CHAPTER IV

PHYLUM — PTERIDOPHYTA

Introduction. The word Pteridophyte is a combination of two Greek words. The latter part, as we have already used it, means "plant." The first part, from the Greek word, *Pteris* or *Pteridos*, meaning "wing," was their name for ferns. The feathery appearance of fern leaves suggested "wings" to the Greeks. The word *fern* is from the Anglo-Saxon — *fearn*.

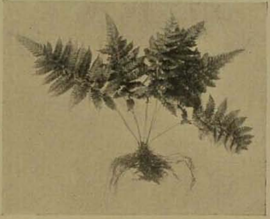

FIG. 39. — A fern. Rhizome is short and hidden among roots; a number of fronds or leaves are shown.

Pteridophytes are much larger than Bryophytes. Common ferns (Fig. 39) have underground stems from which arise thread-like roots, while above the ground occur the large conspicuous green leaves. In warmer climates are found "tree ferns" with upright stems, bearing at the top a crown of green leaves. Ferns have a wide distribution and live in a variety of habitats — near the sea and at high altitude; in dry and wet soils; in cold and warm climates; in rocky crevices and in rich soils. The green fern plant is a *sporophyte, i.e.*, it produces spores. There is also a separate gametophyte stage present, however, which has the important function of producing gametes. The gametophyte is quite inconspicuous, yet the gametes are essential to the complete life cycle since pteridophytes exhibit alternation of generations.

Some types do not, in form, resemble the familiar ferns, yet are similar in general internal structure and life histories.

Pteris

Pteris (Fig. 40) is the type form of the group. In the neighborhood of New York the plants are about two feet high, but in the forests of the northwest (Washington) they may attain the height of 5 feet, in England, 9 feet and in the Andes, 14 feet. Pteris has a wide distribution throughout the world. In dry,

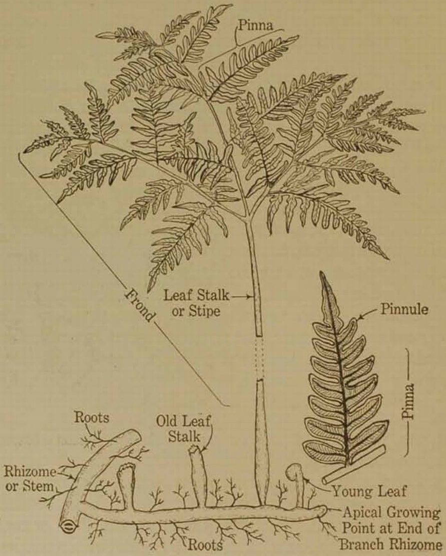

FIG. 40. — Pteris.

open, gravelly places the plants are shorter than when growing in the rich soil of shady woods.

The Stem and Roots. Pteris possesses a woody stem (Fig. 40 — Rhizome), which grows a few inches underground and runs parallel with the earth. It is about a centimeter in diameter from side to side. It is brown or brown-black in appearance and is compressed vertically with two lateral ridges. A study of a cross-section of the stem (Fig. 41) of Pteris reveals a variety of structures. The outer surface consists of a layer of epidermal cells. Beneath this layer are several rows of dark, thick-walled, empty cells. They form a tough sheath under the *epidermis* and help to give rigidity to the stem. This tissue is called *outer sclerenchyma.* Inside of these cells is a mass of thin-walled cells which are filled with food. This tissue is known as *parenchyma.*

In the center of the stem are found two somewhat rectangular (in section) masses of cells like those underneath the epidermis, forming the *inner sclerenchyma.* They also contribute to the rigidity of the stem. Arranged around these inner masses are oval or circular masses of cells of different appearance. These groups of cells are *vascular bundles* and consist of specialized elongated cells fitted end to end, possessing the special function of transporting fluids. There is great variety in their structure. To illustrate this, there is (*a*) one type of cell which transports sugar water from the leaves throughout the rest of the plant. These special cells have definite morphological characteristics and constitute what is known as *phloem tissue;* (*b*) another group of cells transports soil water, containing dissolved minerals, from the roots to all parts of the plant. Such cells (of which there may be more than one kind) constitute *xylem tissue.* Other kinds of cells accompany these. In the vascular bundle of Pteris, the large xylem cells and accompanying cells occupy the central part of the bundle while the smaller phloem cells and the cells which accompany them are found toward the periphery. Parenchyma cells occur in the bundle, some associated with xylem cells and some with phloem cells.

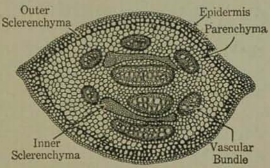

FIG. 41. — Pteris. Cross-section of rhizome.

It should be remembered that solutions are moving slowly in one direction in phloem and in the opposite direction in xylem. The entire bundle is surrounded by a layer of cells called the *endodermis.* The vascular bundles found in the stem of Pteris constitute a very important advance over the stem structure of mosses. We shall find a greater elaboration of xylem and phloem in the stems of the highest plant group, namely, the *Spermatophyta.* Development of wood or xylem makes for greater rigidity, makes possible greater supporting powers and so a greater extension of the leaf system. Continued extension of the vascular system makes possible the supply of soil water needed by this greater leaf mass.

The stem of Pteris grows in the earth like a root and is for this reason called a *rhizome* (root-like). It extends its growth at one end (Fig. 40 — Apical Growing Point), just as the tip-top of a tree does. But unlike a tree, it dies away at the other end. It branches as a tree forms branches, but the branches extend through the earth, growing at their tip ends just as the branches of trees grow. If the decay at the hinder end of the main rhizome reaches the place where one of these branches originates, then the main rhizome and the branch become separated. The branch may send out other branches, and in this way, by a process of vegetative reproduction, ferns may extend over a considerable area if they once get started in a locality. If a farmer wishes to clear such a piece of ground, he must root out every trace of fern rhizome, otherwise any small bit left in the ground may start a new colony. The roots, unlike the roots of a tree, grow out all along the lower surface of the rhizome. As the rhizome grows forward new roots develop. The roots are small and have small branches. Since the stem is underneath the earth, large roots are unnecessary, whereas the tree, with its great upright stem, must have large branching roots extending out in all directions from its base.

Leaf. The leaves of Pteris (Fig. 40 — Frond) are found in groups along the ground. The long rhizome, to which they are connected underneath, is thus indicated. The frond or leaf is divided into the stalk or *petiole*, at the upper end of which is the blade. The blade of the leaf is pinnately (feather-like) divided. There are three main divisions, which is quite characteristic of Pteris. Each portion is variously subdivided into smaller portions called *pinnae*, which are also subdivided into pinnules (Fig. 40).

Superficial examination of a leaflet reveals the midrib, a median linear thickening. Smaller branches of this extend out to the margin of the lobes. The midrib is a smaller division of the vascular system of the petiole, thus connecting the rhizome and leaves. The leaf has an *upper* and *lower epidermis*. Between the two is a chlorophyll-containing tissue called the *mesophyll*. It is in this that the midrib and its branches (veins) run. In the lower epidermis are air pores or stomata. The epidermal layers are protective, while the mesophyll is the region where sugars and starches are made.

Spore Production. The fern plant with its large leaves is a sporophyte or spore-producing plant. Spores are borne in special structures called *sporangia,* found on the under side (Fig. 40) of the pinnules. In Pteris aquilina, the sporangia are borne in a continuous linear group all along the *under margin* of the pinnules and are covered underneath with a narrow fold of tissue reflected from the lower edge. The sporangia (Fig. 42) differ in size. The smaller ones are immature. The largest ones are brownish yellow in color. At the outer end of the sporangial stalk or *pedicel* is a *capsule.* The capsule is somewhat oval in shape and also compressed from side to side. Along one edge is a row of scallop-shaped cells forming the ring or *annulus.* It could more properly be termed a spring. The side walls of the capsule are thin, flat cells. The annulus originates from the pedicel and extends up around the back edge of the capsule and partly around the other end.

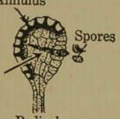

Fig. 42. — Sporangium of fern.

Inside the capsule, spores develop and ripen in the summer. The spore case becomes hard and dry. The annulus, due to this drying, develops considerable tension. Under certain conditions, a rupture occurs in the capsule. The annulus bends back, widening the rupture. It recoils and the spores are discharged. If the wind is blowing at the time, the spores are carried some little distance from the plant. Thousands of these spores are produced by a single plant. Each spore is a single cell. It has been produced asexually from the sporangium, which is the asexual organ of reproduction of the Sporophyte.

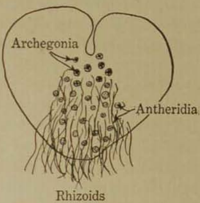

Fig. 43. — Prothallus of fern.

The Prothallus. Falling upon the earth, the spore absorbs water, which softens its hard case. Due to warm air and the absorption of water, the single cell inside is stimulated to divide. Cell division follows cell division. In time there is formed (Fig. 43) a multicellular, small, heart-shaped, flat, leaf-like (thallus) structure about 3 to 5 mm. in diameter and less than 1 mm. thick. It is green in color. On the under side rhizoids develop, and all together it resembles a liverwort such as Marchantia, though much smaller and simpler in structure. It is called a *prothallus*, which means primitive leaf. On the under side develop sex organs, *antheridia and archegonia*, as it is monoecious. The prothalli of some ferns are *dioecious*. The archegonia are formed near the notch of the heart-shaped prothallus. The antheridia are formed farther back among the rhizoids. Each archegonium resembles that of the Bryophytes but is much more simple. There is a neck with a neck-canal, and in the flask-shaped base is a single egg cell. The antheridium is a small case of cells inside which the ciliated male gametes or sperm cells are produced. The sperm are motile and require water in which to swim.

When mature, the sperm escape from the antheridia and swim about in the water. At the time the sperm are discharged from the antheridia, the archegonia of the same prothallus have usually not matured, so that these sperm will probably not fertilize the eggs from the same prothallus. Therefore, although the prothallus is anatomically hermaphrodite, it is not as a rule physiologically so. Self-fertilization is prevented. One sperm enters the archegonium of another prothallus, works its way to the egg or ovum and fuses with it, completing fertilization. The fertilized egg is called an oosperm (ovum-sperm) or zygote.

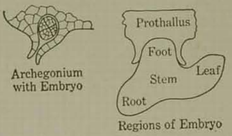

FIG. 44. — Fern. Early development of young sporophyte.

Formation of New Sporophyte. The fertilized egg cell or zygote now begins to divide. It forms two cells, and each of these forms two cells. Each of the four cells (Fig. 44) continues to divide, forming four groups. Let us call these groups A, B, C, D. The cells in group A develop into a structure which remains connected with the prothallus in the region of the old archegonium base. This structure is the *foot* and consists of those tissues which are to act for a time as an intermediary between the green independent prothallus and the new structure about to be described. The cells in group B develop into a young stem; the cells of group C develop into a leaf; the cells of group D, into a root. In a short time, a small plant is discovered clinging to the old prothallus. The little leaf grows up through the notch of the prothallus. The little root grows down into the earth among the rhizoids of the prothallus. The small stem is between them. The little *new plant* (Fig. 45) is still connected to the old prothallus by the foot. Before the new leaf has acquired chlorophyll, this new small plant is dependent upon the prothallus for food for growth. As soon as the new leaf acquires chlorophyll and the new root can absorb mineral materials from the soil and the stem transport these, then the new plant grows rapidly, extending leaf, stem and root far beyond its tiny prothallus, which disintegrates.

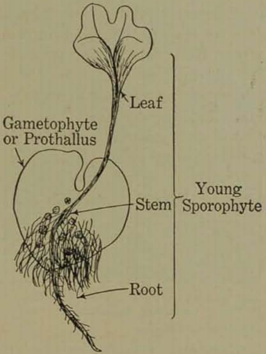

Fig. 45. — Later development of young sporophyte of fern.

Note carefully, however, that it really originated from the fertilized egg. In a sense, the prothallus after fertilization simply nurtures it until it can "carry on" by itself. This little plant is a *new sporophyte.* Eventually it may grow into a large fern plant with its extensive, ramifying underground root-like stem or rhizome, from which will spring multitudes of roots and from which will arise at intervals many large leaves.

Alternation of Generations. Ferns have an *alternation* of *generations.* The large fern plant, with which everyone is familiar, is a sporophyte. This produces spores asexually. A spore develops into a prothallus, which is a gametophyte, bearing sex organs and producing sex cells. The fertilized egg develops into a new sporophyte. However, there is a great contrast to what was found in the Bryophytes. There, the gametophyte was the conspicuous stage, green and independent. During the greater part of its life cycle, a Bryophyte is a gametophyte. The sporophyte is small, inconspicuous, totally dependent on the gametophyte and lives only long enough to produce spores. In Pteris, the gametophyte is small, inconspicuous, short-lived, although it is green and independent because it has to nurture the young sporophyte. The gametophyte is simple in structure — much simpler than the gametophyte of the Bryophytes, for example. The sporophyte, on the other hand, is of great size, green, independent, long-lived and has complexity of structure. The tables are turned. The sporophyte has come into ascendancy, and it has come to stay. The gametophyte in the flowering plants is even less conspicuous, but is still retained because it is needed to perform a vitally important function provided by sexual reproduction.

Fig. 46. — Tree Fern. Hawaii. (Photo by Baker, Honolulu.)

Classification

There are about 4500 species of Pteridophytes, and they are divided into three groups or classes: (1) the Filicineae or Ferns, (2) Lycopodineae or Club Mosses and (3) the Equisetineae or Horsetails.

Class 1. Filicineae. The greater number of Pteridophytes belong to the Filicineae. In general, most of them resemble Pteris. The stem is not always long and slender, as in Pteris, but may be short and stocky. The leaves may be less or more subdivided. The greatest living Pteridophytes are tropical forms (Fig. 46) called Tree Ferns, which may grow to be forty feet in height. They have a rough trunk, at the top of which is a crown of large, feathery leaves.

Fig. 47. — Sori on under side of leaflet of Polypodium.

There is a great deal of variation in the extent of the subdivisions of the leaves of ferns. In some forms the leaf blade is not subdivided, as in the rare walking-fern. In others the leaves are more divided than in Pteris. In many forms the sporangia are borne in little clusters, called sori (Fig. 47), having a dot-like appearance on the under surface of a pinnule. In the Cinnamon fern (Fig. 48) there are two kinds of leaves, first, *sterile* or vegetative leaves, which are green, and second, *fertile* leaves bearing sporangia. In the Interrupted fern, a few pinnules in the middle of the blade are exclusively sporangia bearers. In the Grape fern, the leaf stalk divides into two branches — one green and subdivided as before and the other spore-bearing only.

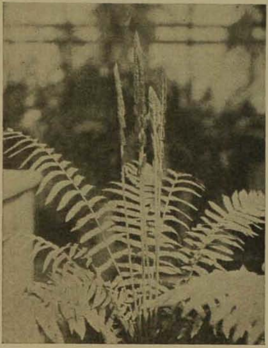

FIG. 48. — Osmunda cinnomomea. Fertile fronds or sporophylls in center surrounded by vegetative fronds. (Photo. by Fread.)

Class 2. Lycopodineae. (1) A study of *Lycopodium,* the Club Moss (Fig. 49), one of the Lycopodineae, shows several points of biological interest. It is one of the oldest of Pteridophytes, long antedating the seed plants. The slender stem grows along the ground among dead leaves or just beneath the surface. Here and there it sends up many upright branches. The leaves are small and crowded, giving an appearance resembling moss, and because of this the plant was called a moss. A study of the stem (Fig. 50) reveals important differences from that of Pteris. It is surrounded by epidermis, beneath which is a large cortex with a cylindrical mass of vascular tissue in the center. In the cortex we find schlerenchyma and parenchyma, but it is not broken into separate masses as in Pteris. In this respect Lycopodium shows a more generalized structure than Pteris. In the central cylinder of vascular tissue we find alternating irregular bands of xylem and phloem tissues, which are not scattered about as in Pteris.

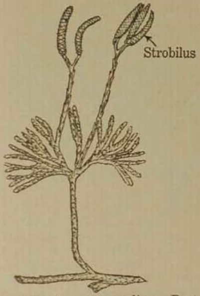

FIG. 49.—Lycopodium. Part of prostrate stem and an erect branch with five strobili at upper end.

At the ends of some branches of certain Lycopods are club-shaped structures.

These are compact masses of special leaves called *sporophylls* because they produce sporangia in which spores are formed. The "club" composed of sporophylls is called a *strobilus* (Fig. 49). The production of spores is thus *limited* to certain definite structures at the upper ends of the branches while the rest of the plant is vegetative. Spores develop into gametophytes.

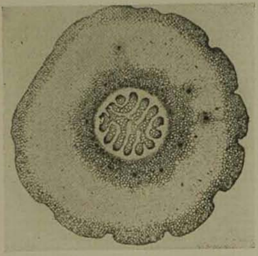

Fig. 50. — Cross-section of stem of Lycopodium. (Photo. by Bratter.)

(2) *Selaginella* (Fig. 51) belongs to another order of the Lycopodineae. It is a delicately-branching little plant, growing prostrate. Rows of small moss-like leaves grow out flat from each side of the stem. At the tip of the branches are also *strobili* which are semi-erect. A matter of especial interest is this, namely, that two kinds of spores are produced in the strobilus, — *small* forms which are called *microspores* and *larger* ones called *megaspores*. On germination, each microspore develops into very simple *male gametophyte* or *microgametophyte*, composed chiefly of a *single antheridium* which produces biciliate sperm. The *megaspore* develops into a simple, *female gametophyte* or *megagametophyte*, which produces *two* or *three archegonia* with one egg in each. This phenomenon occurs also among a few other Pteridophytes, but it is not the rule. We shall consider this matter later and connect it with structures found in lower Seed Plants.

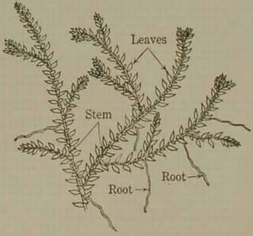

Fig. 51. — Selaginella.

Class 3. Equisetineae. *Equisetum* is an example. It is often found on the dry gravel along the road or by the side of railroad tracks and is commonly known as the horsetail or scouring rush. The rootstock or stem lives in the earth from year to year. From it arise vertical stems of two kinds: *vegetative* and *reproductive*. In some species both are on one stalk. One is a *vegetative* or sterile stem (Fig. 52 *A*), which is fluted and feels harsh to the touch, due to the silica in it. Nodes appear along its length. At each node is a circle of diminutive leaves. From the axils of these grow green stems, also with nodes surrounded by whorls of small scale leaves. Functions carried on by the leaves of ferns are here carried on by these sterile stems. Spores with elaters attached are produced in *sporangia* which occur in *cones* or *strobili*, at the ends of special *fertile* stems (Fig. 52 *B*). The spores look alike but are physiologically differentiated, because one type produces male gametophytes and the other, female gametophytes.

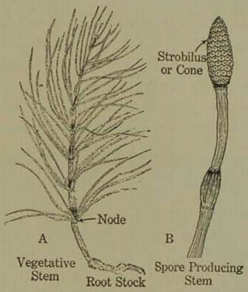

FIG. 52. — Equisetum.

Evolution of Vascular System. A comparative study of the vascular tissues of Pteridophytes shows an interesting series starting with simple conditions and ending in an arrangement like that of higher plants, the *Spermatophyta*. For example, in *Gleichenia* (Fig. 53), one of the Filicineae, the xylem vessels occupy the center of the vascular region and are surrounded by the phloem. The vascular region is restricted to the central portion of the stem and is called the *stele*. In *Lycopodium* (Fig. 50) (Lycopodineae) we found that the stele was composed of irregular alternating bands of xylem and phloem. In *Osmunda* (Fig. 54) (Filicineae) we find that the vascular tissue is in definite groups of cells arranged radially, having the phloem outside and the xylem toward the center of each mass. And this is the arrangement usually found in many of the seed plants.

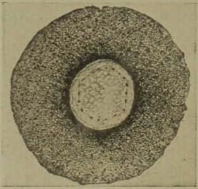
FIG. 53. — Cross-section of stem of Gleichenia. Central cylinder of vascular tissue. Xylem in center of this, surrounded by thin ring of phloem. (Photo. by Martin.)

Summary of Pteridophytes

Pteridophytes are very ancient plants and in bygone ages formed great forests. The carpet-like moss plants with shallow-growing rhizoids and simple stem and leaves have not dominated over the Pteridophytes, which explore deeper into the earth with their roots and bear an enormous increase of leaf area because of their more rigid stems. This great leaf expanse draws from the air great volumes of carbon dioxide, which, with water, makes greater supplies of starch and with added nitrates builds up more protoplasm, more cells and larger plants.

FIG. 54. — Cross-section of stem of Osmunda. (Photo. by Martin.)

Pteridophytes were once more dominant plants than they are today. This was back in the latter part of the Palaeozoic Era of the Earth's history, during the Carboniferous Period millions of years ago and sometimes called the "Age of Coal." The climate was warm and moist and there existed great swamps where now are coal beds. It has been suggested that the atmosphere contained a greater percentage of carbon dioxide than at present. It is known, today, that greater plant growth takes place in air containing a slight excess of CO_2. A warm, moist atmosphere containing an excess of CO_2 would favor great plant growth. The true ferns were represented as an undergrowth, but there were great Lycopod trees, Lepidodendrons and Sigillarias, 100 feet or more in height, with trunks 3 feet or more in diameter and with spreading roots whose branches ramified through the mud of the swamps. Equisetums, called Calamites, were present also, some over 100 feet in height, with great, hollow trunks somewhat like those of bamboo. In spore-bearing time, the air was probably filled with clouds of spores. There existed also large plants formerly considered as ferns but now known as Pteridosperms, primitive seed plants. The swamps teemed with animal life, many types being destined to evolve into terrestrial forms. Dragon-flies and cockroaches existed, but there were no bees, moths or butterflies, and there were no flowering plants. The climate changed during the following Permian period and the great Lycopods and Equisetums disappeared, but smaller forms of the same groups clung to life during all the changes of climate throughout the ages and transmitted their kinds on to present days.

In our study of Bryophytes it was found that there are two kinds of gametophytes, male and female. In some ferns there are also two kinds of prothalli, or gametophytes, male and female. The spores that form them look alike as in Equisetum, but there are real differences between them. In Selaginella there is a visible difference between the spores, *i.e.*, *microspores* and *megaspores*. They come from different sporangia — microsporangia and megasporangia. Sporangia are sporophyte structures. Therefore, sexual differentiation has extended in a sense to the preceding sporophyte generation. Moreover, the microspore develops into a male or *microgametophyte* and the megaspore into a female or *megagametophyte* — both growing while still attached to the sporophyte and both very small. This is similar to what is found in the higher and dominant seed plants, only there the diminution is carried even further. Both gametophytes of Selaginella depend on the sporophyte for nourishment — a condition we will find to be true in the Spermatophytes or seed plants. The developing microgametophyte of Selaginella becomes dislodged from the place where it is formed, at the upper end of the strobilus, and falls to sporophylls farther down and comes into contact with a developing megagametophyte, so that the liberated sperm cells can easily fertilize the egg cells in the archegonia. The bringing together of sperm and egg cells (gametes) *does not depend so much on the motility of sperm* as in cases hitherto studied. *The male gametophytes are in their entirety brought into close juxtaposition with the female gametophytes, so that the sperm are near to the eggs.* A further elaboration of this process is characteristic of the higher plants.

The vegetative functions of Pteridophytes are carried on by the sporophyte, which has come into the ascendancy in this group. In the Bryophytes it was small, inconspicuous and dependent on the gametophyte. The gametophyte stage in Pteridophytes is retained, though reduced in size. It is green in some cases and so physiologically independent but it is short-lived. It is rather dependent in Selaginella. It is retained in Pteridophytes for the production of gametes and the interpolation of a sexual phase between successive sporophyte stages. The retention of the sexual phase appears to be necessary.

The greater development of the sporophyte means more roots that draw upon greater resources of mineral constituents for protoplasm; the stem, increasing in size or extent, can support a greater display of leaves and can conduct the soil ingredients to them, and the greater leaf expanse can make more starch and more protoplasm and provide for a greater plant. In addition to the above, the *new sporophyte has developed the possibility of being perennially active.* There is a great increase in number of sporangia and a much greater multiplication of spores, which, being scattered farther, spread the species into new environments, where individuals are subjected to new conditions which may modify them and so set the stage for the origin of new types. The adoption of the green leafy habit by the sporophyte generation of Pteridophytes was of great evolutionary significance.

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