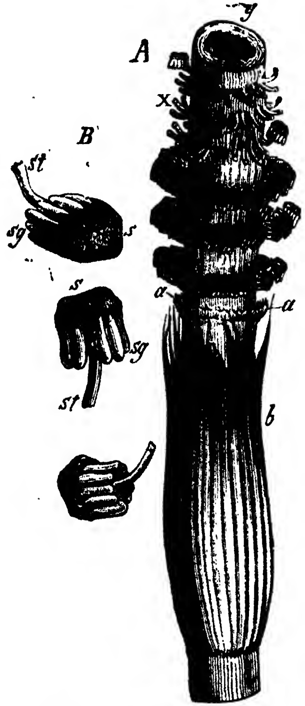
Equisetum Telmateia (nat. size.) Portion of stem.

i, *i*, the internodes, with central hollow space, *h*, and air-spaces in the cortical tissue, *l*; *S*, sheath of united leaves; *z*, their separate apices; *a*, *a'*, *a''*, basal internodes of lateral branches. (After Sachs.)

The stem and root have each a large apical cell forming three rows of segments. The branching of the root is always monopodial. The fibro-vascular bundles in the stem are arranged in a circle when looked at in transverse section. Like those of the monocotyledons, the xylem of the bundles is feebly developed. The central fibro-vascular body in the root has no pericambium layer.

The aerial shoots may be either sterile or fertile, as in Equisetum arvense and E. maximum. The fertile branches are formed in spring, contain no chlorophyll, and are unbranched; the green, sterile, branched stems forming later. In other species, as E. limosum, the fruit is developed at the end of the ordinary green stem. The cone-like fruit (fig. 77) consists of whorls of modified leaves bearing the sporangia on the inner

FIG. 77.



Equisetum Telmateia (nat. size).

A, end of fertile stem; *b*, sheath of united leaves; *a*, annulus or ring formed of imperfectly developed leaves; *x*, stalks of detached shields bearing the sporangia; *y*, section of the axis. *B*, shields, *s* (magnified), bearing sporangia, *sg*; *st* stalk of shield. (After Sachs.)

side. Below the cone is a modified whorl of sheath-leaves called the ring or annulus. The shield-like leaves have an expanded shield-like upper part, and a narrow stalk, and are arranged in alternating whorls round the stem. The emergences forming the sporangia are from five to ten in number, and occur on the inner side. When the spores are ripe, the sporangia open, and the spores are scattered. The spores, which do not arise from a central cell of the sporangium, have a triple wall, the external one breaking up into four long filaments or elaters, by which the spores are scattered. When dry the elaters are spread out like the arms of a cross, and when moist they coil round the spore.

The plants are met with in marshy and wet places, and are all of small size. The Calamites, their remote relations of the Coal Period, were gigantic plants, and very different in appearance from those now living.

Class IX.—LYCOPODINÆ.

The prothallus either developes from one kind of spore, and is monœcious, bearing both antheridia and archegonia, undergound, and capable of independent existence; or there are two kinds of spores, microspores and macrospores, the prothallus with the archegonia remaining attached to the macrospore. The sporophore is a simple or much branched stem developing numerous roots and covered with small, very numerous simple leaves, each with a single central fibro-vascular bundle. The stem and roots always branch dichotomously, the stem often showing subsequent bostrychoid and cicinnoid modifications. The sporangia are developed singly on the upper side of the leaf close to the base, or they are axillary, or may be placed on the stem above the axil. The sporangia arise from groups of cells below the epidermis. The mother-cells of the spores do not develope from a central cell.

Order XXXV. **Lycopodiaceæ.**—Spores of one kind.

FIG. 78.

Lycopodium clavatum (½ nat. size).
Stem with leaves and roots, and bearing fertile spikes, *s*. (After Prantl.)

The prothallus of Lycopodium is a mass of tissue without chlorophyll in the cells. It is developed underground and developes both antheridia and archegonia sunk in the tissue.

The stem of the sporophore (fig. 78), branches dichotomously in alternating planes, and grows greatly in length, often creeping over the surface of the soil and rooting freely. The stems are clothed with small leaves placed close together; the leaves have no ligules; the roots, like the stem, branch dichotomously; the leaves are quite unbranched.

The sporangia spring from the tissue of the upper side of the base of the leaf; sometimes the leaves with the sporangia do not differ from those on the rest of the stem, but in other cases the fertile leaves are collected into a cone-like fruit.

Four genera, including Lycopodium, belong to the Lycopodiaceæ, but nothing is as yet known of the life-history of three of them. These are Tmesipteris, Phylloglossum, a little plant not unlike an Ophioglossum and Psilotum, the latter bearing exceedingly minute leaves, and having no true roots, the peculiar under-ground stems developing root hairs only.

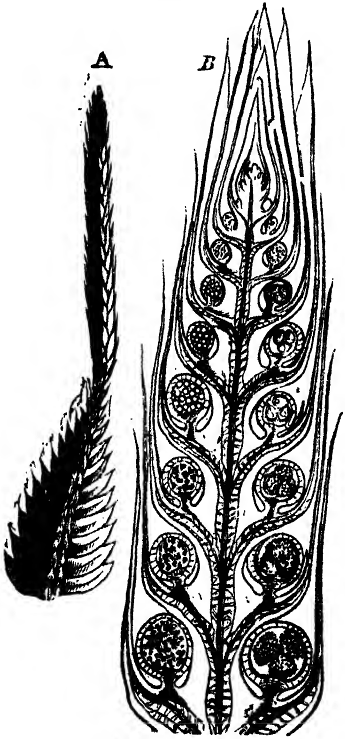
Order XXXVI. **Ligulatæ.**—Leaves with a ligule near the base. Spores of two kinds, microspores and macrospores. The Ligulatæ can be divided into two families, Selaginelleæ and Isoeteæ.

Fam. 1. *Selaginelleæ.*—Prothallus small, of two kinds, never independent of the spore.

The sporophore of Selaginella resembles that of Lycopodium. The stem branches dichotomously, and is creeping or erect. The internodes are short, the leaves small, rounded or slightly elongated, generally in four rows—two of the rows large and two small. The stem is thus bilateral. The leaf has the ligule at the base, a minute scale-like body on the upper surface. The roots branch dichotomously in alternating planes.

The sporangia are placed singly in the axils of the fertile leaves (fig. 79). These leaves are generally

FIG. 79.



Selaginella inæqualifolia.

A, fertile branch (× 2), the quadrangular spore-bearing spike at apex. *B*, section of the spike (magnified), showing the sporangia, with microspores on one side, and macrospores on the other. (After Sachs.)

different from the sterile leaves and form a square or bilateral spike. The macrosporangia are usually developed near the base, the microsporangia near the apex of the fertile spike. The macrosporangia commonly contain four macrospores, the microsporangia numerous microspores. In the macrosporangia only one of the numerous spore mother-cells divides into four and becomes mature, while in the microsporangia all the mother-cells divide.

The macrospores develope a small prothallus which projects slightly from the spore and produces one or more archegonia and a few root hairs. The interior of the spore is filled with cellular tissue, which has been called the endosperm. After fertilisation the embryo developes, with root, stem, leaves, and foot.

The microspores develope an exceedingly rudimentary prothallus, one cell forming the mother-cells of the spermatozoids (fig. 69).

The British species of Selaginella, S. spinosa, resembles a Lycopodium very closely. S. Kraussiana and many other exotic forms are cultivated for their beauty.

Fam. 2. *Isoeteæ.*—The prothallus is small, of two kinds, and never independent of the spore.

The sporophore of the genus Isoetes lives in fresh water lakes. It has a short unbranched stem producing numerous dichotomously branched roots. The leaves are numerous, long, narrow, and sheathing at the base, a groove separating the sheath from the lamina. At the upper part of the groove the ligule is placed.

The sporangia are placed in a depression in the sheath of the leaf, near the base, on the upper side. The macrosporangia are developed by the outer leaves, the microsporangia by the inner. The macrospores, like the microspores, are developed in numbers in the sporangium.

CHAPTER IV.

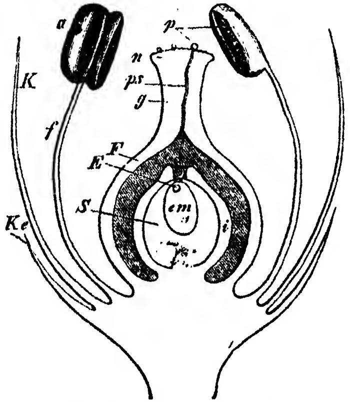
THE PHANEROGAMS.

SUB-KINGDOM IV.—*PHANEROGAMIA or SEED-BEARING PLANTS.*

THE Phanerogams or seed-bearing plants are characterised by their producing flowers and seeds. The seed is formed by the perfect plant, and becomes detached from it when ripe. It is developed as a result of fertilisation, and consists essentially of two parts, namely, the integument or spermoderm, a part of the tissue of the parent plant, and the embryo or young plant, a new formation developed from the germinal cell of the ovule after fertilisation. When the embryo is fully developed it is a small plant furnished with stem, leaves, and root. In addition there generally exists in the interior of the seed, a mass of tissue, the endosperm, containing nutrient matter for the use of the embryo plant during germination. In some plants the endosperm is abundant, the so-called albuminous seeds, while in others, exalbuminous seeds, it is entirely wanting. When the seed is detached from the parent plant it germinates, after a longer or shorter period of rest, and developes a new plant.

The flower (fig. 80) contains the reproductive organs which develope the seed as a product of fertilisation. The male reproductive cells are the pollen-grains.

FIG. 80.



Diagrammatic section of a flower.

Ke, calyx; *K*, corolla; *f*, filament of stamen; *a*, anther, showing the pollen-sacs open, and the pollen-grains, *p*, escaping. The central part or the gynœcium shows the ovary, *F*, style, *g*, and stigma, *n*, on which are pollen-grains, one sending down a pollen-tube, *ps*, to the micropyle of the ovule. The central structure in the ovary is the ovule, showing the integument, *i*, the nucleus, *S*, and the embryo-sac, *em*, with the germinal vesicle, *E*, at the apex, close to the end of the pollen-tube. (After Prantl.)

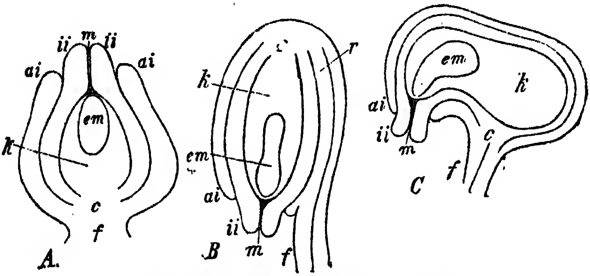
They are contained in the pollen sacs or loculaments of the anther, a portion of the stamen. The stamen consists of the filament or stalk, the anther, and frequently a portion of tissue, between the two halves of the anther, called the connective. The female reproductive cells, the germinal vesicles, are contained in the young seeds or ovules. The ovules are generally enclosed in folded leaves called the carpids—Angiosperms (plants bearing seeds in a case), or Metasperms (secondary seed-bearing plants),—which, after the fertilisation of the germinal vesicles by the pollen-tube, become the carpels and form the fruit. The lower swollen part of the carpid in which the seeds are contained is the ovary. In the group of plants called Gymnosperms (naked seeds), or Archisperms (primitive seed-bearing plants), the carpids are believed by many to be wanting, and the ovules to be thus naked, and hence the term Gymnosperms sometimes applied to them.

The pollen grains are developed, like the spores of many of the lower plants, by division into four of the pollen mother-cells formed in the four pollen-sacs, two sacs in each half of the anther. In the monocotyledons and dicotyledons the pollen grains are single cells, with a double coat. The outer coat is cuticular, often coloured and variously marked, and called the extine. The inner cellulose layer is called the intine. When the pollen grain is applied to the stigma of the carpid the extine is ruptured, and the intine protrudes as the pollen tube, which penetrates the tissue of the style, and ultimately reaches the young ovule. The pollen grains of the Gymnosperms or Archisperms consist of more than one cell, covered by a common external cuticular coat or extine.

The germinal vesicle is developed in the embryo-sac in the interior of the nucleus of the ovule. The ovule consists generally of three parts. The first is the central mass of tissue called the nucleus. The second part consists of the one or two coverings surrounding the nucleus, but not completely inclosing it. These are the ovular integuments. They are distinguished as the outer and inner, or by the names primine and secundine. The inner coat or secundine is developed before the outer or primine. When only one is present, the outer or primine is the one that is wanting. The integuments are incomplete at the top and leave a little opening or foramen, called the micropyle. The micropyle may be formed by the two integuments, when the opening in the secundine or inner integument is called the endostome, the opening in the outer or primine, the exostome. In other cases the inner integument alone forms the micropyle. The third part is a longer or shorter stalk, supporting the ovule, called the funiculus. By means of the funiculus, the ovule is attached to the carpid, or to the axis of the parent plant, and the part, whatever its nature may be, to which the ovule is attached by its funiculus, is called the placenta. Rarely a third external covering forms during the ripening of the seed. It is known as the aril, of which the mace of the nutmeg is an example.

Three kinds of ovules (fig. 81), are generally distinguished by special names according to the form, nature, and position of the parts. Thus there is the anatropous or inverted ovule, the commonest form. The nucleus is straight, the micropyle at the apex, the funiculus is attached along the side of the integument, forming a projection called the raphe. The place of attachment of the funiculus to the placenta, the hilum, is therefore close to the micropyle, and opposite the base of the nucleus, the chalaza. The orthotropous, atropous, or straight ovule, is the rarest form, and has, as its name implies, a straight nucleus, the macropyle and chalaza being at opposite ends, and the funiculus, which is straight, so placed that the hilum is close to the chalaza. In the third, the campylotropal or bent ovule, the whole nucleus is bent on itself, so that the micropyle, chalaza and hilum are all brought close together.

FIG. 81



Diagrammatic longitudinal sections of ovules.

A, orthotropous or straight; *B*, anatropous or inverted; and *C*, campylotropous or bent ovule. *ai*, outer integument or primine; *ii*, inner integument or secundine; *m*, the micropyle; *k*, the nucleus, with the embryo-sac, *em*; *c*, the chalaza or base of the nucleus; *f*, the funiculus; *r*, the raphe of the anatropal ovule, formed by the fusion of the outer integument and funiculus. (After Prantl.)

In the interior of the nucleus of the ovule is a large cell, filled with protoplasm, called the embryo-sac. At the upper end of the embryo sac, that is, at the part nearest the micropyle, two or more cells are formed by free-cell formation, called the germinal vesicles. In the gymnosperms or archisperms, the embryo-sac is filled with cells, the endosperm, the homologue of the prothallium or oophore of the Pteridophyta. At the apex of the endosperm, close to the (so-called) micropyle, several structures called the corpuscula, are developed. These corpuscula, or secondary embryo-sacs of Henfrey, are the central cells of rudimentary archegonia. The neck of the archegonium is represented by a few cells called the rosette, the central part having the rudiment of a canal cell, as pointed out by Strasburger.

Fertilisation is effected by the pollen-tube reaching the germinal vesicle, and a diffusion of matter taking place. The germinal vesicle now forms a cellulose wall, then divides and produces a row of cells, called the suspensor, at the apex of which the embryo is developed. In the gymnosperms the corpuscule divides, the small cell formed at the lower part dividing by successive longitudinal and transverse partitions, and thus forming numerous suspensors, at the ends of each of which an embryo is developed.

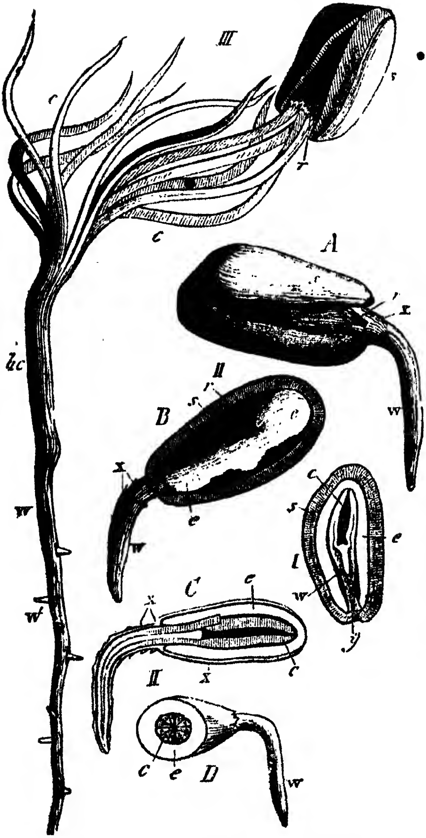
In the gymnosperms the pollen grains are applied directly to the naked nucleus of the ovule, while in the angiosperms the pollen is applied to the stigma, a special part of the carpid ; the pollen-tube penetrates through the tissue of the style, reaches the ovule, enters by the micropyle, and thus comes into contact with the nucleus of the ovule.

The embryo-sac contains, in many cases, a nutrient tissue, the endosperm formed by free-cell formation in the interior of the sac. Many separate cells are at first developed; these adhere and form a tissue, which subsequently grows by cell division. In the angiosperms it forms after fertilisation has taken place ; but in the gymnosperms it forms very early, before fertilisation, and in the latter case represents the prothallium or oophore of the Pteridophyta. In the angiosperms, in a few rare cases, a few cells, the antipodal vesicles, originate very early in the embryo-sac, opposite the germinal vesicles, and these are taken to be the representatives of the endosperm of the gymnosperms or prothallium of the pteridophytes, the embryo-sac representing the macrospore. The endosperm may be present in greater or less quantity. Sometimes it is only present in the early stages of development, and has entirely disappeared when the seed is ripe. In other cases, as in Alisma, no endosperm is formed at all. In a few plants the endosperm is replaced by perisperm, when the tissue of the nucleus of the ovule becomes filled with nutrient matter.

The embryo in the ripe seed is generally furnished with stem, leaves, and root (fig. 82). The root originates at the apex of the short stem or axis which bears the first leaves, the seed-leaves or cotyledons, at the opposite end. In many cases a little bud or plumule is visible between the cotyledons. The stem and root is generally called the radicle; but it is necessary to distinguish the very short primary root from the hypocotyledonary portion of the stem. The first internode above the cotyledons may be called the epicotyledonary portion of the axis.

The reproductive organs are the essential parts of the flower. The stamens and carpids are almost always modified leaves, rarely they are caulomes. The flower is therefore an axis bearing modified leaves, the modified leaves being the reproductive

Fig. 82.



I, ripe seed in longitudinal section; *s*, spermoderm; *e*, endosperm; *w*, radicle of embryo; *c*, the cotyledons; *y*, the micropyle end of seed, with the rootlet directed towards it. *II*, germination commencing, *A*; spermoderm, *s*, ruptured, and rootlet, *w*, protruding; *r* red membrane inside spermoderm; *x*, ruptured embryo-sac; *B*, portion of spermoderm removed; *e*, endosperm; *C*, longitudinal section; *c*, cotyledons; *D*, transverse section. *III*, germination complete, the cotyledons, *c*, unfolding, and the hypocotyledonary part of stem, *h c*, elongated, the main root, *w*, developing lateral rootlets, *w'*.
After Sachs.

Seeds of *Pinus Pinea*, in different stages of germination.

organs. A flower may contain one or many stamens, and the term andrœcium is applied to the male reproductive organs collectively, the stamen being one of the modified leaves forming the andrœcium. So with the female reproductive organs; the modified leaves, carpids before fertilisation, carpels after fertilisation, form the gynœcium. The gynœcium, after it has arrived at maturity after fertilisation, is the fruit. In addition to the reproductive organs certain envelopes or coverings are generally present, surrounding and protecting the essential reproductive organs. The whole covering is known as the perianth. Sometimes the covering is single, consisting only of one series of modified leaves, when it is known as the perigone; in other cases the perianth consists of a double series of parts, when the outer series is distinguished as the calyx, the individual leaves being sepals, the inner as the corolla, the single leaves being petals. Some flowers contain both stamens and carpids, and are known as hermaphrodite; others may be only male or female, and are then unisexual or diclinous. When the flowers are diclinous, the plants may be either monœcious or diœcious—monœcious if the male and female flowers are on different parts of the same plant, and diœcious if on different plants. Rarely the plant is polygamous, producing male, female, and hermaphrodite flowers on the same or on different plants.

Plants either produce seeds once or repeatedly. The former are monocarpic, the latter polycarpic. Plants lasting one or two years, annuals, biennials, are monocarpic, while perennials are rarely monocarpic, but generally polycarpic, and produce seed repeatedly.

The phanerogams can be divided into two groups, the archisperms or gymnosperms, and the metasperms or angiosperms.

A. *Archisperms* or *Gymnosperms.*

Seeds naked, not enclosed in an ovary, but placed on the surface of an open carpel or directly on the floral axis. The embryo sac contains the archegonia (corpuscula), and is filled with endosperm before fertilisation. The pollen-grains consist of two or more cells, from one of which the pollen-tube is developed. The pollen is applied to the naked nucleus of the ovule. Some observers consider the so-called ovular integument to consist of two carpids.

B. *Metasperms* or *Angiosperms.*

[redacted]—The ovules are enclosed in an ovary. The endosperm formed by free-cell formation after the fertilisation of the germinal vesicle. The pollen-grain is unicellular, and applied to the stigma of the carpid.

Class XI. *Monocotyledones.*—The embryo generally small, with one seed-leaf; the endosperm usually abundant, and occupying a large space in the ripe seed, rarely scanty or absent, or replaced by perisperm. Main root of embryo usually becoming abortive and replaced by lateral rootlets. Stem with closed fibro-vascular bundles scattered in the ground tissue. Leaves generally with parallel, rarely with reticulated, veins. Flowers mostly trimerous. Perianth usually with both whorls petaloid.

Class XII. *Dicotyledones.*—The embryo with two opposite cotyledons, very rarely with one or none. The endosperm very frequently wanting in the ripe seed. Main root of embryo usually well developed. Stem with open fibro-vascular bundles arranged in a ring. Leaves most branched, with reticulated veins. Flowers usually with calyx and corolla; the parts pentamerous or tetramerous.

CHAPTER V.

THE ARCHISPERMIA OR GYMNOSPERMIA.

A. *Archisperms* or *Gymnosperms.*

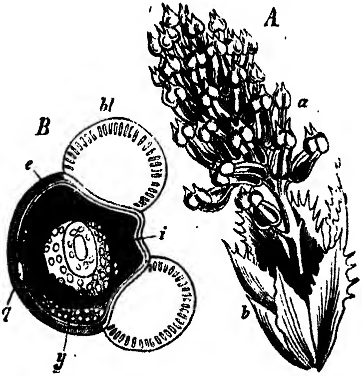
CLASS X.—ARCHISPERMIA.

Plants monœcious or diœcious; the flowers without a perianth, except in the Gnetaceæ. The male flowers (fig. 83) consist of an elongated axis, bearing numerous variously shaped stamens, sometimes shield-like or leaf-like, having on their undersides two or more separate pollen-sacs, which dehisce longitudinally. The pollen-grains consist of two or occasionally more cells, the larger forming the pollen tube. The extine often has peculiar appendages, and the form of the pollen-grain varies.

The female flowers generally have an elongated axis bearing the scales, regarded by some as the open carpels, by others as the placenta, with the ovules either above or between them; at other times the axis directly produces the ovules. The carpels often cover the seeds, without, however, forming a closed ovary. By some the so-called ovular integument is regarded as consisting of two united carpels.

The ovule is straight, rarely anatropous, with a very short funiculus, and possesses but one integu-

FIG. 83.



A, male flower of *Abies pectinata*; *b*, bracts; *a*, stamens. *B*, pollen-grain (magnified); *e*, extine, with the vesicular protrusions, *bl*; *i*, intine; *y*, cell in interior of pollen-grain developing the pollen-tube; *q*, basal cell attaching *y* to the wall of the grain. (After Sachs.)

ment,—the carpels of some authors. The nucleus is very large, and the embryo-sac is placed at some distance from the micropyle. The embryo-sac (fig. 84) is early filled with endosperm, and at the apex several corpuscula are developed. The endosperm or 'prothallium' contains the corpuscula or 'archegonia;' the corpuscule consisting of a central cell, and the rosette with central canal cell, representing the neck of the archegonium. The embryo-sac represents the 'macrospore;' and thus the close relationship between the higher pteridophyta and the flowering plants can be traced. The pollen-grains represent the 'microspores,' which, however, no longer develope spermatozoids.

FIG. 84

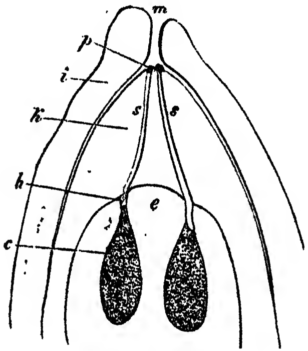
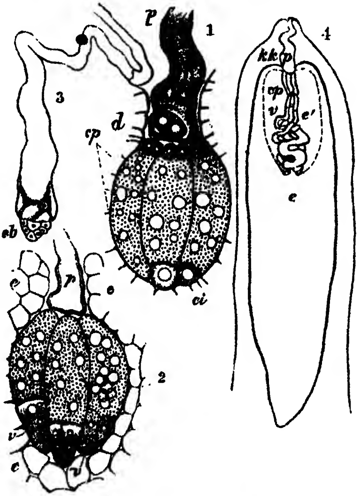


Diagram of ovule of *Pinus*, showing fertilisation.

k, nucleus; *i*, integument (or carpels of some authors); *m*, micropyle; *e*, endosperm, filling the embryo-sac; *c*, the central cell of the corpusculum; *h*, the neck-cell; *p*, pollen-grains applied to the apex of the naked nucleus; *s*, *s*, the pollen-tubes. (After Prantl.)

The pollen-cells are carried by the wind to the micropyle, the orifice of which is filled with a fluid secretion. The fluid dries, and carries the pollen-cells into contact with the end of the naked nucleus. The pollen-tubes are then protruded, and after a longer or shorter time the end of the pollen-tube reaches the rosette of the corpuscule (fig. 85), and fertilisation takes place by diffusion. The corpuscule now divides by a transverse wall to form the germinal vesicle, which subsequently divides by longitudinal walls; and the suspensors or proembryos are formed, at the end

FIG. 85.



Juniperus communis.

Longitudinal section of apex of nucleus. 1, three corpuscula or archegonia, *cp*, close together; *ei*, fertilised germinal vesicle; *d*, cells forming the rosette or neck of the archegonium; *p*, the end of the pollen-tube. 2, similar section; *v*, *v*, the suspensors or pro-embryos; *e*, the endosperm. 3, lower end of pro-embryo, with embryo, *eb*, beginning to develop. 4, longitudinal section of nucleus, *kk*; *e*, endosperm; *e'*, portion of endosperm broken up; *p*, pollen-tube; *cp*, archegonia; *v*, pro-embryos (After Hofmeister.)

of each of which an embryo is subsequently developed.

The ripe seed contains abundance of endosperm. The embryo is surrounded by endosperm, with its root-end directed towards the micropyle. The embryo-plant has two or more cotyledons in a whorl.

The class Archispermia includes three orders—*Cycadaceæ*, *Coniferæ*, and *Gnetaceæ*.

Order XXXVII. **Cycadaceæ.**—The cycads have a considerable superficial resemblance to the tree-ferns on the one hand, and to the palms on the other. The stem, which seldom branches, is short and thick, or tall and cylindrical, thickly covered with the remains of the leaves and has a crown of large branched leaves at the top. The leaves are of two kinds, dry brown scale-like leaves, and pinnate green leathery leaves, formed either annually or at intervals of several years, and forming a crown at the summit of the stem.

The male and female flowers are produced at the apex of the stem, on separate individuals. The male flowers consist of an elongated axis, bearing flat shield-like stamens, on the back of which numerous pollen-sacs are placed. The female flowers are generally cone-like, the axis bearing many carpels, with two straight ovules on the inner side. In the genus Cycas the female flower consists of a rosette of leaves, like the foliage leaves, but smaller, and bearing ovules instead of the lower pinnæ of the leaf (fig. 86). After the Cycas has flowered, the axis again elongates and produces new foliage leaves. The ovules have a single integument, with a thick and succulent outer layer, attaining considerable dimensions when ripe, those of Cycas being about the size of a plum, before

FIG. 86.

Pinnate, open carpellary leaf of *Cycas revoluta* (reduced ⅓). unaltered pinnæ; *sk*, ovules replacing the lower pinnæ; *sk'*, fully developed ovule. (After Sachs.)

fertilisation. The embryo has two cotyledons, which remain in the seed during germination.

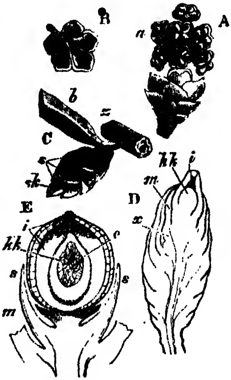
The Cycadaceæ are met with chiefly in the southern hemisphere, tropical and South America, South Africa, South Asia, Australia, and New Zealand.

Order XXXVIII. **Coniferæ**, or Pine-trees.—The stem is much branched, the branching being monopodial and axillary. The structure of the stem is like that of the Dicotyledons, the stem increasing in circumference by a cambium ring, but the wood part of the bundle is very different; no vessels are formed, the whole of the xylem generally consisting of vessel-like wood prosenchyma with bordered pits on the walls.

The male flower is an elongated axis, bearing shield-like leaves, and having two or more pollen-sacs on the under side (fig. 83). The structure of the female flower varies in the different families. The embryo has a well-developed main-root, and bears two or more cotyledons, which appear above ground free from the spermoderm after germination (fig. 82).

Fam. 1. *Taxineæ.*—Flowers always diclinous, the embryo with two cotyledons. In Taxus baccata (fig. 87), the common yew, the ovules are placed singly at the ends of very short side axes. No hard dry scales are developed. The fertilised seed when ripening becomes covered with a red fleshy aril. The leaves are placed spirally, but bent to form two rows. They are linear and of a bright green colour, but without any white lines of stomata. Salisburea adiantifolia (fig. 88), from Japan, has two, rarely three, ovules at the ends of peculiar leafless shoots. The outer layer of the wall of the seed is fleshy, and of a reddish orange colour when ripe. The leaves are flat, stalked, and very unlike those of other conifers. Phyllocladus has leaf-like shoots or cladodes.

FIG. 87.



Taxus baccata.

A, male flower (magnified); *a*, the pollen-sacs; B, stamen seen from below, the pollen-sacs open; C, stem *z*, with leaf *b*, having a shoot in its axil, bearing scale-leaves, *s*, and a single ovule, *sk*, at the end of a lateral branch; D, longitudinal section of C (magnified): *i*, integument; *kk*, nucleus; *m*, aril; *x*, apex of the shoot; E, longitudinal section of ovule further developed, but before fertilisation (magnified); *e*, endosperm; *s*, upper scale-leaves. (After Sachs.)

Fam. 2. *Abietineæ.*—The flowers are monœcious or diœcious. The female flower is the cone, and consists of an elongated axis bearing hard scales, on the upper surface of each of which the seeds are placed in pairs, the micropyle pointing inwards and downwards. The scales are placed, in the true Abietineæ (fig. 89), in the axils of small bracts, which are by some considered as the true carpels, the scale being the placenta. The seed-bearing scales are at first separate, to permit the entrance of the pollen; then they close, and do not open till the seeds are ripe. In the silver-firs (Abies) the whole of the scales and bracts separate from the axis when ripe. The seeds have a hard wall, and are provided with a wing-like appendage which separates from the scale. In Araucaria the bracts are soldered to the scale, and the ovule is enclosed in the scale. In the genus Pinus the seed requires two years to come to maturity. When the cones are very small and purplish-brown in colour, the pollen-tube only grows a minute length into the tissue of the nucleus. In June of the next year the pollen-tube grows and reaches the embryo-sac, and fertilises the corpuscula. In Picea, the leaves are

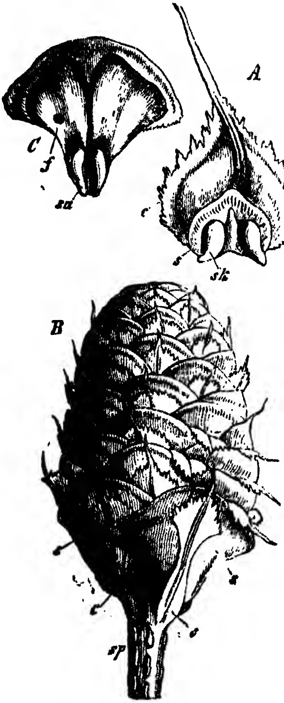
Fig. 88.

Shoot of *Salisburya adiantifolia* (nat. size).

sk, ovules in pairs at the end of naked axes. (After Sachs.)

spirally arranged, and project on all sides of the shoot. They are generally rather tetragonal, and supported on small cushions. In Abies the leaves are inserted singly in a spiral manner, but bent to form two lateral rows. The leaves are rarely pointed, generally blunt and emarginate, and have two white bands of stomata on the under side. They are inserted directly into the stem, and are not placed on cushions. In Pinus the needle-like leaves are in bundles on a very short lateral axis which first forms scale leaves, and then the long needle-like green leaves. The short lateral

FIG. 89.



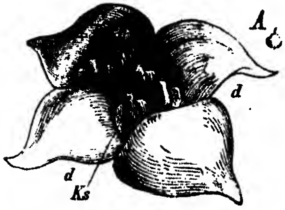
Abies pectinata.

A, bract, *c*, detached from the axis of a young cone, with the scale, *s*, bearing the ovules, *sk* (magnified). *B*, upper part of mature cone; *sp*, axis; *c*, bracts; *s*, largely-developed scales, bearing the seeds on the upper surface (reduced). *C*, ripe scale, with two winged seeds; *sa*, seed; *f*, wing (reduced). (After Schacht.)

axes are placed in the axils of small scale leaves on shoots which have no green leaves. Pinus sylvestris has the needles in pairs, P. Cembra from three to five needles in a bundle, and P. Strobus five. Larix europæa, the larch, has clusters of deciduous green leaves developed in the axils of imperfect soft needle-like leaves. Araucaria imbricata has numerous persistent leaves closely covering the whole stem.

Fam. 3. *Cupressineæ.* The female flowers are formed at the ends of short lateral axes, and consist of several alternating whorls of two or three scales or carpels (Fig. 90), which bear several erect ovules at the base on the inner side. The bracts and scales are entirely soldered together. The carpels become hard and woody, and completely closed, but open when the seeds are ripe like the valves of a capsule. In Juniperus the carpels are fleshy and form a fruit like a berry, which does not open to let the seeds escape. Some species require two years to ripen their seeds. The flowers are monœcious or diœcious, and the embryo has usually two cotyledons. In Juniperus the leaves are needle-like and free, but in other Cupressineæ the leaves are scale-like elevations of the cortical

Fig. 90.



Callitris quadrivalvis, female flower (magnified).

d, d, decussating carpellary leaves, with six ovules, *Ks*. (After Sachs.)

layer of the shoot, the formation of the lamina being suppressed. These leaves are generally decussating, or in whorls of three or more.

Order XXXIX. **Gnetaceæ.**—The Gnetaceæ differ from the Conifers in having the andrœcium and gynœcium surrounded by a perianth resembling that of the angiosperms, the flowers being in monœcious or diœcious inflorescences. Ephedra distachya of Southern Europe is a low shrub with long upright branches and small whorls of sheath-like leaves like an Equisetum, and with diœcious flowers. Welwitschia, a remarkable plant from West Africa, is distinguished by its peculiar stem, two persistent cotyledons, and dichotomously branched inflorescences. The male flowers consist of two outer parts of the perianth, two inner parts, six stamens, formed by branching from two primordial ones, and two carpels, prolonged above into a functionless style and stigma, surrounding the abortive terminal ovule. The female flower has no perianth or stamens, but has two carpels. The terminal ovule has one integument.

The Archispermæ are largely represented in a fossil state. The Cycadaceæ appear in the Carboniferous, and attain their maximum development in the Mesozoic rocks, most of the thirty-seven genera and 300 species enumerated by Schimper occurring in the Triassic, Oolitic, and Cretaceous. The Coniferæ are represented by fifty-three genera and 440 species, chiefly from the Mesozoic. Pinus has 113 species in the Tertiary and recent strata. Pinites extends from the Carboniferous to the Tertiary. Of the

Gnetaceæ only two species of Ephedra occur in the Tertiary.

The true relations of many of the known fossil remains of Archisperms are as yet problematic.

CHAPTER VI.

THE METASPERMIA OR ANGIOSPERMIA.

B. *Metasperms or Angiosperms.*

THE flowers are rarely monœcious or diœcious, usually hermaphrodite. The axis forms a thalamus, torus, or receptacle on which the floral leaves are arranged in whorls; rarely the parts are in spirals. The completion of the spiral, when it corresponds to a change in the value of the parts, and the whorls are to be distinguished as cycles. The axis generally ceases to grow in length after the formation of the floral leaves. The elongated portion below the flower is the peduncle, the smaller branches of the peduncle are the pedicels. If the peduncle be wanting the flower is sessile. Frequently the peduncle bears small leaves, the bracts or prophylla. The floral leaves are generally separable into three series, called the perianth, andrœcium, and gynœcium.

The outer series of floral leaves forming the covering to the reproductive organs is the perianth. The perianth may be wanting, as in the Piperaceæ, but commonly it consists of two cycles, the outer the calyx, the inner the corolla. The individual calyx leaves are called sepals, the corolla leaves petals. Commonly the sepals are green, have a coarser texture, and are smaller than the delicate, generally brightly-coloured petals. Both cycles may, however, have the same texture and appearance, being either both sepaloid or petaloid. Many plants possess only one cycle of perianth leaves. It may then be distinguished as the perigone, the single covering being either sepaloid or petaloid. In other cases one of the coverings may be entirely suppressed, as the corolla of many Caryophyllaceæ, and the calyx of Compositæ (Fig 91). Sometimes the number of parts or number of cycles becomes increased. Two or more cycles of calyx and corolla may be present, and in spiral flowers the parts sometimes become very numerous, and the cycles run into each other. In Nymphæa this is well seen, there being every transition from green calyx leaves to perfect petals and then to perfect stamens.

Fig. 91.

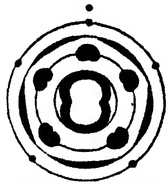


Diagram of the flower of *Compositæ*. (After Sachs.)

The floral leaves forming each cycle are either completely separate from each other or united into a long or short tube, having as many lobes or teeth above as theoretically there are united leaves. When the calyx or corolla consists of separate sepals and petals, then the terms eleutherosepalous or polysepalous, and eleutheropetalous or polypetalous are employed. If by the united growth of a common ring-like structure from the receptacle (sometimes distinguished from ordinary phyllomes as a cyclome), the parts are apparently united, then the calyx or corolla is called gamosepalous and gamopetalous. The perigone may similarly consist of separate or apparently united or coherent parts, and be thus eleutherophyllous or gamophyllous. Rarely the parts of two cycles unite into a common tube, as in Hyacinthus, the six-lobes representing three calyx and three corolla leaves.

The outline of the sepal is generally simple, with a broad base of insertion, while the petal can be separated into two parts, the limb, broad and often with an irregular outline, and the narrow basal portion, the claw. Ligules of the petal leaves exist, as in Lychnis, and form the corona, which appears in its most highly developed state in the united ligules of the corona of Narcissus. Extra coverings are sometimes met with outside the perianth. The extra covering or calyculus may consist of the stipules of the calyx leaves, or of one or two leaves with stipules. The green bracts of Anemone hepatica might readily be mistaken for a calyx, and the petaloid calyx for a corolla. Bracts sometimes occur singly or in verticils, and may be mistaken for parts of the flower. In Aroids the large sheathing leaf surrounding the axis of inflorescence is distinguished as the spathe, while the leaves around the inflorescence in Compositæ and Umbelliferæ form the involucre.

The andrœcium is the collective male reproductive organs of the flower, the individual parts being stamens. The stamen consists of an anther, in which the pollen grains are developed, and a longer or shorter stalk, the filament. The anther is a double structure with two lobes, each lobe or half-anther containing pollen sacs. The two lobes are separated by the upper part of the filament, called the connective. Occasionally the connective is so narrow that the two lobes are in contact. Sometimes the filament and connective are continuous, in other cases, as in versatile anthers, the filament is only slightly attached. The connective may be very broad, and thus separate the lobes more or less widely. The separation is carried to an extreme in the distractile connective of Salvia, where one of the halves of the anther becomes abortive. When the connective is continued above the anther, appendages are formed which vary in length from a mere point to a long prolongation. The filament is generally rounded or cylindrical, but it may be broad and flat, or wanting altogether, as in sessile anthers. The filaments occasionally have appendages of different kinds, or the anthers may be provided with spur-like developments.

FIG. 92.

Longitudinal section of flower of *Calothamnus*, the stamens, *st*, branched like a pinnate leaf. *f*, ovary; *g*, style; *p*, petals; *s*, calyx. (After Sachs.)

The filament of the stamen may branch. The branching may be like that of an ordinary leaf, either in one plane like a pinnate leaf (fig. 92), or in different planes as in Ricinus (fig. 93), the ultimate branches bearing the anthers. Sometimes the stamens are apparently coherent, developing as a ring-like cushion or cyclome. The monadelphous and diadelphous stamens of Papilionaceæ are thus produced, while the polyadelphous stamens of Hypericum are produced by branching of three or more primordial stamens. The anthers and generally the upper ends of the filaments are free. More complicated is the case of the Malvaceæ (fig. 94), with cohesion and branching. In the Compositæ the filaments are free, and the an-

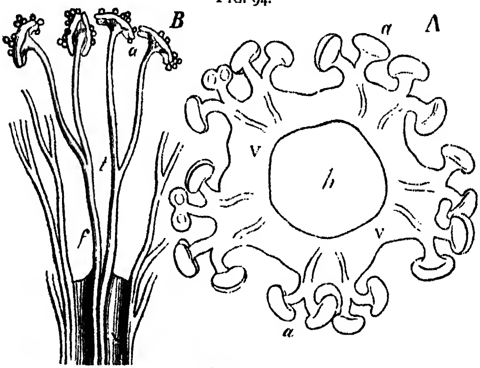
FIG. 93.

Part of male flower of *Ricinus communis*.
f, f, basal portion of the branched stamens ; *a*, the anthers. (After Sachs.)

thers slightly connected together laterally, but not originally coherent—the syngenesious condition. Sometimes the stamens are united to other parts of the flower. The filaments or anthers appear to be inserted not on the axis but on the perianth—epipetalous stamens. This condition is most frequent when the perianth leaves are themselves united into a tube, and by growth at the base, the perianth and stamens rise on a common ring-like structure. A less common condition is the union of the staminal leaves with the carpels, and the formation of the Gynostemium as in Orchids (fig. 95), and Aristolochia.

In some flowers the filaments are of different lengths. Thus in Cruciferæ there are six stamens, four

FIG. 94.



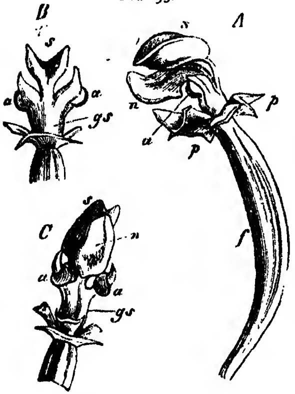
Althæa rosea.

A, horizontal section through young andrœcium, showing the union of five stamens into a tube, *v*, *v*, the stamens subsequently branching ; *h*, cavity of the tube. *B*, portion of mature andrœcium ; *v*, tube ; *f*, *t*, branches of filament ; *a*, anthers (both magnified). (After Sachs.)

long and two short, tetradynamous ; and in the Labiatæ four stamens, two long and two short, didynamous.

Staminodes are stamens without anthers, generally leaf-like in form. They occur in the flowers of Canna. Double flowers are generally formed by the staminal leaves assuming the form of the corolla-leaves, while ordinary green leaves are produced instead of the carpels, as in the double flowering cherry.

Fig. 95.



Cypripedium Calceolus.

Flower with the perianth removed. *A*, side view; *B*, back view; *C*, front view; *p*, *p*, remains of perianth; *f*, inferior ovary; *gs*, gynostemium formed by union of the stamens with the carpels; *a*, *a*, two fertile stamens; *s*, staminode; *n*, stigma. (After Sachs.)

Two pollen sacs are usually developed in each anther lobe, sometimes only one, very rarely four. By the opening of the anther-lobes the pollen is scattered. The dehiscence occurs in different ways, as by longitudinal openings in the inner or outer side, or by pores, or transversely. The wall of the anther consists of two coats, the endothecium and exothecium.

When the pollen grain comes into contact with the stigma (pollination), or is placed in a solution of sugar, the intine forms one or more pollen tubes. The places at which the intine will protrude are frequently indicated by markings or cap-like coverings of the extine. The pollen grains of Asclepiadaceæ and of most orchids do not separate from each other in the pollen sacs, but form the pollen masses.

The gynœcium is always developed at the end of the floral axis. The individual leaves, carpels, carpids, form the completely closed ovary containing the seeds. If all the carpels of a flower take part in the formation of a single ovary, with one or more cavities containing the seeds, the gynœcium is syncarpous; if each individual carpel forms an enclosed ovary so that the flower may have as many ovaries as carpels, the gynœcium is apocarpous. The upper part of the carpel is narrowed to form the style which has at its apex a special structure for receiving the pollen—the stigma (fig. 96).

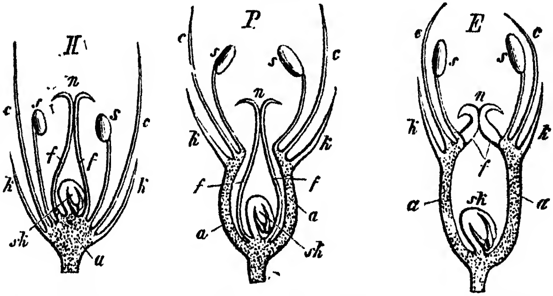
FIG. 96.

Gynœcium of *Lilium*. *f*, ovary; *g*, style; *n*, stigma (nat. size). (After Prantl.)

If the axis be greatly elongated, with the gynœcium at its apex, and thus placed above the free and separate insertions of the andrœcium and perianth, the ovary is then superior, and the other parts of the flower hypogynous (fig. 97, *H*). In other flowers the perianth and andrœcium are carried up by the axis, which forms a ring-like wall around the deeply-seated gynœcium at the apex of the axis. If the carpels remain at the base of the cavity, and are surrounded by the ring-like axis or calyx-tube as it is often improperly called, then the flower is perigynous, and the ovary superior (fig. 97, *P*). Lastly, the carpels may spring from the upper part of the cavity, and merely close it in. The ovary is then inferior, the flower epigynous (fig. 97, *E*). Between these different forms there are many intermediates, as in Rosaceæ and Saxifragaceæ.

The ovary is monocarpellary when it is formed by a single carpel, with its margins united (fig. 98, *A*). The position of the midrib marks the dorsal suture of the

Fig. 97.

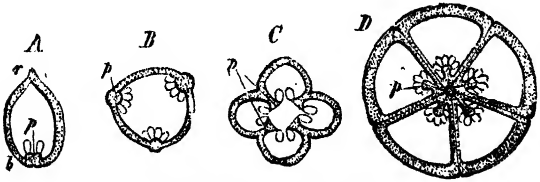


Diagrammatic sections of hypogynous (*H*), perigynous (*P*), and epigynous (*E*), flowers.

a, axis, forming convex or concave receptacle, or wall of ovary; *k*, calyx; *c*, corolla; *s*, stamens; *f*, carpels: *n*, stigma; *sk*, ovules. (After Prantl.)

carpel; the other, formed by the united margins of the folded leaf, is the ventral suture. The cavity of one

Fig. 98.



Diagrammatic sections of ovaries.

p, the placenta, to which the seeds are attached; *A*, monocarpellary unilocular; *B*, polycarpellary unilocular; *C*, polycarpellary falsely multilocular; *D*, polycarpellary multilocular; *r*, dorsal suture, or midrib; *b*, ventral suture, or margins of carpel. (After Prantl.)

carpel is not divided by a true septum, but is unilocular. Only very rarely, spurious partitions are found in the interior. These are transverse in Cassia fistula and longitudinal in Astragalus. If several carpels take part in the formation of the ovary, the ovary is polycarpellary, or bi- or tri- carpellary, according as there are two three or more carpels united. It may be unilocular (fig. 98, *D*) when the individual carpels are united by their margins so that they enclose a single cavity. If the margins of the carpels project inwards, the ovary may become falsely multilocular (fig. 98, *C*), as in the poppy ; or multilocular when the projecting margins unite in the middle, and the cavities of the individual carpels are completely separated by the true septa formed by the united walls of the contiguous carpels. In some cases the margins of the carpels do not grow completely in at the upper part of the ovary, as in Saxifraga, where the lower part is two-celled or bilocular, the upper part only one-celled. In all these cases the floral axis may rise up in the centre of the ovary, and if the ovary is multilocular, may unite with the septa. In multilocular ovaries spurious partitions may be formed by growth of the inner surface of the carpel, a spurious partition being any partition not formed by the margins of united carpels. The ovary of the Boragineæ and Labiatæ is thus originally two-celled ; each is, however, divided into two parts by a false partition, and when ripe the fruit breaks into four parts.

The inferior ovary of epigynous flowers is usually polycarpellary, and may be either unilocular or multilocular, the margins of the carpels apparently running down the inner wall of the cavity formed by the hollow axis.

The style is developed between the ovary and the stigma. Monocarpellary ovaries have only one style; polycarpellary, as many styles as there are carpels. These may be wholly united, free above, or entirely free. Rarely the style is branched. The style is always placed at the apex of the carpel; but occasionally by excessive growth of the dorsal side of the carpel, it becomes apparently lateral and sunk in the ovary, as in the gynobasic style of Boragineæ, Labiatæ, and Alchemilla. Sometimes the style is exceedingly short or wanting, as in the poppy. The tissue of the style is soft and parenchymatous, known as the conducting tissue through which the pollen-tubes can easily pass. In a few cases, as in Viola, the style is tubular, and the conducting tissue absent.

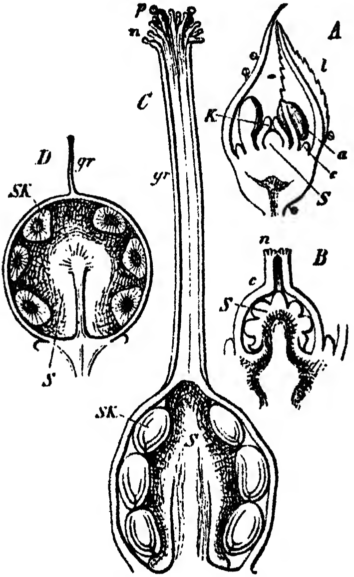
The stigma is the modified apex of the carpel, covered with papillæ or collecting hairs, or secreting a sticky fluid. The stigma is variously constructed to retain the pollen-grains and facilitate the production of the pollen-tubes. Frequently the stigma is a lobed expansion slightly separated from the style; at other times it forms a special surface either at the apex or at the side of the ovary (Pleurogyne).

The ovules are contained singly or in numbers in the cavity of the ovary. They are generally appendages of the carpels; in many cases, however, they are special structures springing from the floral axis (Piperaceæ, Rheum, Primula). The part from which the ovule springs is called the placenta. The ovules formed on the carpels are generally marginal; the placenta occupies the longitudinal margins or ventral suture of the individual carpel. When the ovules are at the margin of united carpels and the ovary unilocular, the placentas are said to be parietal. If the margins are united as in a multilocular ovary, the ovules, although still marginal, are said to be on an axile placenta. Rarely, the ovules spring from the whole inner surface of the carpel, the midrib or dorsal suture alone remaining free (Butomus). When the ovules are developed directly from the axis, they sometimes arise singly from the base of the cavity of the ovary, sometimes from near the apex of the axis, or on a special bearer, the free-central placenta rising up in the centre of the ovary as in Primulaceæ (fig. 99).

Nectaries are glandular organs secreting an odorous or sweet fluid which attracts insects, and thus contributes to the fertilisation of hermaphrodite flowers, as such flowers are not usually self-fertilising. Almost any part of the flower may be changed wholly or partially into a nectary, the modifications being exceedingly numerous. The spurred sepals of Tropæolum, the modified petals in Aquilegia and Helleborus, or the spurred petal in Viola containing the prolongation of the stamen, are all connected with the secretion of nectar. In Gesneraceæ one stamen becomes a nectary, while in Rheum the nectary is developed at the base of the stamens. A disc is a ring-like cushion secreting nectar. It is found on the upper part of the carpels in Umbelliferæ, or on the floral axis under the gynœcium in Citrus.

Fertilisation.—When the pollen is applied (Pollination) to the stigma, it sends out a pollen-tube, which penetrates down through the conducting tissue of the stigma into the ovary, and enters the micropyle of the ovule to reach the nucleus. The time the pollen-tube takes to penetrate the style depends on the length of that structure, and also on some peculiarity in the plant itself, because in different plants the time required varies with the same length of style.

FIG. 99.

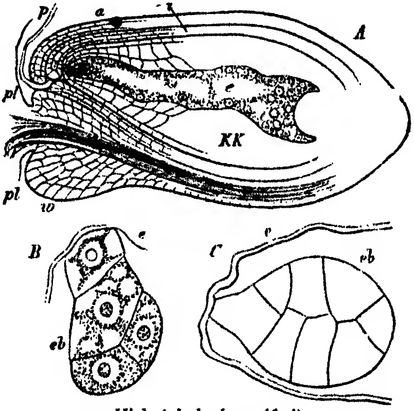


Anagallis arvensis.

A, longitudinal section of young flower bud; *l*, sepals; *c*, petals; *a*, stamens; *K*, carpels; *S*, apex of floral axis. *B*, gynœcium further advanced; *c*, carpel; *n*, stigma; *S*, ovules, on end of floral axis. *C*, gynœcium ready for fertilisation; *p*, pollen-grains on the stigma, *n*; *gr*, style; *S*, free-central placenta; *SK*, ovules. *D*, unripe fruit, the placenta, *S*, has swollen, and fills up the spaces between the seeds, *SK*. (After Sachs.)

Thus in the Crocus the development of the tube is rapid, from one to three days only being required with a style of from five to ten centimeters. In the Orchids the growth is exceedingly slow; weeks or months being required for the tube to grow only a few millimeters, the growth of the ovules themselves in the ovary taking place between pollination and fertilisation.

FIG. 100.

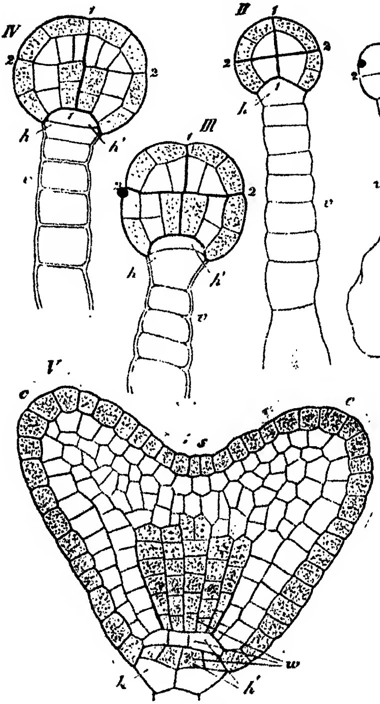


Viola tricolor (magnified).

A, longitudinal section of anatropous ovule after fertilisation; *pl*, placenta; *w*, swelling on the raphe; *a*, outer; *i*, inner integument; *p*, pollen-tube entering micropyle; *e*, embryo-sac, with the fertilised germinal vesicle at the micropyle end, and numerous endosperm-cells at the other. *B*, apex of embryo-sac *e*, with young embryo, *eb*, of three cells, and one cell forming the suspensor or pro-embryo. *C*, same, further advanced. (After Sachs.)

The embryo-sac is placed with its apex close to the apex of the nucleus (fig. 100). Certain cells form by free-cell formation in the sac of the embryo. Those near the apex are the germinal vesicles, of which two or more are generally developed, and one of these is fertilised when the pollen-tube comes into contact with the nucleus, through the micropyle. Sometimes the apex of the germinal vesicle elongates to form the filiform apparatus of Schacht. After the contact, and as a result of the process, a wall forms round the naked mass of protoplasm forming the germinal vesicle. The cell now grows and divides, forming a cellular filament, generally short, called the suspensor or pro-embryo, and the embryo. The embryo is at first rounded, but soon becomes elongated, and developes one or two cotyledons. The rootlet is also marked, the root-cap being in contact with the suspensor. In the young embryo three sets of tissues can be distinguished, called by Hanstein the dermatogen or primary epidermis, the periblem, and the plerome or central zone (fig. 101). After fertilisation has taken place, other cells arise at the base of the embryo-sac—these are the endosperm cells. Generally the endosperm cells arise by free-cell formation (fig. 102), the cells coalescing to form a tissue; but occasionally the endosperm arises by division of the embryo-sac itself. Rarely a few cells form before fertilisation at the base of the embryo-sac. These are known as the antipodal vesicles, and represent the endosperm in the pine, forming before fertilisation, and therefore equivalent to the prothallium of the higher Pteridophyta. When the endosperm cells have united and formed a false tissue, nutrient matter is stored up in these cells for the nourishment of the young embryo-plant during germination. Endosperm cells are formed in nearly all plants, but partial or complete absorption may take place during the growth of the embryo, the seed becoming exalbuminous. When the nutrient material is

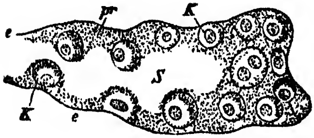
FIG. 101.



Development of the embryo of *Capsella Bursa-pastoris* (highly magnified). *I*, *v*, pro-embryo or suspensor of five cells, the end cell, forming the chief part of the embryo, divided into two by the longitudinal wall, 1, 1, then into four by the transverse wall, 2, 2. *II*, *v*, suspensor; *h*, the hypophysis, the basal part of the embryo formed by the division of the end-cell of the suspensor. The dermatogen shown by the shaded peripheral cells. *III*, embryo further advanced, the two inner shaded cells, the plerome, separated from the unshaded cells, the periblem. The hypophysis divided into two cells, *h*, *h*. *IV*, still older condition. *V*, older embryo; *c*, *c*, cotyledons; *s*, apex of stem, dermatogen, periblem, and plerome distinctly shown; *w*, root, the root-cap and base of periblem formed from the cell *h'* of the hypophysis. (After Hanstein.)

stored up in the enlarged tissue of the nucleus itself, instead of in the embryo-sac, then the nutrient mass is called perisperm, as in Piper and Canna. In some seeds both endosperm and perisperm occur. Lastly, in ex-albuminous seeds, those without either endosperm or perisperm, the nutrient matter is all stored up in the tissues of the embryo, as in the large cotyledons of the bean or horse-chestnut.

Fig. 102.



i tricolor (magnified).

Posterior part of embryo-sac. *e*, wall; *S*, cavity of the cell; *K*, *K*, young endosperm cells formed by free-cell formation in the protoplasm, *pr*. (After Sachs.)

After fertilisation the germinal vesicle developes into the suspensor and embryo, the endosperm forms, the ovule is changed into the seed, the fruit is formed, and changes take place in all the parts of the flower, the perianth and stamens generally withering and disappearing. The fruit contains the seed, and is the entire gynœcium arrived at maturity after fertilisation. When other parts than that containing the seed undergo changes after fertilisation, a false fruit is often formed, as in the apple, strawberry, mulberry, and fig. In the apple, the ring-like development of the axis of the perigynous flower enlarges and becomes succulent, and adheres to the gynœcium. Above, it bears the remains of the calyx, and in the interior are the seeds, each surrounded by its thin indehiscent pericarp. In the strawberry numerous dry single-seeded fruits, each developed from a single carpel, are seen scattered over the surface of the enlarged succulent receptacle. In the mulberry, the dry single-seeded fruits are surrounded by the succulent perianth. In the fig the hollow inflorescence is succulent, and encloses the minute dry single-seeded fruits, popularly known as the seeds of the fig. Fruits are either dry or succulent, according to the condition of the wall of the fruit or pericarp. In general the pericarp can be separated into three layers—the outer or epicarp, the middle or mesocarp, and the inner or endocarp. When all these are thin and dry up, then a dry fruit is produced. In others the mesocarp becomes thick and fleshy, or the mesocarp and endocarp both become pulpy. The pericarp either opens to allow the seeds to escape (dehiscent fruits), or it does not (indehiscent fruits). In some cases the carpels split into one-seeded indehiscent portions, or the polycarpellary ovary breaks up into indehiscent pieces, the splitting fruits or schizocarps; the portions in the latter case being described as mericarps. In some cases, in polycarpellary ovaries, one cavity with even a single seed may develope in excess so that all the others become abortive, as in the Valerian, Oak, and Coco-nut.

Inflorescence.—A flower is an axis bearing reproductive organs. The flowers are generally arranged at the ends of special branches, parts of a system of branches to which the name of inflorescence is given. The flowers are rarely developed at the end of the primary axis of the embryo-plant; generally many lateral branches are produced bearing the flowers. As the branching of Metasperms is monopodial and axillary, the inflorescences are thus formed, the branches being usually different from the ordinary vegetative shoots, and bearing bracts instead of foliage leaves. Sometimes, however, the bracts are wanting, or by adhesions and displacements the branches are apparently extra-axillary, as in the Solanaceæ. Some authors think that the inflorescences of Boragineæ and Solanaceæ are sympodial arrangements of dichotomies. If this view be correct they are the only examples of dichotomous branching in Metasperms.

There are two chief types of inflorescence—the botryoid and the cymose. In the botryoid there is a main axis, generally indefinite in its growth, but sometimes with a terminal flower, the main axis developing an indefinite number of side axes in acropetal order. In the cymose type the main axis produces a terminal flower, and gives rise to one or two, rarely more, side axes of the same value; these terminate in flowers, and grow more rapidly than the main axis producing them.

A. BOTRYOID INFLORESCENCES.

1. *Raceme.*—Stalked flowers on an elongated main axis, sometimes with a terminal flower; Hyacinth, Berberis.

2. *Umbel.*—Stalked flowers on a contracted main axis; Primula veris, Allium ursinum.

3. *Spike.*—Sessile flowers on an elongated main axis. Plantago. When the axis is fleshy, the inflorescence is called a spadix; if the spike is deciduous, a catkin.

4. *Capitulum.*—Sessile flowers on a contracted main axis. Heads of flowers of Compositæ.

B. CYMOSE INFLORESCENCES.

1. *Dichasium.*—Two lateral axes from the main axis. This is the biparous cyme of Bravais; the dichotomous cyme of English authors; Cerastium. Contracted form, verticillaster, Lamium.

2. *Monochasium.*—One lateral axis from the main axis. There are two varieties:—*a.* Bostryx; lateral axis always from the same side, either right or left of the main axis; the helicoid uniparous cyme of Bravais, Hemerocallis.—*b.* Cicinnus; lateral axes developed alternately right and left from the main axis—the scorpioid uniparous cyme of Bravais; Helianthemum, Drosera.

C. MIXED OR COMPOUND INFLORESCENCES.

1. *Dibotryoid.*—Branches of first and succeeding orders botryoid. The chief forms are the compound umbel, or umbel of umbels, in the Umbelliferæ; the compound raceme or panicle in the vine; the compound spike, as in the rye; the raceme of capitula in Petasites.

2. *Cymo-botryoid.*—Branches of the first order botryoid, the succeeding ones cymose; thyrsus of De Candolle. The raceme of cicinnal monochasia in the horse-chestnut, and the capitulum of monochasia in Armeria.

3. *Botryo-cymose.*—Branches of the first order cymose, the succeeding ones botryoid, as the bostryx of capitula in Cichorium.

4. *Dicymose.*—Branches of first and succeeding orders cymose, as in Geranium, where the bostryx and cicinnus occur together.

Symmetry of Flowers.—Some flowers are asymmetrical—that is, they cannot be divided by any vertical plane into symmetrical or equal portions—one the exact repetition of the other. Many flowers are monosymmetrical or zygomorphic ↑—that is, they can be divided by one vertical plane into two symmetrical halves. The plane may be either median or lateral. If the plane cuts the axis and the bract, and thus runs antero-posteriorly, the plane is median, and the flower is cut into two halves right and left. In other cases the plane is lateral, running from right to left, and cutting the flower into two halves—the anterior next the bract, the posterior next the axis. Such zygomorphic flowers are often called irregular (fig. 103). When the flower can be divided symmetrically by several planes, then the flower is polysymmetrical or actinomorphic ⚹. Occasionally polysymmetrical flowers become zygomorphic; and it frequently happens during growth, or in closely crowded inflorescences, as in Umbelliferæ and Cruciferæ, that some of the flowers are polysymmetrical, others zygomorphic. Normally zygomorphic flowers may become polysymmetrical, as in the formation of the peloria in Linaria, or the peculiar monstrous

FIG. 103.

Heracleum pubescens.

Zygomorphic flower, monosymmetrical, divisible by a median plane into two lateral symmetrical halves. (After Sachs.)

flowers occasionally terminating the raceme of Digitalis.

Relative Positions and Numbers of the Parts of the Flower.—Flowers may have the parts arranged in spirals, more or less complete, or in whorls. If the parts are in whorls, the flowers are called cyclic. When the parts are more less spirally arranged, the cycles of the spiral corresponding to change, in the nature of the part, or the formation of a new spiral, then the flower is hemicyclic, all the cycles being as sharply defined as in a cyclic flower, although the parts are spirally arranged. Lastly, such flowers as Nymphæa and Cactus are acyclic, being wholly spiral without any marked boundary, showing where one cycle ends and another begins; in fact, these flowers have usually very numerous parts, and show every transition from one to another, from sepal to petal, or sepal to carpel. In acyclic and hemicyclic flowers the parts are generally numerous and variable, a condition well seen in the Ranunculaceæ.

In cyclic flowers the parts are arranged in whorls, each cycle sharply separated from the others. The number of cycles varies; generally there are four or five; such flowers are called tetra- and pentacyclic. The cycles may be denoted by symbols, thus: Ca=Calyx, Co=Corolla, An=Andrœcium, Gn=Gynœcium. The chief modifications might be thus expressed:—

$$\text{Tetracyclic—}Ca_n,\ Co_n,\ An_n,\ Gn_n;$$
$$\text{Pentacyclic—}Ca_n,\ Co_n,\ An_{n+n},\ Gn_n.$$

The number of parts in each cycle is indicated by using the terms di-, tri-, tetra-, penta- merous, when there are two, three, four, five, parts in each cycle. Thus n may stand for any of these numbers, and a tetracyclic pentamerous flower would be thus expressed: Ca_5, Co_5, An_5, Gn_5.

The cycles are generally alternating; but sometimes there is a break in the arrangement, and the parts become superposed.

When the number of parts in each cycle is the same, and the parts regularly alternating, the flowers are said to be eucyclic. Thus in the monocotyledons the flowers are typically eucyclic and pentacyclic tetramerous; the formula for the flowers, say of the tulip, being—

$$Ca_3, Co_3, An_{3+3}, Gn_3.$$

The number of parts in each whorl is liable to much variation, and also the number of whorls. Heteromery may depend on various causes, such as abortion, cohesion, or deduplication. In heteromerous flowers the parts are either more numerous (pleiomery) or less numerous (oligomery) than normal. Oligomery of carpels is common in tetra- and pentacyclic flowers, the number being usually less than four or five. Oligomery may also depend on the parts being abortive, ablastic, or coherent. Pleiomery may be occasioned by deduplication or collateral chorisis; two stamens, formed by splitting or bifurcation of a single stamen, standing in place of one. Two sets of stamens may also arise by having a series of stamens interposed.

As examples of the more important variations, we may take the following. Taking Liliaceæ (fig. 104) as a normal type, the formula may be thus expressed—

$$Ca_3, Co_3, An_{3+3}\ Gn(\underline{3}).$$

•The flower is pentacyclic trimerous. The brackets signify that the carpels are united, and the stroke

FIG. 104.

Diagram of the flower of *Liliaceæ*. (After Sachs.)

below indicates that the ovary is superior. This formula can be expressed more fully thus—

Gn	—		—		—
An		—		—	
An	—		—		—
Co		—		—	
Ca	—		—		—
		- -	B	- -	

The alternating whorls are shown, and B indicates the position of the bract. The calyx consists of a median anterior sepal and two lateral posterior.

FIG. 105.

Diagram of flower of *Iridaceæ*. (After Sachs.)

In Iris (fig. 105), one of the whorls of stamens is wanting, represented by o; the carpels are united, the ovary inferior. Formula. Ca_3, Co_3, An_{3+0}, $Gn(\bar{3})$, or

Gn	—		—		—	
An		o		o		o
An	—		—		—	
Co		—		—		—
Ca	—		—		—	
		—	B	—		

Triglochin (fig. 106) is hexacyclic trimerous. The

FIG. 106.

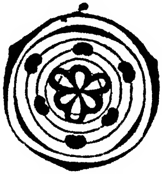


Diagram of flower of *Triglochin*. (After Sachs.)

carpels separate; ovary superior. Formula. Ca_3, Co_3, An_{3+3}, Gn_{3+3}, or

Gn		—		—		—
Gn	—		—		—	
An		—		—		—
An	—		—		—	
Co		—		—		—
Ca	—		—		—	
		—	B	—		

Butomus (fig. 107) is hexacyclic trimerous, but with deduplication of the outer series of stamens, indicated by An $_{3}^{2}+_{3}$. The carpels separate; ovary superior. Formula. Ca_3, Co_3, $An_{3}^{2}+_{3}$, $Gn_{\underline{3+3}}$, or,

Gn		—		—		—
Gn	—		—		—	
An		—		—		—
An	2		2		2	
Co		—		—		—
Ca	—		—		—	
		—	B	—		

Dictamnus (fig. 108) is tetracyclic pentamerous,

FIG. 107.

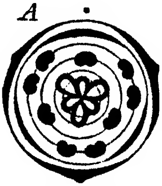


Diagram of flower of *Butomus*. (After Sachs.)

FIG. 108.

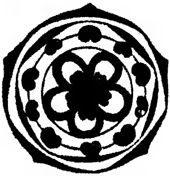


Diagram of the flower of *Dictamnus Fraxinella*, the interposed stamens of later origin (lightly shaded). (After Sachs.)

with interposed stamens. In the formula that can be indicated thus : Ca_5, Co_5, $An_{5\,.\,5}$, $Gn_{(5)}$, or

		—	A	—						
Gn		—		—		—		—		—
An	—	i	—	i	—	i	—	i	—	i
Co		—		—		—		—		—
Ca	—		—		—		—		—	

Here the small i indicates the position of the interposed stamens. A represents the position of the axis, and indicates that the median sepal is posterior, or next the axis. Flowers with two series of stamens are diplostemonous. The two series may not appear simultaneously, and either the stamens superposed to the calyx may develope first, or those superposed to the corolla. When the normal stamens develope first, the flower is diplostemonous. When the interposed stamens—that is, those superposed to the corolla—first appear, the flower is obdiplostemonous, as in Epacridaceæ and Ericaceæ.

FIG. 109.

Diagram of flower of *Æsculus*, Horse-chestnut.

The interposed stamens represented between the dark shaded normal ones. The interposed whorl being imperfect, the two-shaded ones represent the two fully-developed ones, the three dots the abortive ones. (After Sachs.)

Sometimes the interposed stamens are fewer than the normal stamens. This is seen in the horse-chestnut, Æsculus, (fig. 109); the flower being tetracyclic pentamerous, with an incomplete series of interposed stamens, giving the formula, Ca_5, Co_5, $An_{5\,\cdot\,2}$, $Gn(\underline{3})$. Three of the interposed stamens are ablastic, and represented by a small o, thus—

— A —

Gn — — —

An — o — i — o — o — i

Co — — — — —

Ca — — — — —

Lastly, in such a flower as that of Hypericum calycinum (fig. 110) there are branched stamens (br) superposed to the corolla, indicated by | . The flower is tetracyclic pentamerous, with the formula, Ca_5, Co_5, | , $An_5{}^{1}$, Gn $(\underline{5})$, or

					— A —					
Gn	—		—		—		—		—	
An		br		br		br		br		br
Co		—		—		—		—		—
Ca	—		—		—		—		—	

Classification of Fruits.—The classification of fruits is quite artificial, and founded on characters

FIG. 110.

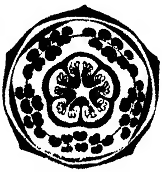


Diagram of the flower of *Hypericum calycinum*. (After Sachs.)

derived from the nature and mode of opening of the pericarp.

DRY FRUITS.—The cell-sap disappears rapidly, leaving the pericarp dry, and of varying degrees of hardness and thickness.

1. Dry indehiscent one-seeded fruits.

The Nut.—The pericarp thick and hard. Acorn.

The Achene.—The pericarp thin—Ranunculus. There are several varieties of the achene. Two are frequently separated, as the caryopsis in grasses, the thin pericarp being adherent to the spermoderm, and the cypsela in Compositæ, formed by an inferior ovary.

2. Dry indehiscent, two or more-seeded fruits, splitting into single-seeded indehiscent portions—

Schizocarps. The splitting may be transverse, longitudinal, or in both directions.

The Lomentum.—Splitting transversely. When the splitting is longitudinal, the separate parts, or mericarps, resemble achenes. Sometimes the portions are suspended by a forked part of the axis, as in the *cremocarp* with carpophore, of most Umbelliferæ. In the *carcerulus* of the mallow no carpophore exists. When the mericarp is winged it becomes the *samara*, as in Acer, to be distinguished from the samaroid achene, as in Ulmus. In Platystemon the fruit splits both ways —the *dischisma.*

3. Dry dehiscent fruits. Capsular fruits. These fruits may have one, two, or more carpels, and may open in different ways.

Follicle.—One carpel, opening by one suture, and generally by the dorsal suture—Hellebore.

Legume.—One carpel, opening by two sutures, the dorsal and ventral—Pea pod.

Siliqua and Silicula.—Two carpels united, and forming an ovary with two cavities, the partition, or replum, being a false partition formed by the placentas, and remaining after the fruit has opened. When the fruit is long, it is the siliqua ; short, the silicula—Cruciferæ generally.

Capsule.—Two or more united carpels forming a one or more locular ovary, and opening transversely, longitudinally, or by pores. When the dehiscence is transverse the fruit is the pyxidium, as in Hyoscyamus and Anagallis. Longitudinal dehiscence may be septicidal (Colchicum), loculicidal (tulip), or septifragal (Rhododendron). In Papaver the capsule opens by pores underneath the stigma.

4. Succulent indehiscent fruits.

The Drupe.—The pericarp is separable into a thin epicarp, a thick fleshy mesocarp, and a hard endocarp or stone—Plum.

The Berry.—The epicarp is usually thin and soft, the other tissues forming a soft pulp, in which rarely one, usually many, seeds are imbedded. The ovary is superior, uva, in the grape; or inferior, bacca, in the currant and cucumber. In the date the berry (uva) is one seeded.

5. Succulent dehiscent fruits.

A succulent capsule occurs in Æsculus and Impatiens, a dehiscent drupe in the walnut, and a dehiscent berry in the Elaterium, or squirting cucumber.

CHAPTER VII.

THE MONOCOTYLEDONS.

CLASS XI.—MONOCOTYLEDONES.

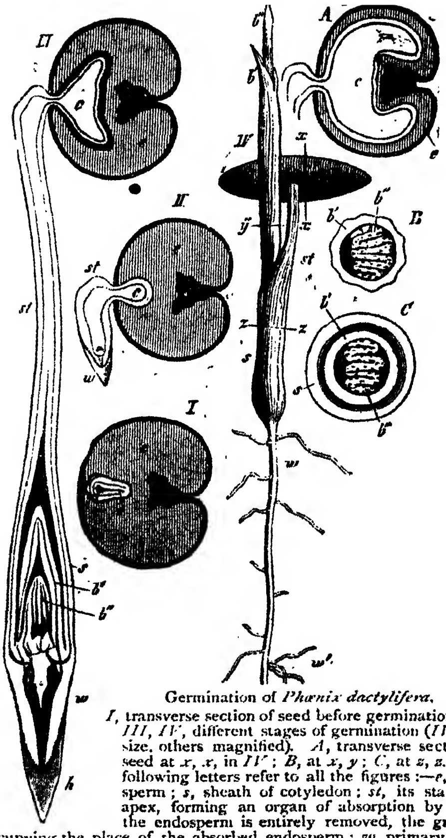
THE seed generally contains a small embryo, and abundance of endosperm. In some cases, as in Alismaceæ and Orchidaceæ, the endosperm is entirely wanting, while, in the Zingiberaceæ, it is replaced by perisperm. The embryo has usually a short axis and a large cotyledon, the end of the axis often with a few young leaflets. In the Orchidaceæ the embryo is exceedingly imperfect, consisting of a rounded mass of tissue, which undergoes further development during germination.

During germination the lower part of the cotyledon elongates, pushing the rootlet and stem out of the seed (fig. 111), the end of the cotyledon remaining in contact with the endosperm, and acting as an organ of absorption. In grasses the cotyledon is largely developed and called the scutellum (fig. 112). In other cases the rootlets first elongate, pushing through the root-sheath that envelopes them, each being thus surrounded at its base by the so-called coleorhiza. The cotyledon in some forms, as Allium, developes at once into the first green foliage-leaf of the plant.

The growth of the main root is generally of short duration, lateral roots developing from the axis, soon replacing it. These develope always higher and higher up the stem; hence no primary root system is formed. A few orchids, as Corallorhiza are rootless.

The embryonic axis in some cases becomes the main axis of the plant, as in palms. The main axis may be either erect or creeping. The first formed parts of the axis are very small, but each succeeding part becomes stronger and stronger, the stem being thus conical, with the apex downwards. After a certain maximum has been reached the stem grows cylindrically. The stem is permeated by separate fibro-vascular bundles. There is no cambium, but in a few cases, as in Yucca and Dracæna, circumferential growth takes place by the formation of a meristem zone in the ground tissue, developing both new ground tissue and new fibro-vascular bundles. The embryonic

FIG. 111.

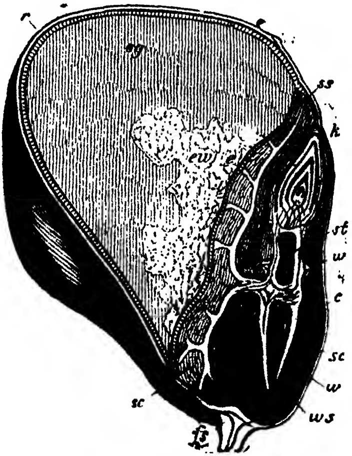


Germination of *Phœnix dactylifera.*

I, transverse section of seed before germination. *II, III, IV*, different stages of germination (*IV*, nat. size, others magnified). *A*, transverse section of seed at *x, x*, in *IV*; *B*, at *x, y*; *C*, at *z, z*. The following letters refer to all the figures :—*e*, endosperm ; *s*, sheath of cotyledon ; *st*, its stalk ; *c*, apex, forming an organ of absorption by which the endosperm is entirely removed, the growing end occupying the place of the absorbed endosperm ; *w*, primary root ; *w'*, secondary root ; *b'*, *b*, leaves succeeding the cotyledon ; *b''*, the first foliage leaf ; *h*, pileorhiza ; in *B, C*, the folded lamina is seen cut across.

(After Sachs.)

axis may grow in length, or it may remain short and thick, forming the stem tuber of Polygonatum, or the bulb (onion) if the thickened bases of the leaves are present. The main stem is either erect or horizontal (rhizome), and the internodes are either elongated or

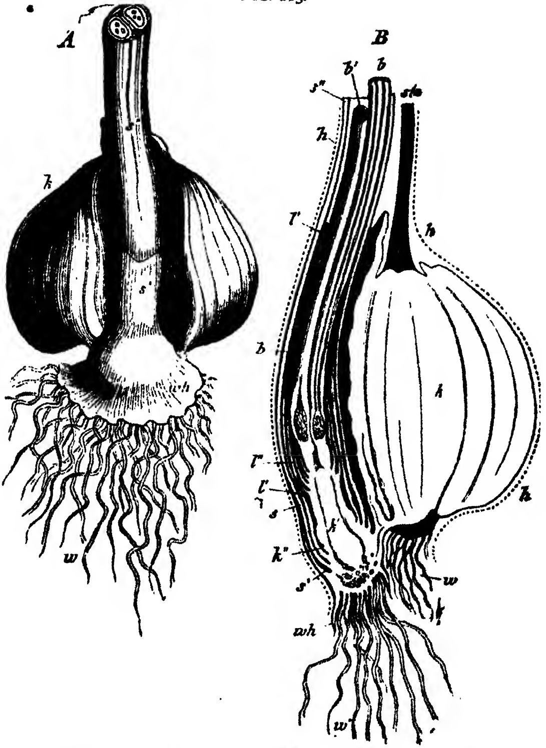


Longitudinal section of fruit of *Zea-Mais* (× 6).

c, pericarp; *n*, remains of the stigma; *fs*, base of the fruit; *eg*, hard yellowish part of endosperm; *ew*, white softer portion of endosperm; *sc*, scutellum (cotyledon) of embryo; *ss*, its apex; *e*, its epidermis; *k*, plumule; *w* (below), the main root; *ws*, sheath covering main root; *w* (above), lateral rootlets springing from the first internode of the stem, *st*. (After Sachs.)

suppressed. Sometimes the main axis dies after a lateral branch has been formed, as in the crown-imperial and Colchicum (fig. 113) and in our native orchids. At other times the secondary axes remain

FIG. 113.



Underground parts of flowering plant of *Colchicum autumnale*.

A, front view ; *k*, thick short underground stem or corm ; *s'*, *s''*, scale-leaves surrounding flower stalk ; *wh*, base of stem with roots *w*. *B*, longitudinal section ; *hh*, brown skin covering all the underground parts ; *st*, withered flower axis of previous year, its basal swollen portion (*k*) remaining as a reservoir of nutrient matter for the new plant, which is a lateral branch from the base of the corm, *k*. The middle part, *k'*, will swell up into a corm next year, while the old corm, *k*, disappears. The axis bears sheathing scale-leaves, *s*, *s'*, *s''*, and the small still undeveloped foliage-leaves, *l'*, *l''*. The flowers are formed in the axils of the upper foliage-leaves, the rounded end of the axis visible between the flower-stems, *b*, *b'*. (After Sachs.)

attached, and give rise to the sympodial arrangement seen in Polygonatum multiflorum.

The branching is always monopodial and generally axillary. One bud is formed in each leaf axil. Occasionally the bud remains undeveloped, as in Dracæna, and at other times several buds are developed in the axil of the leaf, as in Muscari botryoides. The bracts are sometimes wanting (Arum). Adventitious buds are formed on the leaves of Malaxis and on the roots of Epipactis macrophylla.

The leaves are generally arranged in two rows and alternate, the $\frac{1}{2}$ and $\frac{1}{3}$ spiral arrangements being the most common. Occasionally more complex spirals are developed, as in Palms. In Fritillaria imperialis the fractions are inconstant and the arrangement very complex. Whorled leaves are rare, but occur in Elodea. The leaf generally consists of a lamina and a well-developed sheath. A petiole is sometimes developed between the lamina and sheath, as in Palms and Aroids. Stipules are not developed. Frequently a ligule is produced where the sheath and lamina meet. The lamina is generally entire and simple in its outline, commonly linear, rarely round, cordate, or sagittate. Branching of the lamina occurs in Aroids as well as peculiar openings in the leaf. The leaves of palms assume the pinnate and palmate forms by splitting and tearing of an originally entire lamina, certain zones of tissue drying and tearing during growth. The tendrils of Smilax are formed by branching of the leaf-stalk.

The venation of the leaf is peculiar. In general the veins do not project on the under side, and run more or less parallel from base to apex. In the banana and others there is a prominent midrib, the lateral veins running from it to the margin in a parallel manner. Occasionally the veins are reticulated, as in the Aroids.

The flowers are usually pentacyclic and trimerous. They are hexacyclic in Butomus, there being two whorls of carpels. Sometimes the flowers are dimerous (Smilacina), tetramerous (Paris), or pentamerous, (Orontiaceæ). The formula is thus $C\,a_n\ C\,o_n\ A\,n_{n+n}\ G\,n_n\ (+n)$, where n equals, 3 rarely 2, 4, or 5. Abortion of parts is very common. Single parts or whole whorls may be abortive, and in Aroids the flowers are often reduced to a single carpel or single stamen. The small closely-crowded flowers generally have some parts abortive. Deduplication occurs in the stamens of Alismaceæ. Petaloid staminodes are common in Zingiberaceæ and Canna. The perianth leaves are generally in two series, an outer (calyx), and inner (corolla). Sometimes the calyx is green, the corolla coloured or white. Frequently both whorls are of the same appearance, either petaloid (Liliaceæ), or sepaloid (Juncaceæ). In Grasses the perianth leaves consist of small scales (lodiculæ), while in the Cyperaceæ, the perianth is replaced by hairs or setæ. The stamens generally have a well-developed filament and a four-celled anther. In Canna (fig. 114), only half an anther is developed on one of the staminodes. Branching of the stamens is very rare. In Typha

FIG. 114.

Diagram of flower of *Canna*. (After Sachs.)

and Naias the stamens are supposed to be caulomes, and not phyllomes, i.e. stem structures and not modified leaves.

The gynœcium usually consists of a three carpellary ovary, syncarpous, and either three-celled or rarely one-celled. Many of the large flowered forms have the ovary inferior, usually the ovary is superior. Some times the gynœcium is apocarpous, as in Alismaceæ and Juncagineæ, the number of separate carpels being more than three, in one or two whorls. Adhesions, and displacements are not common. Epipetalous and episepalous stamens occur; while in some forms the leaves of the two whorls of the perianth become adherent to form a single tubular structure, as in Convallaria and Hyacinthus. The most complicated adhesion is that of the andrœcium and gynœcium to form the gynostemium in Orchids. In Zingiberaceæ and Orchidaceæ the flowers are zygomorphic.

The ovules are generally produced on the margins of the carpels, but in Butomus they cover the whole inner surface, except along the midrib. In Naias and Typha the end of the axis is supposed to form the single orthotropous ovule. In Lemna the ovules arise from the base of a unilocular ovary. Generally the ovules are anatropous, rarely orthotropous (aroids, Naias, &c.), or campylotropous (grasses). Usually the ovule has two integuments; in Crinum there is only one. The embryo-sac generally remains surrounded by the tissue of the nucleus, but projects upwards in Crocus and Gladiolus, and destroys the tissue at the apex. In the Orchidaceæ the embryo-sac, during growth, destroys the tissue of the nucleus. In some cases (Allium odorans), the embryo-sac destroys the inner integument after fertilisation. After fertilisation, endosperm begins to form by free-cell formation. In some cases no endosperm forms, while in others it is rudimentary.

The Monocotyledons can be still further subdivided. Various methods have been proposed. The following arrangement, modified from Prantl and Luerssen, gives a general idea of the orders and chief families of the Monocotyledons.

Order XL. **Helobiæ.**—Water or marsh plants. Seeds with little or no endosperm. Hypocotyledonary axis of embryo greatly developed, larger than the cotyledon. Leaves often with petiole and lamina, the latter with somewhat netted veins. Flowers not according to type. Perianth either wanting, of one cycle, or with outer sepaloid and inner petaloid whorls. The Helobiæ include the following families:—

1. Lemnaceæ; 2. Naiadaceæ; 3. Hydrocharidaceæ; 4. Juncagineæ; 5. Alismaceæ.

Order XLI. **Spadicifloræ.**—Land and marsh plants. Flowers small and numerous, generally crowded on a thick simple or branched spadix, surrounded by a spathe. Perianth always inconspicuous, never petaloid, often wanting. Flowers usually diclinous, the male and female flowers generally on the same spadix. Ovary always superior. Seed with much endosperm. Embryo generally small and straight.

Fam.: 1. Aroideæ; 2. Pistiaceæ; 3. Typhaceæ; 4. Pandanaceæ; 5. Cyclantheæ; 6. Palmæ.

Order XLII. **Glumaceæ.**—Flowers small in spikelets or panicles, generally enclosed in scale-like bracts or glumes. Perianth absent or incomplete. Floral formula referable to type (Bambusa) but wanting the outer whorl of the perianth. Pericarp and Spermoderm completely adherent. Seed with large farinaceous endosperm.

Fam. : 1. Gramineæ ; 2. Cyperaceæ.

Order XLIII. **Enantioblastæ.**—Flowers with the typical monocotyledonous formula, rarely single parts abortive or flower dimerous. Ovules orthotropous, the embryo at the end of the endosperm farthest away from the hilum.

Fam. : 1. Centrolepidæ ; 2. Restiaceæ ; 3. Eriocaulonaceæ ; 4. Xyridaceæ ; 5. Commelynaceæ.

Order XLIV. **Liliifloræ.**—Flowers generally large, placed singly or in different kinds of inflorescence, usually pentacyclic trimerous, rarely dimerous, tetramerous or pentamerous. When parts abortive, usually the whole whorl wanting, not individual parts. Two whorls of perianth usually petaloid. Ovary superior or inferior, usually three-celled. Embryo surrounded by the endosperm or at the side.

Fam. : 1. Juncaceæ ; 2. Liliaceæ ; 3. Amaryllidaceæ ; 4. Iridaceæ ; 5. Taccaceæ ; 6. Dioscoreæ ; 7. Pontederiaceæ ; 8. Bromeliaceæ.

Order XLV. **Scitamineæ.**—Flowers with typical formula, usually zygomorphic, parts of the andrœcium often abortive, or represented by staminodes. Perianth petaloid, or with inner cycle only petaloid. Ovary inferior, three-celled. Fruit a capsule or berry. Seeds with no endosperm, but with copious perisperm.

Fam. : 1. Musaceæ ; 2. Zingiberaceæ ; 3. Cannaceæ.

Order XLVI. **Gynandræ.**—Flowers zygomorphic, referable to type. Stamens partially abortive, united to carpels. Ovary inferior, usually spirally twisted, inverting the parts of the flower; capsule one-celled. Seeds very small, with no endosperm, the embryo minute with no indication of axis and cotyledon.

Fam. : 1. Orchidaceæ; 2. Apostasiaceæ; 3. Burmanniaceæ.

The Monocotyledons are represented in a fossil state according to Schimper, by seventy-six genera and 418 species. The orders Enantioblastæ and Gynandræ have not yet been found fossil. All the others are, however, represented. The Spadicifloræ (Palms) appear in the Carboniferous (Fasciculites and Palæospathe). The Lilifloræ (Yuccites), in the Triassic; the Helobiæ in the Oolitic; Pandanus (Spadicifloræ); Eolirion (Liliaceæ), and Cannophyllites (Cannaceæ), appear in the Chalk. The Tertiary contains many genera of Helobiæ, Spadicifloræ, Glumaceæ (Poacites, Carex), Lilifloræ (Juncus, Iris), and Scitamineæ.

CHAPTER VIII.

THE DICOTYLEDONS.

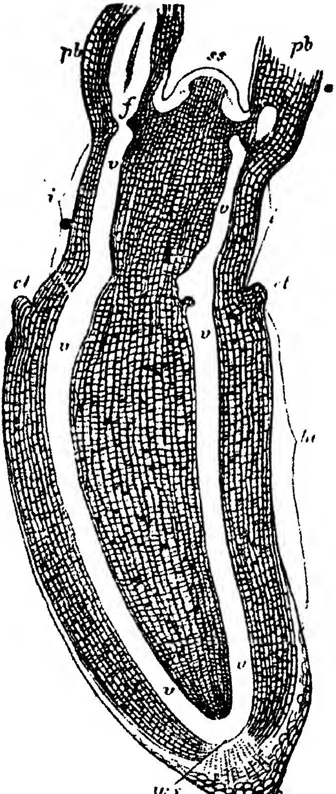
CLASS XII.—DICOTYLEDONES.

The mature seed frequently contains an embryo without any endosperm, as in Leguminosæ (with a large embryo), and in Cruciferæ and Compositæ (with a small embryo). The embryo is large and the endosperm scanty in Labiatæ; the embryo small and the endosperm large in Umbelliferæ. In Nymphæaceæ and Piperaceæ, the endosperm is minute, but the seed contains abundance of perisperm.

The embryo may be minute and exceedingly imperfect in parasites and saprophytes. It is only two-celled in Monotropa. The embryo is large in Cucurbita, with two cotyledons, and a rounded *punctum vegetationis* between. In the bean, the plumule or bud at the apex of stem bears several leaves. Generally the two cotyledons are of similar dimensions, but in Trapa one is much smaller than the other. Sometimes the cotyledons are three in number (Oak), rarely only one is formed, as in Ranunculus Ficaria. The cotyledons generally form the largest part of the embryo, the axis appearing as a small spindle-shaped structure between them, as in the bean. The cotyledons may be thick or thin, flat or folded, rarely they are spiral. The axis of the embryo, the so-called radicle, consists almost entirely of the hypocotyledonary portion of the stem, the primary root developing at its apex (fig. 115).

During germination the hypocotyledonary portion of the axis elongates rapidly, and pushes the root out of the seed (fig. 116). The cotyledons remain enclosed by the spermoderm. Sometimes the petioles of the cotyledons elongate, and the plumule grows upright between them. Thick fleshy cotyledons usually remain in the seed until they are consumed, but thin cotyledons generally form the first foliage leaves, the hypocotyledonary portion of the stem elongating, and pulling the cotyledons out of the seed (Cruciferæ). If the seed contains endosperm, the co-

Fig. 115.

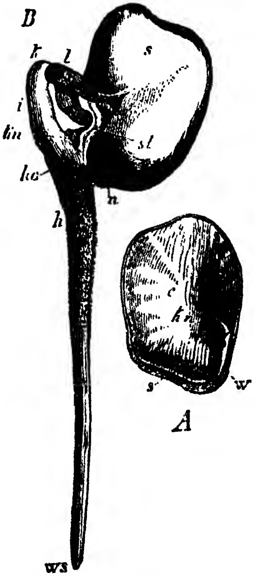


Phaseolus multiflorus (× 30).

Longitudinal section of axis of the embryo in a ripe seed. *ss*, apex of stem; *ws*, apex of root; *ct*, swelling near insertion of cotyledons; *i*, the first internode; *pb*, the petioles of the first foliage-leaves; *v*, *v*, *f*, the procambium of the fibro-vascular bundles; *hc*, the hypocotyledonary portion of the stem. (After Sachs.)

yledons are not liberated until it is all absorbed (fig. 117).

FIG. 116.

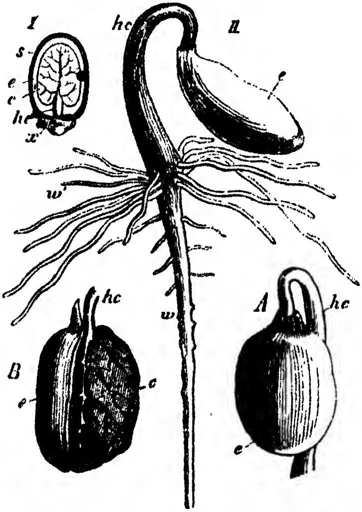


Vicia Faba.

A, seed, with one cotyledon removed; *c*, remaining cotyledon; *kn*, the plumule; *w*, the radicle; *s*, the spermoderm. *B*, germinating seed: *s*, spermoderm, a portion torn away at *l*; *n*, hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary portion of axis, *i*; *hc*, short hypocotyledonary portion of axis; *h*, main root; *ws*, its apex; *kn*, bud in axil of one of the cotyledons. (After Sachs.)

Growth generally takes place by the development of the primary axis, which branches more or less frequently. It often happens that the side branches grow as strongly as the main stem. If the lower slighter lateral branches die, a crown of leaves and branches like that of our ordinary deciduous trees, with a straight trunk, will be produced, while in shrubs the strong ones remain and spring from near the base of the main stem. In many deciduous trees the stems and branches are sympodia, the upper lateral bud annually assuming the direction of the mother axis and continuing it, while the apex ceases to develope. The primary axis may die shortly after germination, and after a bud has been formed in the axil of the cotyledon, as in Ranunculus Ficaria, and in Dahlia. Bulbs are rare in Dicotyledons, but occur in some species of Oxalis. Tubers, stolons, and perennial underground stems or rhizomes are common. Most dicotyledons produce adventitious roots from the stem either when placed in darkness and kept moist, or

FIG. 117.



Ricinus communis.

I, longitudinal section of ripe seed. *II*, germinating seed, the cotyledons still within the spermoderm, shown more distinctly in *A* and *B*; *s*, spermoderm; *e*, endosperm; *c*, cotyledon, *hc*, hypocotyledonary portion of axis; *w*, primary root; *w'*, lateral rootlets; *x*, the caruncle (or aril), a peculiar appendage to the seeds of *Euphorbiaceæ*. (After Sachs.)

normally, as in Ivy. Upon this depends the propagation of dicotyledons by cuttings.

The fibro-vascular bundles of the stem are almost always open, and by the activity of the cells forming the cambium ring, large stems are developed by circum ferential growth. In individual cases, outside this ring of bundles other isolated strings run through the stem, as in Begonia and Aralia, or still more complex modifications are met with in the arrangement of the bundles, as in the Piperaceæ, Sapindaceæ, Menispermaceæ, Phytolacca, &c.

The branching is generally monopodial and axillary. In the inflorescences of Boragineæ the branching is probably dichotomous. Usually one bud forms in each axil, but several buds form in Lonicera and Aristolochia Sipho. Extra axillary branching occurs in the branch tendrils of the vine, and Ampelopsis. Bracts are frequently absent, as in the inflorescence of Cruciferæ, from abortion. Adventitious buds from leaves are rare, but occur in Bryophyllum calycinum. Adventitious buds spring from roots in Linaria vulgaris, Populus tremula, and others. Dormant buds on old stems of trees are not to be confounded with adventitious buds.

The leaves are very variable in form, size, and position. The leaf-arrangement begins with two opposite cotyledons, and may continue in decussating or alternating series, or pass into whorls or spirals. Simple arrangements are the most constant. Axillary branches generally begin with a pair of leaves, right and left. The kinds of leaves are very numerous, as scale leaves, bud-scales, bracts, floral leaves, and foliage leaves. The foliage leaves generally have a thin petiole and a flat blade. The blade is generally branched; cleft, partite, or compound. When simple, the tendency to branching is shown by serrations or lobes on the margin. The branching of the lamina is monopodial, but it resembles a helicoid cyme in Rubus and Helleborus. The sheath is rare, as the pericladium of Umbelliferæ, but stipules are very frequent. Some of the special peculiarities of the leaves of Dicotyledons are peltate leaves (Tropæolum, Victoria), leaf-tendrils, leaf-spines, and the remarkable ascidia or pitchers, in Nepenthes, Sarracenia, and others. The venation is distinguished by the projection of the veins on the under side, and by their forming frequent anastomoses. Generally a midrib is present giving off numerous branches right and left. The venation is very simple in scale-leaves, bracts, and in the perianth leaves.

The flowers generally have the parts in whorls (cyclic). Sometimes they are wholly (acyclic), or partially spiral (hemicyclic), as in Ranunculaceæ and Nymphæaceæ. Cyclic flowers are usually pentamerous, less frequently tetramerous. Dimerous and trimerous flowers are rare. The pentamerous and tetramerous flowers are generally tetracyclic. In dimerous and trimerous flowers the number of whorls is variable, but generally they are increased. Apetalous flowers are frequent.

Fig. 118.

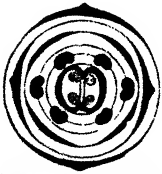


Diagram of the flower of *Cruciferæ*. (After Sachs.)

When the calyx and corolla are both present, the parts are usually equally numerous. Papaver is an exception, with two sepals and four petals. Occasionally the number of whorls is increased. Thus in the hexacyclic Cruciferæ (fig. 118), there are two whorls of the calyx, two outer sepals, anterior, and posterior, two inner sepals, right and left. When perianth and androecium are both present, the parts are usually equally numerous, and the flower isostemonous. Rarely there are more stamens, often fewer than the parts of the perianth, anisostemonous. In pentamerous and tetramerous flowers the carpels are usually fewer than five or four. In trimerous or dimerous flowers, and also in spiral flowers, the number of carpels is generally increased. Interposed stamens are frequent, as in Ericaceæ and Geraniaceæ. Superposed stamens occur in Ampelidaceæ, Primulaceæ, and Plumbaginaceæ, Rhamnaceæ, Celastraceæ, in Hypericum calycinum and in Tiliaceæ. Numerous whorls of stamens occur in Aquilegia. Deduplication or Dédoublement is not unfrequent, while branching of stamens occurs in many natural families.

Branching of carpels is rare, but occurs in the Malvaceæ. Abortive carpels are called carpodes.

In dimerous and trimerous flowers there is often a tendency to form more than one whorl of each part. This is seen in Fumariaceæ, Cruciferæ, and also in Berberidaceæ. The formula of Berberis is

$$\mathrm{Ca}_{3+3} \quad \mathrm{Co}_{3+3} \quad \mathrm{An}_{3+3} \quad \mathrm{Gn}_{1}.$$

Epimedium, belonging to the same natural family, is

$$\mathrm{Ca}_{2+2} \quad \mathrm{Co}_{2+2} \quad \mathrm{An}_{2+2} \quad \mathrm{Gn}_{1}.$$

The flowers of Rheum are peculiar, the formula being—

$$\mathrm{Ca}_{3} \quad \mathrm{Co}_{3} \quad \mathrm{An}_{3}{}^{2}{}_{+3} \quad \mathrm{Gn}_{3}.$$

In the androecium of Papaveraceæ and Rosaceæ, the number of whorls of stamens is increased, while the actual number of stamens in each whorl is variable, thus leading to various complications.

In dicotyledons it is not possible to refer the flower to one type formula, as in monocotyledons, the flowers being apparently constructed on several different plans.

In the dicotyledons, as in the monocotyledons, abortion of parts is frequent, and the flower may be reduced to a single carpel or single stamen. There is no trace of a perianth in Salix and Piperaceæ. In Populus the perianth is reduced to a cup-like structure, or to hair-like scales, as in Platanus. In Euphorbia it is difficult to say whether we have an inflorescence or a flower, most probably it is a peculiar inflorescence. Perigynous flowers, hollow inflorescences, as in the fig, and the cupule of Quercus and its allies, are peculiar to dicotyledons.

The ovules have frequently only one thick integument, as in the Gamopetalæ. The third integument, or aril, is more frequent than in monocotyledons. When the two integuments are present the outer forms part of the micropyle, the exostome. In many parasites the ovules are rudimentary, in certain Balanophoraceæ reduced to a naked four-celled nucleus. In Lorantheæ the ovules are fused with the tissue of the floral axis in the inferior ovary.

The embryo-sac is like that of monocotyledons. The endosperm is generally formed by free-cell formation. In some cases special growth of the embryo-sac takes place, the blind tube-like projections in Pedicularis and others sometimes even protruding out of the ovule. In some plants the endosperm originates by division of the sac of the embryo itself. In Aristolochiaceæ the embryo-sac is divided by the first partition wall into two halves. In Viscum the endosperm is formed by division at the upper end, in Labiatæ in the middle, and in Loranthus at the lower end of the embryo-sac. In Nymphæa, Nuphar and Ceratophyllum the endosperm is formed by free-cell formation at the upper end of the sac. The endosperm is quite rudimentary in Tropæolum and Trapa, and perisperm occurs in Nymphæa, Piper, and others.

The Dicotyledons are classified into subordinate groups. The classification of De Candolle and Endlicher is commonly used in this country, that of Braun and Hanstein, as given by Sachs, in Germany. The following classification, modified from Prantl and Luerssen, may be adopted.

SUB-CLASS I. CHORIPETALÆ.—Petals never united, flowers often mono- or achlamydeous.

I. JULIFLORÆ. Flowers very small and inconspicuous, in close inflorescences, as spikes, capitula, or panicles, usually diclinous, perianth absent, or simple and sepaloid.

Order XLVII. **Piperinæ.**—Flowers very small, in a spike, with small bracts. Perianth absent, ovules orthotropous, single and axile, or many and parietal. Embryo small and surrounded by endosperm in a cavity in the copious perisperm.

Families : 1. Piperaceæ ; 2. Saurureæ ; 3. Chloranthaceæ.

Order XLVIII. **Urticinæ.**—Flowers small, hermaphrodite or unisexual, generally with a simple perigone of four or five parts, in inflorescences of varying form. Stamens usually superposed to parts of perianth (except Platanus). Ovary superior, one-celled, usually with one ovule. Fruit indehiscent, seeds usually with endosperm.

Fam.: 1. Urticaceæ; 2. Moraceæ; 3. Artocarpeæ; 4. Cannabineæ; 5. Ulmaceæ; 6. Plataneæ.

Order XLIX. **Amentaceæ.**—Flowers small, diclinous, in catkins. Female flowers sometimes surrounded by a common covering, the cupule, developed during the ripening of the fruit. Ovary inferior, usually two or more celled, the indehiscent fruit becoming one-celled and one-seeded by abortion. Ovules mostly pendulous, anatropous. Seed with large embryo; no endosperm. Trees and shrubs.

Fam.: 1. Betulaceæ; 2. Corylaceæ; 3. Cupuliferæ; 4. Hamamelidaceæ.

II. Terebinthinæ. Aromatic plants. Leaves usually pinnate, without stipules. Flowers generally with perigone, actinomorphic, hermaphrodite or diclinous. Two whorls of stamens, rarely more, the superposed stamens often wanting. Ovary superior or inferior, of one or more separate carpels, or united to form a multilocular fruit; the cells with one or more seeds.

Order L. **Juglandinæ.**—Flowers achlamydeous or with a simple perigone.

Fam.: 1. Myricaceæ; 2. Juglandaceæ; 3. Casuarineæ; 4. Balsamifluæ.

Order LI. **Rutinæ.**—Flowers usually dichlamydeous, rarely the corolla wanting.

Fam.: 1. Terebinthaceæ; 2. Rutaceæ.

III. Tricoccæ.—Flowers diclinous or hermaphrodite, with simple, double, or no perianth. Ovary usually three-celled, the partitions united in the middle by an elongation of the axis; one or two suspended ovules in each cell. Seed with a fleshy appendage, the caruncle. Embryo surrounded by copious endosperm.

Order LII. **Euphorbiinæ.**

Fam.: 1. Euphorbiaceæ; 2. Buxaceæ; 3. Empetraceæ.

IV. Aphanocyclicæ.—Spiral flowers, hemicyclic or acyclic, the parts of the flower usually separate, the parts of the gynœcium sometimes coherent. Perianth mostly separable into calyx and corolla, parts variable in number, generally stamens more numerous than perianth-leaves. Carpels frequently forming numerous apocarpous ovaries.

Order LIII. **Hydrobryinæ.**—Water plants, with incomplete flowers.

Fam.: 1. Podostemaceæ; 2. Callitrichaceæ; 3. Hippuridaceæ; 4. Ceratophyllaceæ.

Order LIV. **Nymphæinæ.**—Water plants, with large, often floating, leaves, and spiral flowers. Embryo surrounded by a small quantity of endosperm, and placed in a depression in the perisperm.

Fam.: 1. Nymphæaceæ; 2. Nelumbiaceæ; 3. Cabombaceæ.

Order LV. **Polycarpicæ.**—Flowers spiral, rarely cyclic; when cyclic, with two or more whorls in each cycle. Ovaries numerous (rarely one), one or many seeded. Embryo small. Seed with or without endosperm.

A. *Apetalous Fam.*: 1. Myristicaceæ; 2. Lauraceæ.

B. *Dichlamydeous Fam.*: 3. Berberidaceæ; 4. Menispermaceæ; 5. Magnoliaceæ; 6. Anonaceæ; 7. Dilleniaceæ; 8. Ranunculaceæ.

Order LVI. **Rhæadinæ.**—Flowers hermaphrodite, actinomorphic, or zygomorphic. Carpels united. Flowers cyclic, often dimerous, each cycle of several whorls. Seeds usually without endosperm.

Fam.: 1. Papaveraceæ; 2. Sarraceniaceæ; 3. Fumariaceæ; 4. Cruciferæ; 5. Capparidaceæ; 6. Resedaceæ.

Order LVII. **Opuntinæ.**—Flowers spiral, with numerous petals and stamens, epigynous; ovary one or more celled, placentas parietal.

Fam.: 1. Cactaceæ; 2. Mesembryanthemaceæ; 3. Begoniaceæ.

V. Eucyclicæ.—Flowers cyclic, in four whorls.

Order LVIII. **Parietales.**—Perianth in two whorls, usually pentamerous. Ovary superior, of three united carpels, one-celled, placentas parietal. Embryo usually in centre of endosperm.

Fam.: 1. Violaceæ; 2. Cistaceæ; 3. Droseraceæ; 4. Frankeniaceæ; 5. Turneraceæ; 6. Loasaceæ; 7. Passifloraceæ; 8. Papayaceæ; 9. Bixaceæ.

Order LIX. **Guttiferæ.**—Perianth usually of two pentamerous whorls, rarely wanting. Calyx with imbricate, corolla with contorted æstivation. Stamens numerous or branched. Ovary of from two to five carpels, one-celled, with parietal placentas, or multilocular, with the placentas at the inner angles of the cells. Seeds usually without endosperm.

A. *Apetalous Fam.*: 1. Salicineæ.

B. *Dichlamydeous Fam.*: 2. Tamariscineæ; 3. Hypericaceæ; 4. Clusiaceæ; 5. Ternstrœmiaceæ; 6. Dipterocarpeæ; 7. Aurantiaceæ; 8. Meliaceæ; 9. Humiriaceæ.

Order LX. **Frangulinæ.**—Flowers actinomorphic, pentamerous or tetramerous, usually one whorl of stamens, alternate or superposed to the corolla. Perianth and andrœcium on a disc, which sometimes surrounds the ovary. Ovary two to five celled. Seeds with endosperm, embryo straight. Woody plants.

Fam.: 1. Vitaceæ; 2. Rhamnaceæ; 3. Celastrineæ; 4. Aquifoliaceæ; 5. Hippocrataceæ; 6. Pittosporaceæ.

Order LXI. **Æsculinæ.**—Flowers generally zygomorphic. Stamens usually eight by dédoublement or partial abortion of an interposed whorl. Ovary frequently surrounded by a disc. Carpels two or three, ovary two or three-celled, with one or two anatropous ovules. Seeds without endosperm. Embryo straight or curved. Usually trees or shrubs.

Fam.: 1. Sapindaceæ; 2. Malpighiaceæ; 3. Erythroxylaceæ; 4. Tropæolaceæ; 5. Polygalaceæ; 6. Tremandreæ.

Order LXII. **Gruinales.**—Flowers actinomorphic, rarely zygomorphic. Stamens ten, with interposed whorl. Carpels five, united ovary superior, five-celled or ten-celled by false partitions. Fruit capsular.

Fam.: 1. Balsamineæ; 2. Oxalideæ; 3. Zygophylleæ; 4. Linaceæ; 5. Geraniaceæ.

Order LXIII. **Columniferæ.**—Calyx valvate, corolla usually with contorted æstivation. Stamens branched, and generally united, indefinite. Carpels two or indefinite, usually five, forming a many-celled ovary by branching when young. Seeds with little endosperm surrounding the embryo.

Fam. : 1. Sterculiaceæ; 2. Tiliaceæ; 3. Malvaceæ.

VI. CENTROSPERMÆ.—Corolla often absent. Ovary superior, one-celled; ovules single and terminal, or on an elongated axile placenta. Flowers actinomorphic, usually hermaphrodite.

Order LXIV. **Polygoninæ.**—Perianth of one or two whorls, generally trimerous, hexamerous, or pentamerous, petaloid, or sometimes sepaloid. Stamens simple, in one or two whorls, generally six, eight, or nine, alternate or superposed to parts of perianth. Carpels two or three; ovary one-celled, with one orthotropous central and terminal ovule. Fruit covered by the persistent perianth. Endosperm farinaceous. Leaves spirally arranged, sheathings with a closed tubular stipule, the ochrea.

Fam.: 1. Polygonaceæ.

Order LXV. **Caryophyllineæ.**—Perianth of two whorls, the corolla sometimes wanting. Calyx sometimes petaloid. Number of parts variable. Stamens in one or two whorls, often partially abortive, rarely branched. Ovary of one to five carpels, usually one-celled. Ovules anatropous or campylotropous, one or more on an axile placenta. Embryo long, curved in the periphery of the endosperm. Leaves usually opposite and decussate.

Fam. : 1. Nyctagineæ; 2. Chenopodiaceæ; 3. Amarantaceæ; 4. Caryophyllaceæ; 5. Phytolaccaceæ; 6. Portulacaceæ.

VII. CALYCIFLORÆ.—Flowers perigynous or epigynous, gynœcium superior or inferior, surrounded by a disc.

Order LXVI. **Serpentariæ.**—Perigone simple, usually petaloid. Andrœcium and gynœcium more or less adherent, ovary many-celled. Embryo small, in the centre of the endosperm, or rudimentary, with or without endosperm.

Fam.: 1. Aristolochiaceæ; 2. Nepenthaceæ; 3. Rafflesiaceæ.

Order LXVII. **Santalinæ.**—Parasites with or without chlorophyll. Stamens superposed to the perigone leaves, and equally numerous. Ovary one-celled. Seeds often without integument. Embryo large or small, usually with endosperm.

Fam.: 1. Santalaceæ; 2. Loranthaceæ; 3. Balanophoraceæ.

Order LXVIII. **Thymelinæ.**—Perigone simple, generally four-lobed, sepaloid or petaloid, the lower part surrounding the gynœcium. Stamens inserted in upper part of tube in one or two whorls. Ovary generally one-celled, with one anatropous ovule. Endosperm scanty or absent.

Fam.: 1. Thymelæaceæ; 2. Elæagnaceæ; 3. Proteaceæ.

Order LXIX. **Umbellifloræ.**—Flowers epigynous, in umbels. Ovary usually two-celled, sometimes multicellular, with a single pendulous anatropous ovule, and well-developed disc. Seed with copious endosperm. No stipules.

Fam.: 1. Cornaceæ; 2. Araliaceæ; 3. Umbelliferæ.

Order LXX. **Saxifraginæ.**—Flowers perigynous or epigynous, usually pentamerous. Ovary generally two-celled, with numerous ovules on the septa; sometimes apocarpous. Ovules usually anatropous, with endosperm. Embryo straight.

Fam.: 1. Elatinaceæ; 2. Crassulaceæ; 3. Saxifragaceæ; 4. Grossulariaceæ.

Order LXXI. **Myrtifloræ.**—Flowers perigynous or epigynous, sometimes zygomorphic, usually pentamerous, sometimes tetra-, di-, or hexa- merous. Stamens often numerous, sometimes branched. Ovary generally multilocular, with numerous horizontal anatropous ovules attached to a central placenta.

Fam.: 1. Gunneraceæ; 2. Halorrhagidæ; 3. Rhizophoraceæ; 4. Onagraceæ; 5. Combretaceæ; 6. Melastomaceæ; 7. Lythraceæ; 8. Myrtaceæ.

Order LXXII. **Rosifloræ.**—Flowers perigynous. Stamens numerous, in many whorls, rarely one whorl or one stamen; when numerous the outer whorls alternate with petals. Ovaries one-celled, usually numerous, apocarpous, rarely syncarpous, and multilocular, often at the base of the hollow receptacle, calyx-tube or hypanthodium, or on a prolongation of the axis. Ovules anatropous, erect or pendulous. Seeds usually without endosperm. Pseudocarps often formed.

Fam.: 1. Calycanthaceæ; 2. Monimiaceæ; 3. Pomaceæ; 4. Rosaceæ; 5. Poteriaceæ; 6. Dryadaceæ; 7. Neuradaceæ; 8. Spiræaceæ; 9. Amygdalaceæ; 10. Chrysobalaneæ.

Order LXXIII. **Leguminosæ.**—Flowers actinomorphic or zygomorphic, usually pentamerous, not properly perigynous, but with corolla, andrœcium and gynœcium placed on an expansion of the axis inside the tubular calyx. Stamens usually ten, united into a tube, rarely three or many, free or united. Gynœcium of one carpel. Ovary superior. Fruit usually a legume, sometimes with spurious longitudinal or transverse partitions.

Fam.: 1. Mimoseæ; 2. Cæsalpiniaceæ; 3. Papillionaceæ.

SUB-CLASS II. GAMOPETALÆ.—Petals united into a tube, or at least united at the base, scarcely quite separate, rarely wanting.

I. ISOCARPEÆ.—Carpels as many as sepals and petals. Ovary generally superior.

Order LXXIV. **Primulinæ.**—Flowers usually pentamerous, rarely zygomorphic. Stamens almost always epipetalous and superposed. Ovary generally superior, one-celled, with a free central placenta or single central ovule. Carpels superposed to sepals.

Fam.: 1. Primulaceæ; 2. Myrsineæ; 3. Plumbagineæ.

Order LXXV. **Diospyrinæ.**—Parts of flower variable in number, actinomorphic. Stamens epipetalous, or on a receptacle, often twice as many as petals. Ovary superior and multilocular. Ovules one or two, rarely more, in each cell. Placentas parietal. Fruit usually fleshy. Seed with or without endosperm.

Fam.: 1. Sapotaceæ; 2. Ebenaceæ; 3. Styracaceæ.

Order LXXVI. **Bicornes.**—Flowers tetramerous or pentamerous. Stamens twice as many as petals, the interposed whorl rarely absent, all inserted with the corolla on an inferior, rarely superior, ring. Pollen grains usually cohering in fours. Ovary superior or inferior, multilocular; placenta large, projecting forward into the cavity of the loculament. Seeds with endosperm; carpels superposed to petals.

• *Fam.*: 1. Epacridaceæ; 2. Ericaceæ; 3. Vaccinieæ; 4. Rhodoraceæ; 5. Pyrolaceæ; 6. Monotropaceæ.

II. ANISOCARPEÆ.—Generally with only two median carpels, united to form the ovary. Parts or whorls never increased in number.

a. Hypogynæ.—Ovary superior.

Order LXXVII. **Diandræ.**—Flowers usually dimerous or tetramerous. Stamens two, lateral, epipetalous; two median carpels. Ovary two-celled, each with two seeds; style one. Leaves generally opposite and decussate; no stipules.

Fam.: 1. Oleaceæ; 2. Jasmineæ.

Order LXXVIII. **Contortæ.**—Flowers usually pentamerous. Corolla twisted to the right in the bud. Stamens epipetalous; two median carpels. Leaves generally opposite and decussate, without stipules.

Fam. 1. Gentianaceæ; 2. Apocynaceæ; 3. Asclepiadaceæ.

Order LXXIX. **Tubifloræ.**—Flowers pentamerous, actinomorphic, rarely zygomorphic, if so, not median symmetrical. Stamens epipetalous. Ovary of two (rarely five) carpels. Leaves alternate; no stipules.

Fam.: 1. Convolvulaceæ; 2. Cuscutaceæ; 3. Polemoniaceæ; 4. Hydrophyllaceæ; 5. Boragineæ; 6. Solanaceæ.

Order LXXX. **Labiatifloræ.**—Flowers pentamerous, zygomorphic, corolla generally labiate, the two posterior petals united to form a helmet-like bent upper lip; anterior petal and often two lateral petals forming the lower lip. Posterior stamen often wanting; the two lateral generally shorter than the two anterior, didynamous; two median carpels forming a two-celled ovary. Leaves alternate or opposite.

Fam.: 1. Labiatæ; 2. Scrophulariaceæ; 3. Lentibulariaceæ; 4. Gesneraceæ; 5. Bignoniaceæ; 6. Acanthaceæ; 7. Globulariaceæ; 8. Verbenaceæ; 9. Plantaginaceæ.

β. *Epigynæ.*—Ovary inferior.

Order LXXXI. **Campanulinæ.**—Flowers actinomorphic or zygomorphic, pentamerous; gynœcium of from two to five united carpels. Stamens often coherent, rarely adherent to gynœcium, sometimes partially abortive.

Fam.: 1. Campanulaceæ; 2. Lobeliaceæ; 3. Stylidiaceæ; 4. Goodeniaceæ; 5. Cucurbitaceæ.

Order LXXXII. **Aggregatæ.**—Flowers actinomorphic or zygomorphic, generally in capitula or close inflorescences, usually pentamerous or tetramerous. Stamens as numerous as parts of the corolla, and epipetalous. Calyx often rudimentary, pappose. Carpels two to five, united.

Fam.: 1. Rubiaceæ; 2. Caprifoliaceæ; 3. Valerianaceæ; 4. Dipsacaceæ; 5. Compositæ.

According to Schimper, the Dicotyledons are represented in a fossil state by 361 genera and about 2,032 species. Dicotyledons are first met with in the Chalk, most of the great divisions being there represented:—The Julifloræ by Ficus, Platanus, Quercus, Castanea, Fagus, Dryophyllum; the Terebinthinæ by Liquidamber; the Tricoccæ are not represented in the Chalk; the Aphanocyclicæ by Daphnophyllum, Sassifras, and Magnolia; the Eucyclicæ by Salix, Populus, Cissites, Pterospermites; the Centrospermeæ are not represented in the Chalk. The Calyciforæ by Aristolochia, Araliophyllum, Myrtophyllum, and Pyrus; the only representative of the Gamopetalæ in the Chalk is Leucothöe (Ericaceæ). In the Tertiary all the orders are represented except Piperinæ, Hydrobryinæ, Opuntinæ, and Campanulinæ. The following important families of other orders are not as yet known to occur in a fossil state:—Buxaceæ, Empetraceæ, Cabombaceæ, Myristicaceæ, Dilleniaceæ: none of the Rhœadinæ, except two genera of Cruciferæ, Lepidium and Clypeola, in the Tertiary; none of the Parietales except Violaceæ, Cistaceæ, and Bixaceæ; no Tamariscineæ, Hypericaceæ, Aurantiaceæ, Polygalaceæ, Tropæolaceæ; no Gruniales except Zygophylleæ; and no Malvaceæ. Polygonaceæ, Nyctagineæ, and Chenopodiaceæ are present in the Tertiary, but Caryophyllaceæ, Amarantaceæ, and Portulacaceæ are absent. Many families of Gamopetalæ are present in the Tertiary, but the following are absent, viz.:—Epacridaceæ, Plumbagineæ, Primulaceæ, Valerianaceæ, Dipsacaceæ, Jasmineæ, Plantaginaceæ, Acanthaceæ, Gesneraceæ, Lentibulariaceæ, Labiatæ, Polemoniaceæ.

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