CHAPTER III

PHYLUM — BRYOPHYTA

Introduction. The second *phylum* of plants is known as the Bryophyta. This word literally means "moss" plants. The mosses or Musci are, however, only *one* of *two* groups which form the Bryophytes. The other group is that of the liverworts or Hepaticae. These two groups differ markedly in their general appearance and structure, but their organs of reproduction and general life histories are so similar that both are included in the general term, Bryophytes.

Class I — Hepaticae

Marchantia (Fig. 32), a typical liverwort, is a little, flat, leaf-like plant, living in patches on damp soil or rocks near water. It is strap-shaped, with a distinct mid-rib, and the plant body forks at one end. This forking is brought about by a special type of growth at the tip and the plant dies away at the opposite end. After a time each of the branches will fork again, and the opposite end will die and separate the two branches which were originally united. In this way the plant spreads slowly over the ground, forming green areas. This method of extension is a *type* of *vegetative reproduction* which is not restricted to the liverworts, but is present in ferns and flowering plants.

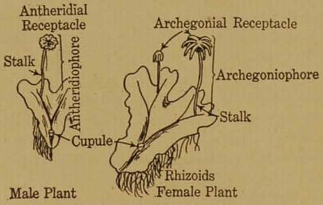

FIG. 32. — Marchantia.

Marchantia is a *liverwort,* which word literally means "liver plant." The liverworts have a lobed appearance and someone long ago fancied that the plant body resembled the lobes of the human liver. There used to be a medical philosophy known as the Doctrine of Signatures. According to this the medical properties of plants and other objects could be determined by certain signs. In this particular case it was thought that a decoction made from liverwort would be good medicine for the cure of liver disease. It was also used in the treatment of kidney and lung diseases, but there is no evidence that it was efficacious.

Examination of a portion of a Marchantia *thallus* or plant body shows that it is green in color above, and underneath, it has many threadlike structures, to which earth adheres. If one examines the upper surface with a strong hand lens, many small pores are found, each in the center of a diamond-shaped area. A section (Fig. 33) through the thallus, studied microscopically, shows that the upper surface is composed of a single layer of protective cells, called the *upper epidermis*. Here and there are *air-pores*, guarded by special cells. These air pores open into *air chambers* and in the air chambers are strings of cells which contain *chloroplasts*, whose presence gives the green color to the thallus. It is here that carbohydrates are made. Below the air chambers are several layers of thin-walled, polygonal-shaped cells constituting the *parenchyma* tissue where carbohydrates are stored. The upper parenchyma cells form the floor of the air chambers, while the side walls of the air chambers are made of cells which extend from the parenchyma to the upper epidermis. Underneath the parenchyma is a single layer of *lower epidermal* cells which protect the parenchyma from the earth below. Both epidermal layers prevent loss of water from the cells by evaporation. *Scales*, which are very small, leaf-like, multicellular extensions, are found on the lower epidermis and there are also fine, thread-like *rhizoids*, which are long, slender, thin-walled cells which extend into the soil, absorbing soil fluids containing compounds from which will be made protoplasm for added plant growth. The new protoplasm is not made from these soil compounds alone, for the carbohydrates made

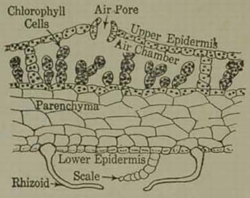

FIG. 33. — Marchantia. Vertical section through thallus.

by the chlorophyll cells are also necessary. The study of the plant body has revealed the fact that liverworts possess considerable *tissue differentiation.*

Marchantia has a unique method of asexual reproduction. Small cup-like organs called *cupules* (Fig. 32) grow on the upper surface. In these cupules are produced tiny leaf-like structures called *gemmae.* They are miniature vegetative organs. When mature, they become dislodged and are shed from the mother thallus. They may be scattered by the wind to a new area, which if favorable will be the site where a new growth of Marchantia becomes established. Many of course fall on "barren ground."

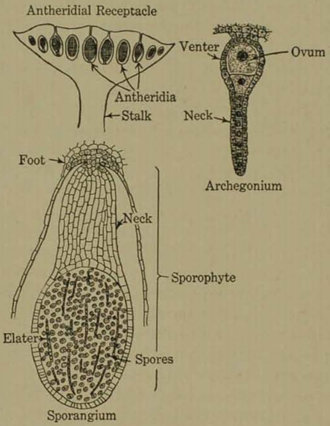

FIG. 34. — Antheridia, archegonium, and sphorophyte of Marchantia.

There are also elaborate sex organs, borne on separate plants, and so Marchantia is *dioecious.* These sex organs in some respects are similar but also show important differences. Arising from the mid-line of a male thallus is one or more long stalks, each with a disc-like structure at its upper end. The entire organ is an *antheridiophore* (Fig. 32) composed of the stalk and an upper disc, the *antheridial receptacle.* A study of a cross-section of the antheridial receptacle (Fig. 34) reveals a number of organs, the *antheridia.* Those near the center of the disc are larger and more mature. Within the antheridium are rows of cells which produce antherozoids, sperm or *male gametes, i.e.,* small bi-ciliated cells which swim actively about in water.

The female sex organs arise from female thalli and are called *archegoniophores.* Each consists (Fig. 32) of a stalk, at the upper end of which is an inverted disc, the *archegonial receptacle*, with several finger-like projections. On the under side of this are the *archegonia* (Fig. 34), small flask-shaped organs, each with a neck and a globular base or *venter* consisting of one layer of cells. Within the neck is a row of neck-canal cells; the lower cell inside the venter is a single *ovum* or *female gamete*. The whole archegonium is on the under surface of the receptacle and the neck is directed downward. When the plants are sexually mature and when the water conditions are favorable for sperm locomotion, as during a heavy rain, the sperm, swimming about, arrive near the archegonial necks. The neck-canal cells have degenerated, thus forming an open passage. A single sperm works its way down one of these archegonial neck-canals and its nucleus unites with that of the ovum, forming a fertilized egg or zygote. The green, independent, male and female Marchantia plants are *Gametophytes* because they produce gametes. The word *independent* is used, because the plant makes its own protoplasm and supplies its own energy from organic compounds, which it has made from inorganic ingredients. The stalk of the female archegoniophore is short at time of fertilization, but later grows longer.

The fertilized egg or zygote develops a small but many-celled structure which remains attached to the archegonial receptacle at the place where the fertilization took place, namely, in the venter of an archegonium. This many-celled structure is the *Sporophyte* (Fig. 34). It is about 1 mm. in length, and has three parts: (*a*) the foot, a group of cells by which the sporophyte is attached to the archegonial receptacle and through which the sporophyte obtains food from the parent gametophyte thallus; (*b*) the neck or short, thick stalk connecting the foot with the (*c*) terminal spore case or *sporangium*. The spore case is a thin-walled capsule within which many small *spores* are produced. Along with these are small spirally-twisted cells called *elaters*. When the spores are mature, the spore case splits open. The twisting movements of the elaters, which occur as a result of changes in the moisture content of the air, aid in the scattering of the spores, which is also favored by the elongated stalk of the archegoniophore. Once free of the plant, air currents may carry the spores far from the plant which produced them. Each spore is a single cell which is capable of growing into a new Marchantia thallus. The differences between the gametophyte and sporophyte should be noted. The gametophyte is large, green, independent and long-lived, while in comparison the sporophyte is small, without chlorophyll, dependent on the gametophyte and short-lived. Nevertheless the sporophyte is an essential generation interpolated between two successive gametophyte generations. Further reference to this will be made in our study of the moss, the fern and the seed plant.

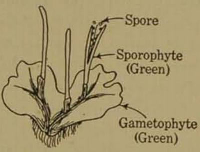

FIG. 35. — Anthoceros.

Anthoceros (Fig. 35) is a liverwort which possesses a long, stalk-like, *green sporophyte*, extending upward from the flat thallus. Cells in the wall of *this* sporophyte contain chlorophyll, with the result that the sporophyte has a certain degree of independence of the gametophyte thallus. True breathing pores are present and there is a special tissue, *meristem*, which provides for continued growth of the sporophyte. It lacks only roots to become independent.

Class II — Musci

The true mosses are more specialized Bryophytes. A true moss is a *land plant,* although it inhabits damp and shady places. A " piece of moss " can be easily separated into many very small plants, each with a central upright stem, from which radiate still smaller green " leaves." The lower end of the stem is buried in the earth. Thus, the mosses are distinctly different from the prostrate thallus-like liverworts.

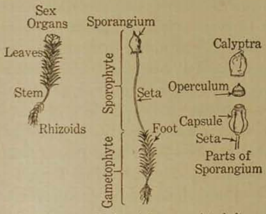

FIG. 36. — Polytrichum. At left, a gametophyte; middle, gametophyte with sporophyte; right, parts of sporangium.

Polytrichum (Fig. 36) is a genus with relatively large plants and hence more convenient for study. It has a number of common names such as robin's-wheat moss, pigeon's-wheat moss and hair-cap moss. A microscopic study of a cross-section of the slender upright stem (Fig. 37) demonstrates a surface layer of *epidermal* cells which contain chloroplasts, also a central region where there are somewhat elongated cells which serve for the *conduction* of fluids from the root-like structures in the earth to the "leaves," and vice-versa from the "leaves" to the rest of the plant. Between the central cells and the peripheral epidermis are polygonal-shaped, thin-walled cells, constituting the *parenchyma,* used for food storage.

Radiating out from the stem (Fig. 36) are many small leaf-like organs, green in color but more simple in structure than the true leaves of higher plants. They consist as a rule of but one layer of polygonal-shaped cells, containing chlorophyll. Here, sugar (starch) is made from water and carbon dioxide with the aid of sunlight. Some of the surface cells of the underground portion of the stem have long, thread-like, thin-walled extensions called *rhizoids.* These are filamentous lines of cells with oblique cross walls. The rhizoids may branch and form an underground network of threads. They not only assist in anchoring the plant but also absorb the mineral compounds in the soil water, so important for the manufacture of new protoplasm.

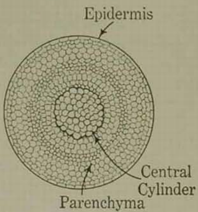

FIG. 37.— Polytrichum. Cross-section of stem.

The amount of leaf surface determines the amount of starch (and eventually new protoplasm) that can be made. The amount of starch manufactured by Marchantia is directly proportionate to the ground area it occupies because it is a prostrate thallus. On the other hand, each Polytrichum plant occupies a much smaller ground area than Marchantia, yet has a much greater starch-producing surface. Although each "leaf" is small, yet the total area of all the "leaves" is much larger than the ground area occupied by the plant.

The Polytrichum plant, we have just studied, is a *gametophyte. Gametes* are produced in special sex organs, as in Marchantia, and they resemble those of Marchantia. Some moss plants are monoecious, others dioecious. Polytrichum and Marchantia are dioecious, *i.e.,* some plants are male and others female. The sex organs are borne at the tips of the plant (Fig. 36) among modified leaves. The whole structure has been wrongly styled a "moss flower." It is *not* a *flower.* At the tip of a male plant (Fig. 38), in among the modified leaves, are a number of long, thin-walled sacs, or antheridia, in which are formed *sperm,* long, coiled, bi-ciliated cells. The antheridia are free and not buried in tissue as in Marchantia. The archegonia (Fig. 38) are free, also, and resemble somewhat those of Marchantia. Incidentally, they are examples of the largest archegonia formed during the evolution of plants, and they also possess more cells. Each archegonium consists of a neck and venter inside which is a single *egg.* When eggs and sperm are mature and the water conditions are favorable, the bi-ciliate sperm swim about, and if one comes near to an *archegonium* it works its way down the neck, and the nucleus of the sperm unites with the nucleus of the egg, forming a zygote. From the zygote, a *sporophyte* (Fig. 36) gradually develops.

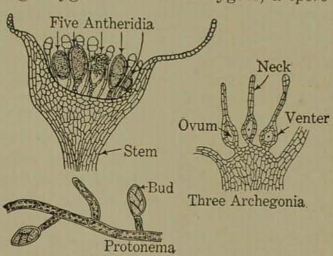

FIG. 38. — Polytrichum. Upper left, tip of male plant; right, tip of female plant; lower left, protonema.

This is not the minute structure that we found in Marchantia. It possesses the same three parts, however: (*a*) a *foot,* which is an elongated mass of cells located in the upper end of the gametophyte stem, having grown down through the archegonial venter into the stem; (*b*) from the foot there extends *up into the air,* a long, slender, brown stalk or *seta,* a few inches in length; (*c*) at the upper end of the seta is a large capsule or *sporangium* (Fig. 36), which consists of a box-like structure with a lid, called an *operculum,* surmounted by a cap called the *calyptra.* The calyptra and operculum may fall off, and the spores still be retained by the *peristome,* an internal border of teeth. In damp weather the teeth spread over the spores, preventing escape. In dry weather the teeth bend out and the spores escape.

Each spore is the germ of a new *gametophyte generation.* Undoubtedly many spores fall on "barren ground" and do not develop. When shed from the spore case, they are probably carried away by air currents. The elevation of the sporangium favors distribution by air currents.

If conditions are favorable, they develop into a branching, filamentous network (Fig. 38) of long cells with oblique cross walls. This plant body is called a *protonema.* Its resemblance to filamentous Green Algae is at once evident. Certain branches of the protonema grow along the surface, others grow into the soil. The latter lose their chlorophyll and become rhizoids. Any green cell of the surface filaments may form a bud from which an upright moss plant will grow, with stem and leaves. The protonema is distinctly part of the gametophyte generation. It may continue to progress along the ground, forming buds and new aerial plants. This is a type of vegetative reproduction comparable to that described in the case of Marchantia.

Sphagnum is a moss which grows in swampy or wet places. The gametophyte has a branching stem to which are attached very small leaves. The leaves have some cells which have no protoplasm but can absorb and retain water. Between them are small cells with chloroplasts. A mass of dried sphagnum absorbs water like a sponge. The best kinds will take up fifteen to twenty times their weight in water. Sphagnum was widely used as a surgical dressing in the Russo-Japanese war, and to a considerable extent in the World War. Nurserymen pack plants for shipment in sphagnum. In certain localities there are beds of it which have been growing for centuries. New growths form on top of the old. Thus, a peat bog is formed. Peat cut out in blocks and dried makes excellent fuel. The surface plants are literally lineal descendants of ancestors whose dead remains are directly under them.

Summary. A comparison of the gametophyte with the sporophyte generation shows resemblances to the liverwort life history. The green plant which we call a moss is a gametophyte, just as the liverwort is a gametophyte. Both produce sex organs, antheridia and archegonia, sperm and eggs. In each case the gametophyte is independent, *i.e.,* it has chlorophyll-bearing cells where starch can be manufactured from inorganic materials. In both liverwort and moss, the gametophyte is longer-lived than the sporophyte. The sporophyte is dependent on the gametophyte. The sexual generation alternates with the asexual. The asexual generation produces spores, no longer motile as in the Algae, but provided with a capsule rendering them proof against destruction by dessication. The spores are wind-driven and thus the species is distributed

Summary of the Bryophytes

Bryophytes are small forms. They live in a variety of habitats, such as cold, damp places where there is little sunlight or where the soil is poor. They have a wide distribution over the earth. They have left little, if any, fossil record in the rocks. They are descendants of plants which developed from the Green Algae. Liverworts are more primitive than mosses. The Musci represent the most *specialized* forms attained by the Bryophytes — standing *at the end* of a line of evolution which began with the liverworts.

Alternation of Generations is well established in the Bryophytes and is characteristic of all higher groups. Spores and gametes are produced in different plants. The gametophyte is the conspicuous, chlorophyll-bearing, starch-making stage. It has attained its highest development among the Bryophytes. In higher groups it is further and further reduced in size but does not lose its essential importance.

The Bryophytes represent the successful transition of plants from their original home in the water to life upon the land. It is interesting to note that the liverwort still remains near water. It has organs for absorbing water from the soil and thick-walled, upper epidermal cells which prevent too rapid loss of water from its tissues. It has special tissues for manufacture of starch. Why did not the Bryophytes become larger, more conspicuous or dominant? Let us consider this question. We think of a great oak tree as a successful type of plant. What are important features of such a successful product? There is a great stem exhibiting many branches above ground and we rightly think of the extensive root system. But after all, the essential feature of the entire stem system is the display of myriads of leaves presenting an enormous, thin, green layer to the sunlight, making possible the production of a proportionate amount of starch. Such a magnificent structure is impossible in the Bryophyte, for there the gametophyte is the starch-producing stage and also the gamete-producing stage. Gametes of Bryophytes require water for the completion of their function. This keeps the gametophyte *near* the ground — close enough to it so that rains at the right time of year will produce enough water to enable the sperm to swim to the eggs. The combination of producing starch and free-swimming gametes on the same plant restricts the size of the gametophyte. Polytrichum possibly represents the extreme extent to which a starch-making gametophyte could develop.

If the starch-making and starch-storage function could be transferred to a *green* sporophyte, which possessed the power of furnishing material for unlimited increase in cells, it could grow to a greater size. Furthermore, it could make just so many more spores and so aid greatly the distribution of the species. Water would be used chiefly for metabolism, not reproduction. At the same time there would be no reason for increased size of the gametophyte. This could remain small and inconspicuous and develop only long enough and large enough to effect fertilization. It would not be necessary for any *one* gametophyte to produce a great many sex organs, for the increased size of the sporophyte would produce so many more spores that the great increase in number of gametophytes would obviate this.

The green sporophyte of Anthoceros referred to above indicates the possibility of the realization of the hypothesis just outlined. The transfer of the starch-making function from the gametophyte to the sporophyte was not made in the case of the Bryophytes. It appears as an accomplished fact in the Pteridophyta. Some botanists believe that forms like Anthoceros were ancestors of Pteridophytes.

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