CHAPTER II

PHYLUM — THALLOPHYTA

Introduction. In most cases there is little difficulty in deciding whether a particular living thing is plant or animal. One of the obvious differences is the animation, or movement of animals, in contrast to the more passive state of plants. Both plants and animals, however, are fundamentally similar. If this were not true, there could be no general science of biology.

In order to discuss general biological principles, we must know something about the kinds of plants and animals and we must proceed with our study in a systematic, orderly fashion, which is one of the first rules of any science. The forms and functions of *Plants* will be our first study.

Parts of a Complex Plant. Plants differ in complexity. Fig. 1 is a *diagram* of a complex plant. It has different *organs* — *i.e.*, (*a*) leaves; (*b*) stem; (*c*) roots; (*d*) flowers; and (*e*) fruit, with its seeds. The organs in turn are made up of more specialized structures called *tissues*. Fig. 2 is a diagram of the *tissues* of one of these organs, *i.e.*, a leaf. The microscopical study of tissues reveals the fact that they are made up of very small units called *cells*. A cell is a biological unit, and it has both structure and function. The cell wall and sap of the plant cell shown in Fig. 3 are non-living matter. The shaded portion is living matter or *protoplasm*. The oval-shaped body at one side is the *nucleus*, which differs chemically from the *cy-*

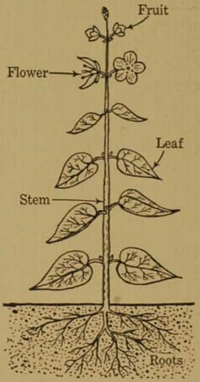

Fig. 1. — Diagram illustrating the organs of a complex plant.

toplasm or the remainder of the protoplasm of the cell. A tree is a composite of thousands and thousands of cells. Bessey estimated that a single leaf of the size of an apple leaf contained at least 50,000,000 cells. The total number of cells in an entire apple tree is incomprehensible to the human mind.

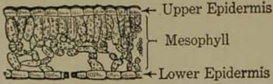

FIG. 2. — Diagram of tissues of leaf.

It is also a remarkable fact that these millions or billions of cells constituting the apple tree are all descendants of one original fertilized egg cell.

Single-Celled Plants. But there are plants which consist of single cells only, and yet are complete organisms. This implies that they carry on all the processes essential to life. They do many different kinds of things, as does the apple tree, in order to live. We naturally think of them as simple plants and we think of the apple tree as a complex sort of plant. Our comparison is based chiefly on the apparent differences in morphological complexity or of form. If we study the functional phenomena of a single-celled plant, we find it exceedingly complex. In fact, the most exhaustive studies yet made have not revealed the whole story of what goes on in one of these simple plants. The same statement can be made concerning *any* of the cells of the complex apple tree. It is safe to say that the scientific attitude in regard to this question is, that what we do not know is greater than what we do know.

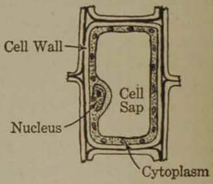

FIG. 3. — Diagram of a plant cell.

Some plant organisms consist of a single cell and others consist of multitudes of cells, which are organized into different tissues and organs. Many plants are within these two extremes of cell organization and vary in degree of complexity between the lowest single-celled types and the highest types, represented by the apple tree.

Four Phyla of Plants. At least a quarter of a million specific kinds of plants are known. It is manifestly impossible for most persons to become acquainted with every one of them. The *taxonomist*, however, finds that there are only four chief types of organization, and it is easy to become familiar with the characteristics of these and some of their subdivisions. It often gives pleasure to be able to assign plants to their proper morphological *group* even though one may not know the *species*. A species is a particular kind of animal or plant. The four groups or *phyla* into which the plant taxonomist divides the plant world are: 1st, *Thallophyta;* 2nd, *Bryophyta;* 3rd, *Pteridophyta;* 4th, *Spermatophyta.*

PHYLUM — THALLOPHYTA

A free translation of this word is " leaf-like plants." It suggests that Thallophytes do not have different organs like the apple tree, but are more simply organized. Some are single cells, some are mere rows of cells, some form thin sheets of cells. Some, as the single-celled types, are exceedingly minute, while some multicellular kinds form a great mass of cells. On the whole they do not possess any rigid tissues by virtue of which they can grow high above the ground like the apple tree. Thallophytes usually live in the water or in wet places. There is little cell differentiation among them. They have the simplest type of plant organization, and are thought to be the oldest types of plants, *i.e.*, their ancestors appeared on the earth *many* centuries (see page 487) before such forms as the apple tree. One of the great generalizations of biologic science is that of evolution. Its application here indicates that the plant world began with simple forms which developed as time went on into more complex forms. We are prone to regard the more simple forms as lower, and the more complex as higher. It is probably more correct to say that there has been a slow modification of generalized forms into specialized forms. Classifications of plants and animals attempt to portray the course taken in this evolutionary process. Classifications indicate relationships, and taxonomists determine these relationships by anatomical, histological, embryological and physiological studies of the forms. Taxonomists consider any sort of information that has a bearing on their problems.

From one point of view, Thallophytes are divided into two groups, *Algae* and *Fungi*. The Algae possess that unique pigment, chlorophyll, the green coloring matter of green plants, which is so vitally important to all life on this earth. Plants that possess chlorophyll can, in the presence of sunlight, make sugar and starch out of carbon dioxide and water. The Algae can do this. They possess this form of physiological *independence*. The Fungi, on the other hand, possess no chlorophyll and are thus physiologically *dependent*. They get their nourishment from dead organic matter, in which case they are *saprophytic;* or they are nourished on the tissues of living organisms, in which case they are *parasitic.*

Sub-Phylum I — Algae

Most Algae live in water or damp places. There are four groups according to their color: (*a*) *Cyanophyceae;* (*b*) *Chlorophyceae;* (*c*) *Phaeophyceae;* (*d*) *Rhodophyceae;* or stated more simply, the Blue-Greens, Greens, Browns and Reds, respectively.

Class 1. Cyanophyceae. These are single-celled forms or linear arrangements of cells, forming simple colonies. They have a blue-green color due to the presence of blue and yellow pigments in addition to the green. There are other combinations of pigments, and as a result some of these Algae appear to be orange or pink. The Red Sea derives its name from the color of certain Cyanophyceae which occur there in great numbers. Investigators do not agree as to the existence of a distinct nucleus. Some types form mucilaginous masses in which the cells are imbedded. Some types float on water in hot springs, while others grow on wet earth or stones. Single-celled forms reproduce by *fission*, *i.e.*, the cell divides into two cells, each of which grows to the size of the parent cell. If the form is filamentous, the filament increases in length by the division of some of its cells and the subsequent growth and division of their daughter cells. Longer filaments break, forming shorter ones, which again increase in length as indicated.

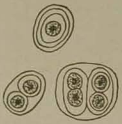

Fig. 4. — Gleocapsa.

Three forms are here described. (*a*) *Gleocapsa* (Fig. 4) is a single cell with a wall which forms a mucilaginous coating. When such a cell divides, each daughter cell wall becomes mucilaginous and is retained within the mucilaginous envelope developed by the mother cell, to form a simple colony. Gleocapsa is a blue-green, jelly-like mass found on damp walls and rocks. Its method of reproduction is called *simple fission.* (*b*) *Nostoc* (Fig. 5) is a linear arrangement of cells resembling a chain of beads, coiled up within a jelly-like envelope. At intervals a larger and clearer cell, the *heterocyst*, occurs. Segments between heterocysts may work their way out of the mucilaginous envelope and start new colonies. Usually little gelatinous colonies break away from the main colony. Nostoc is found in slimy masses floating on water or on damp soil. If the habitat becomes dry or cold, certain cells in the filament increase in size, storing food reserves, and the wall becomes thicker. Such cells resist destruction during unfavorable periods and on the return of better conditions have the power of forming new filaments. In this form we note three types of cells: 1st, vegetative cells; 2nd, heterocysts; 3rd, resting cells.

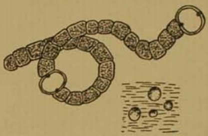

FIG. 5. — Nostoc. Two heterocysts are indicated in this filament. Four colonies at lower right.

(*c*) *Oscillatoria* (Fig. 6) is one of the most common forms. It is filamentous, with a very thin jelly-like envelope about the filament. The cells are short cylinders or discs. The filaments have a swaying movement; hence the name of the plant. The end cell where the movement is greatest is rounded. Any cell in the filament may divide into two cells. Often gelatinous discs are formed at intervals. The longer filaments break at these points and the pieces grow again by division of cells, and by later growth of the daughter cells. This method of reproduction is *vegetative.*

FIG. 6. — Oscillatoria.

The Blue-green Algae are often called *Fission Algae* because their method of reproduction is by a simple form of cell division, called fission. In some types, certain cells may grow to be larger than usual. Such cells, isolated from the filament, form new filaments. These special cells are called *spores.* A similar process is found among the Bacteria. The spores just indicated are not motile. Some of these Blue-greens become established in municipal reservoirs, imparting to the water a bad taste and odor.

Class 2. Chlorophyceae, or Green Algae. These are the common Algae of fresh water. There is no other pigment associated with the chlorophyll which occurs in bodies called *chromatophores.* The nucleus is well defined, and the plant body is very simple. The methods of reproduction are not specialized, except in a few cases. Existing Green Algae are considered to be similar to the ancestral forms from which the higher or more specialized plant groups have developed by evolution. Four forms are considered here.

FIG. 7. — Diagram of a cell of Spirogyra.

(1) *Spirogyra* (Fig. 7), sometimes called pond scum, occurs as masses of filaments floating in fresh water. The plant body is a long, slender filament consisting of cylindrical cells. Just inside the cell wall is one or more spirally wound green chromatophores with irregular edges, and at intervals in the chromatophores are small bodies called *pyrenoids* or starch formers. Around them small granules of starch are found. In the center of the cell space is the *nucleus* surrounded by a small amount of *cytoplasm.* From this central mass, strands of *cytoplasm* extend out to the periphery to a thin layer of cytoplasm lining the cell wall. The remaining space is filled with cell sap. The wall is composed of cellulose. Reproduction is peculiar. (*a*) Any cell may divide and make the filament longer. This is vegetative reproduction. (*b*) When two filaments lie side by side, two adjacent cells coming in contact may develop small tubes (Fig. 8) which form a canal connecting one cell with the other. The entire contents of one cell pass across through this canal to the protoplasm of the other cell and fusion takes place, forming a special cell with a thick wall. Studies indicate that the *chloroplast* of the motile cell disintegrates and that the *spiral chromatophore* of the fused cell is derived from that of the passive

FIG. 8. — Conjugation in Spirogyra.

cell. Specimens are found in which nearly all the cells of one filament have passed over into opposite cells of the other filament. It is now believed that the cells *moving across* are *male*, while the *stationary* cells are *female*. The two cells which unite are called *gametes* and the single fused cell is a *zygote*. In this condition, the winter or some other unfavorable period is passed. When conditions are right, the original walls decay, and each of the zygotes develops eventually into a new filament. It should be noted that such new filaments began life as a single cell formed by the *fusion* of two cells. Spirogyra is excellent laboratory material for obtaining a knowledge of the characteristics of plant cells.

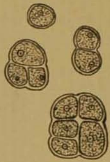

Fig. 9. — Pleurococcus. One cell, two cell, three cell, and five cell groups.

(2) *Pleurococcus* (Fig. 9), is morphologically simpler than Spirogyra. You may have observed a green coating on the shaded side of trunks of trees. A study of a minute portion of this green material reveals the fact that it consists of a great many very small green-colored cells. Each cell has a nucleus and a chlorophyll body. The cells divide and the daughter cells remain in association with the other cells. Possibly they secure mutual protection. Although apparently simple cells, each performs all the necessary functions of life, such as digestion, circulation, excretion, oxidation and photosynthesis.

Fig. 10. — Ulothrix. Holdfast indicated at lower end of filament.

(3) *Ulothrix* (Fig. 10) is a filamentous form, consisting of short cylindrical cells, each with a nucleus and chromatophore. The basal cell acts as a holdfast to the substratum. This Green Alga has three methods of reproduction: (*a*) Vegetative. (*b*) Internal division of one cell into a number of cells. Each of these is called a spore. This method, called *Sporulation*, is employed by all the higher groups of plants. In the case of Ulothrix, each spore (Fig. 11), when liberated, has four motile processes, or *flagella*, which are organs of locomotion and by which the spores swim actively about for a time, settle to the bottom and by cell division form a new filament. Such actively swimming spores are

known as *zoospores*. There is a distinct advantage in this type of reproduction, because some spores may lodge in a new place, more favorable for successful development. (*c*) Any cell of the filament except the holdfast may divide internally more times than in the formation of zoospores, and so form still smaller spore-like cells. When mature, these are discharged, possessing only two flagella. After swimming about, if these bi-flagellate cells settle to the bottom, they disintegrate because individually they do not possess the power of developing into a new plant. But some of the swimming cells *fuse in pairs* (*conjugate*) and form *zygospores*, which have four flagella. Later these settle to the bottom and produce active zoospores, which then develop into filaments. It has been suggested that the small bi-flagellate cells are small zoospores. They differ from the latter, however, in that they must *fuse in pairs* to continue functioning. In *conjugating* there is a chance that bi-flagellate forms from different filaments may unite, forming a new combination of protoplasm which may have a better chance of survival than the ordinary zoospores. The small bi-flagellate cells are called *gametes*, because they unite (marry) to produce a cell that will eventually grow into a new individual. Since the gametes are approximately equal in size, they are called *isogametes*. The single, four-flagellated cell formed by the fusion of two gametes is called a zygospore. A more general name is *zygote*. The type of reproduction just described may be considered a very primitive form of sexual reproduction.

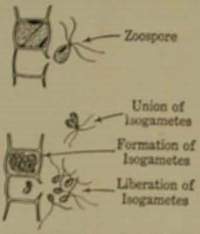

FIG. 11. — Reproduction in Ulothrix.

(4) *Oedogonium* is another filamentous Green Alga whose cells (Fig. 12) are cylindrical in form. Oedogonium reproduces in three ways also. (*a*) Vegetatively. This has already been defined. (*b*) Zoospores. These are produced by internal division of certain cells of the filament. The liberated spores are ovoid in shape with a crown of cilia near the smaller end. After swimming about they settle to the bottom and form new filaments. (*c*) Sexual Reproduction. Certain cells increase in size by storing up food, become spherical in shape and covered with a firm capsule. In-

side this capsule is a single large *egg cell, ovum, female gamete* or *megagamete.* All these words are synonyms. The ovum and its capsule form a body known as an *oogonium.* Other cells in the filament subdivide internally, forming very *small* ovoid cells, resembling the zoospores but much smaller. Each has a crown of cilia at its small end. These are *sperm cells, male gametes* or *microgametes.* The special body where they develop is an *antheridium.* The wall of the oogonium has a small perforation. The sperm cells (microgametes) escape from the antheridia and swim about actively among the filaments containing oogonia. Sperm penetrate the oogonia. Fertilization consists in the union of an egg nucleus with a sperm nucleus. The fused or conjugated sperm and egg (microgamete and megagamete) is a *zygote* or *fertilized egg.*

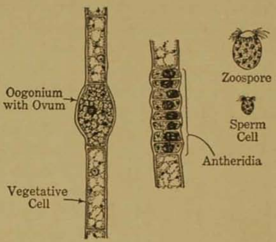

FIG. 12. — Oedogonium. Types of cells. (In part after Strasburger.)

The zygote germinates, *i.e.*, divides and grows, forming four zoospores, each of which produces a new Oedogonium filament (plant). The equal-sized gametes of Ulothrix were called *isogametes* in contrast with those of Oedogonium, which, being unequal or dissimilar are called *heterogametes.*

Reproduction involving the union of a microgamete and a megagamete to form a zygote is *sexual reproduction.* Oedogonium presents one of the simplest examples of sexual reproduction. At this point it is possible to state several generalizations of broad biological importance. It is evident that the setting apart of special cells for the production of eggs and sperm occurs in the simplest of plant forms, *i.e.*, sexual reproduction was established early in the evolution of plants. It is noted also that sex organs — even though simple — are organized before the appearance of special cells or organs for any of the other kinds of physiological processes. We will note these two generalizations in the animal world also. In the next place we find that eggs and sperm cells differ in important respects, while at the same time they agree in other just as important respects. Let us see what these are. Eggs are large, passive and filled with nutriment. Sperm are small, very active and possess a minimum of nutriment. Egg and sperm agree in the *quantity* of their *nuclear contents* although the nuclei are probably *qualitatively* different. The essential feature of fertilization consists in the fusion of the two nuclei. The entire mechanism suggests a scheme for bringing this about. In certain species of Oedogonium, oogonia and antheridia may occur on the same filament. Such species may be called *monoecious* or *hermaphrodite,* in which case the *individual* is double sexed. In other species, some filaments possess only antheridia and may be considered male. Others, that possess only oogonia, may be considered female. In this case, the species is *dioecious* or separate sexed. Oedogonium possesses a very simple plant body, but it is specialized in its reproductive mechanism. Ulothrix illustrates the transition from the simpler asexual method of reproduction toward the sexual method, which is clearly present in Oedogonium. *Sex organs* may be defined as structures specialized for the production of sex cells. The sex organs of Oedogonium are very simple, being merely specialized single cells. Sex organs are far more complicated in higher plants and animals. In addition there are also highly specialized accessory structures. Such elaborate systems are necessary to bring about the same result that is effected by the simple method we have studied in Oedogonium. The result in all cases of sexual reproduction is a conjugation of a male cell, or sperm, and that of a female cell, or egg. Reproduction by spores, which is asexual, means continuation of the same protoplasm, while sexual reproduction, because of the union of different cells, means the possible formation of a new combination of protoplasmic characteristics.

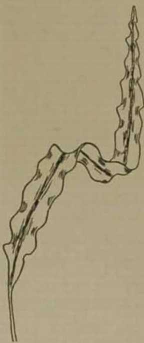

FIG. 13.—Laminaria —a kelp.

Class 3. Phaeophyceae. The Brown Algae are usually marine forms attached to rocks. A brown pigment gives the characteristic color which masks the green chlorophyll. Some of these forms are of great size, being about 150 feet in length. Along the Pacific Coast are great kelp beds (Fig. 13), many miles in extent. They are of great potential value because they contain potassium salts, an important ingredient of commercial fertilizers. It is said that one ton of dried kelp contains 500 pounds of these salts and three pounds of iodine, together with other valuable compounds. Phaeophyceae are very specialized Algae of uncertain origin. Chlorophyceae are comparatively small aggregations of cells, while the Phaeophyceae possess innumerable cells. Differentiation into special tissues is evident in the kelps. One form is described because it illustrates further specialization in the development of sex organs.

FIG. 14. — Fucus growing on rocks. Photographed at low tide. (Photo by Fread.)

Fucus or Rockweed (Fig. 14) lives as masses of short plants attached to rocks, where tidal waters cause it to be uncovered at low tide. It has strap-shaped branches (Fig. 15) which fork in twos or *dichotomously*. The branches possess air bladders which float the plant. Fucus produces no asexual spores, but always reproduces sexually. The ends of some branches have swollen tips or *receptacles*, covered with warty bodies. There is a small pore at the outer end of each of these small swollen bodies. This pore leads into a chamber (Fig. 16) called a *conceptacle*. Its walls are lined with a mass of hair-like filaments called *paraphyses*. Some species of Fucus are

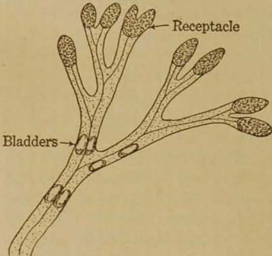

FIG. 15. — Fucus. Drawing indicates branching habit of plant body.

FIG. 16. — Section through receptacle of Fucus showing eight oogonial conceptacles.

monoecious, while others are *dioecious.* In either case the sex organs are located among the paraphyses of a conceptacle (Fig. 17). In the *monoecious* type, little club-shaped bodies or antheridia are attached to paraphyses. The antheridia produce many biciliated sperm. In the same conceptacle are found large spherical bodies attached to the wall by a short stalk. These are *Oogonia.* Each Oogonium produces eight eggs, as a rule. The eggs and sperm are discharged and the active, swimming sperm swarm about the floating eggs and fertilize them. From this union a new plant develops. In the *dioecious* forms, the conceptacle contains only antheridia *or* only oogonia. It should be noted that the organs of reproduction are restricted to particular places in this form. Although Fucus does not reproduce by spores, yet some Brown Algae reproduce by spores as well as sex cells. Both are produced in special organs, the spores in *sporangia* and the sex cells in *gametangia.* The conceptacle of Fucus is a *gametangium.*

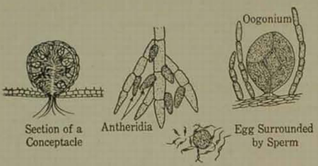

Fig. 17. — Reproduction in Fucus. From Sinnott's *Botany*, copyright by McGraw-Hill Book Co Reprinted by permission.

Class 4. Rhodophyceae. The Red Algae are the most specialized of the Algae, and have no apparent relationships with the other groups. They are mostly marine, not so large as the browns and occur most abundantly in warmer seas. A red pigment masks the green chlorophyll. Some types (*Corallines*) secrete lime, and such forms aid in the building of coral reefs. Rhodophyceae reproduce by spores, asexually, and also sexually by means of eggs and sperm, which occur in special organs. From *Chondrus crispus*, Irish Moss (Fig. 18) *gelatin* is obtained and from certain other types such as Gelidium, *agar-agar,* a gelatinous substance used extensively in bacteriology, as a culture medium for bacte-

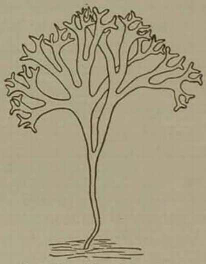
Fig. 18. — Chondrus crispus.

ria. In some species of Red Algae, the life history is cyclical. Certain individual plants produce only spores. These form plants which bear sex organs which produce sex cells. The fertilized egg or zygote forms a plant which produces only spores. In other words, a spore-producing plant develops from a fertilized egg, and a plant producing sex cells develops from a spore. The plant that produces spores is called a *Sporophyte*, while the plant that produces gametes (eggs and sperm) is called a *Gametophyte*. The Sporophyte generation alternates with the Gametophyte generation. This is known as *Alternation of Generations*. It is characteristic of all the higher plant groups, and is one of the great features of plant phylogeny or race development.

Diatoms (Fig. 19) are unicellular Algae varying greatly in shape. They are bilaterally symmetrical. One of the two halves or valves overlaps the other like the lid of a box. They contain considerable silica. Their walls are marked with projections or depressions in regular patterns of many kinds. They reproduce by division, the two valves separating and each forming half of a new cell or plant. They not only occur in fresh water, but countless millions are found at certain seasons near the surface of the ocean, where, with other minute forms of plants and animals, they make up that vast world of microbiology called the *Plankton*. You have heard the statement that "All flesh is grass," because plants are the basic food of animals. That statement could be amplified, for fish is flesh and someone has said that "All fish is diatom." This is explained as follows. Some of our larger food fishes of the sea subsist on smaller fishes. These smaller fry eat other organisms which subsist on others which feed on plankton, of which diatoms may be the chief constituent. The siliceous "shells" of dead diatoms settle to the ocean floor, forming thick deposits during the ages. Due to changes in the earth's surface vast areas of what was once the floor of the sea become part of the dry land, and here

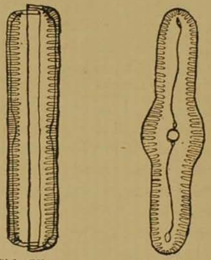

FIG. 19. — Navicula — a diatom. From Smith and Others: *General Botany*, Revised Edition, copyright 1928 by The Macmillan Company. Reprinted by permission.

and there are found great deposits of siliceous or *diatomaceous earth.* Petroleum is also said to have been derived from diatoms. The surface markings of certain diatom valves are so fine that they serve as objects for the testing and standardization of microscopic lenses. The color of diatoms is due to chlorophyll and a yellowish brown pigment. Some taxonomists classify them with the Chlorophyceae and others with the Phaeophyceae. Diatomaceous earth is used as an abrasive medium in silver polish and tooth pastes.

Summary. The Algae range in form from single-celled plants and simple chains of cells to great masses of cells associated in three dimensions of space. Reproduction is at first by *simple fission,* then *vegetative,* then by *asexual spores* and by *gametes.* Fission, vegetative reproduction and sporulation are forms of asexual reproduction. The sexual method of reproduction, with sex organs, is also well established although the plant body seldom becomes highly differentiated. While alternation of generations (asexual alternating with the sexual) is not characteristic of the Algae as a group, yet it is represented. The Algae are the most ancient of true plants that have chlorophyll. Of all the four groups, the botanists are agreed that the Chlorophyceae must be regarded as that group which was ancestral to the next group of higher plants, known as the *Bryophytes.*

Sub-Phylum II — Fungi

Fungi are simple dependent plant forms that cannot make carbohydrates from carbon dioxide and water. They possess no chlorophyll and are either *parasitic* or *saprophytic.* They reproduce by cell division, by budding, by means of spores, and there is also an indication of the sexual method of reproduction in some cases.

Class 1. The Bacteria. Bacteria are here considered with those plants which do not possess chlorophyll and are *parasitic* or *saprophytic.* Some do not regard them as Fungi, because the word *fungus* literally means mushroom, and the plant body of the mushroom consists of a mass of filaments. Yet Bacteria are *sometimes* called *Schizomycetes,* which literally means Fission Fungi, because they reproduce by fission and because they often form *filamentous colonies,* and the plant body of true fungi is a mass of filaments.

Indeed some bacteriologists regard Bacteria as comprising a group of organisms entirely distinct from plants and animals.

Bacteria are the very smallest known organisms. High powers of microscopic magnification are needed to make them visible, and even then, some which are known to exist because of their influence cannot even be seen. Three types as to form (Fig. 20) are: (1) the *Coccus*, which is a spherical cell. *Pneumococcus*, the organism which causes pneumonia, belongs to this general group. Cocci may be arranged in rows, in which case they are called *Streptococci*, as the organisms which cause septic sore throat, blood-poisoning and possibly tonsillitis. (2) The *Bacillus* is rod shaped. Bacillus subtilis, the hay bacillus, is a common form. (3) The *Spirillum* is shaped like a cockscrew, the number of revolutions varying from one to many. Organisms which cause cholera have this form. The student should not conclude that all Bacteria are disease-producing. Every person may take Bacteria into the body daily with food, drink or air. Even though some of these are potential disease makers they are actually harmless when we are *immune* to them. But there are many very useful Bacteria. Bacteria possess no organized nucleus, but it is believed that nuclear material is distributed throughout the protoplasm. Some have little protoplasmic motile processes, called flagella, by the movement of which they possess considerable power of locomotion. Some have a single flagellum at one end. Cholera Bacteria move in water at the rate of 15 mm. an hour. Bacteria reproduce by simple *fission*, *i.e.*, the bacterium divides in two and each daughter cell soon grows to a mature size and is then ready for division. So rapid is the reproduction at times that millions may be formed from one original cell in the course of a single day. Certain types are able to surround themselves with a sticky gelatinous matrix, forming a capsule which they secrete. Such a formation is known as *Zoogloea*, as "Mother of Vinegar." Under unfavor-

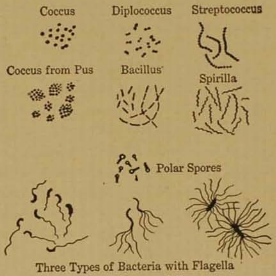

FIG. 20. — Types of Bacteria.

able conditions some bacteria go into a resting stage called a *spore*, in which the organism is surrounded by a very thick wall. In this state the cells resist death from desiccation or other adverse conditions. When proper conditions return, the spore wall bursts and the living cell escapes, feeds and reproduces, thus recolonizing the medium in which it lives. Bacteria live practically everywhere, — in water, in deserts, in air, in soil, in hot springs, in ice, in milk and in the bodies of plants and animals. They concern civilized life to such an extent that the separate biological science of Bacteriology has come to be of the greatest importance.

In studying them the bacteriologist determines first their morphology, which is the smallest part of his task. He also studies the form, color and structure of their colonies, grown on various types of nutritive media, such as gelatin and agar-agar. The physical and chemical changes produced by these colonies on the media are important criteria of identification. Some species are so small that they cannot be studied microscopically.

After the Germ Theory of Disease had been accepted, of course many investigators attempted to discover the specific microorganisms causing infectious diseases. Bacteria were shown to be the causative agents in many cases. But no microorganisms were found in many others. It was suggested that in these cases the organism was so small it could not be seen microscopically and so could not be isolated. But, on the other hand, it might be present in infectious material from a diseased animal even though this substance were passed through a bacteria-proof filter. Frosch and Löffler in 1898 succeeded in *transmitting* foot and mouth disease with such a *filterable virus.* Today about forty filterable viruses are known. Among them are those of rabies, infantile paralysis, typhus fever, measles and smallpox. Whether the organisms are Bacteria or Protozoa is not known.

It is an almost universal characteristic of living things that they use atmospheric oxygen in their metabolic activities. There are Bacteria, however, that exist in the absence of atmospheric oxygen. These are known as *anaerobic* Bacteria, to distinguish them from the great majority of air-loving forms which are called *aerobic.* Special cultural methods are used for the cultivation of such forms. Indeed, anaerobic Bacteria perish if exposed to the atmosphere. Some kinds of Bacteria are *parasitic, i.e.*, they inhabit and obtain their food from living organisms. They are not always harmful. In the large *coecum* of the rabbit, cellulose, which is a large part of its diet, is digested by the resident Bacteria. On the other hand, in the human intestine, under certain conditions they cause excessive fermentation, produce distressing volumes of CO_2 and sufficient organic acids to irritate the mucous membrane of the intestine and cause diarrhea.

Cycle of the Elements. Saprophytic Bacteria live on dead organisms and play an important rôle in the cycle of organic life. By means of ferments or enzymes they break down, step by step, the complex proteins of the organism into simpler compounds of putrefaction, so evident by their offensive odors. They form ammonia. Carbohydrates and fats are disintegrated into carbon dioxide and water. The classes of Bacteria that bring about decay are of vital importance to the existence of plant and animal life. These Bacteria free chemical elements for further use in new generations of animals and plants. They have been called the traffic policemen of the elements, keeping these in circulation, now forming substance of living matter and later being part of the inorganic world to be organized still later into living tissues again. The carbon dioxide formed in processes of decay is returned to the atmosphere and may again be used by green plants in the manufacture of carbohydrates. A certain group of Bacteria, *Nitrosomonas*, converts the ammonia above referred to into nitrites. Some of these nitrifying Bacteria can even use carbon dioxide in the absence of chlorophyll.

Fig. 21.— Tap root of a legume showing several nodules of nitrogen-fixing Bacteria.

Some biologists have speculated as to the earliest formation of living things in the comparatively early days of the Earth. They have suggested that Bacteria similar to Nitrosomonas might have been the first living things. *Nitrobacter* is a bacterium which can change nitrites into nitrates, and thus such salts as potassium and calcium nitrates may be formed which are taken up by roots and from such compounds, the nitrogen for plant proteins may be obtained. Certain nitrogen-fixing Bacteria (Fig. 21) live in nodules on roots. They are able to utilize the free nitrogen of the air and form compounds which are used by those plants with which the nitrogen-fixing Bacteria are associated. Other Bacteria decompose organic compounds containing sulphur, iron and phosphorus, and so bring about compounds of these elements which can be utilized by living plants.

Pathogenic Bacteria. — It is generally known that some Bacteria cause disease. They destroy tissues directly or secrete toxins or poisons which prevent normal physiological function. Pneumonia, typhoid fever, tuberculosis, diphtheria, cholera and bubonic plague are caused by pathogenic Bacteria.

Relationship. — The Bacteria resemble the Cyanophyceae in some respects. Reproduction in both groups is by fission. Both types of organisms produce a jelly-like matrix. In neither is there a well-defined nucleus. Some biologists, on account of these resemblances, group Bacteria and Cyanophyceae into the group *Schizophyta, i.e.,* plants that reproduce by fission. Some regard Bacteria as degenerate Blue-green Algae. However, Blue-green Algae possess chlorophyll, in spite of the fact that this is masked by a blue pigment, *phyocyanin.* The presence of chlorophyll makes it possible for these Algae to manufacture carbohydrates from carbon dioxide and water. This, the Bacteria, as a whole, cannot do. They must have already prepared carbohydrates to feed upon. In other respects, Bacteria resemble still other groups of organisms.

Class 2. Myxomycetes. This is a group of simple organisms of somewhat uncertain position, which are usually considered with plants. Some taxonomists, however, regard them as simple animals and call them *Mycetozoa.* The common name is *slime molds.* The organism consists of a mass of naked, slimy protoplasm which has a creeping motion. Tongue-like processes at one side are put forth and extend in a certain direction. The protoplasmic mass at the opposite side glides slowly in the direction of the movement. Slime molds live on decaying wood or dead leaves in dim, damp places. There is no chlorophyll present and they are therefore dependent. In the protoplasmic mass are found distributed nuclei. The entire mass is a colony of cells without cell walls. Such an association of cells without separating walls is called a *syncytium.* The slime mold feeds on Bacteria and other small organisms. It simply engulfs its food. At times the superficial protoplasm forms a hard external layer inclosing a thickened protoplasmic mass within. In this resting state it may remain for years but will resume its normal activity when proper external conditions return. The method of reproduction is more plant-like than animal-like. In this process very small, spherical, single-celled spores are formed. When the spores are mature, the sporangium, or spore case in which they were formed, becomes dry, bursts and the spore cells are discharged. From the spore a single irregular-shaped cell escapes. This cell develops a *flagellum.* It moves about and in this stage it resembles Protozoa or single-celled animals. It may divide by fission many times, producing many similar cells. At a later period the flagella disappear. Many such irregular-shaped cells come together. In this way a new protoplasmic mass, similar to the parent organism, is formed again. In food habits, Myxomycetes resemble animals. In the flagellated motile state, as well as in the single-celled ameboid stage, they are quite animal-like. But in the production of spores, they are like plants and especially like the Fungi. When one considers all the characteristics of simple forms like the Myxomycetes, one feels that, after all, it is quite difficult to decide as to just what an animal or plant is. When we think of plants and animals, we usually have in mind higher plants and higher animals, between which there are many apparent differences. Consideration of these lowly organisms, on the other hand, serves to emphasize the underlying unity of organic nature. The words *plant* and *animal* were *invented* many years ago before much was known concerning microorganisms. It is probable that many new puzzling organisms will be discovered. It may be necessary to establish a new category of living things.

Class 3. The Phycomycetes. The body of these plants is called a *mycelium.* The same name applies to the plant body of the next two groups. The mycelium is composed of a mass of filaments called hyphae, and it is connected with dead or living organisms by special absorbing root-like organs called *rhizoids.* Upright branches produce spores and so are called *sporophores.* The Phycomycetes resemble filamentous Algae that have lost their chlorophyll. There are no walls to separate the cells of the mycelium. Such an arrangement is a *syncytium.*

1. *Albugo* (Fig. 22) is a mold which grows in leaves or flowers of plants such as the mustard and radish. The mycelium grows into cell spaces of the host, forming a ramifying network. The spore-producing organs form clusters under the epidermis, separating this from the tissue underneath. Thus the epidermis becomes broken. Spores are formed one after the other by constrictions of the end of the sporophore. They form in rows. Spores pro-

duced in this way are called *conidia*. A leaf infected with sporophores presents the appearance of a white blister. The fungus is, therefore, commonly known as *white rust* or *blister blight*. The spores are scattered by wind. They germinate on the surface of wet leaves and form zoospores which move over the leaf, rest and send hyphae through the air pores in the epidermis of the leaf, thus infecting it. This form possesses sexual reproduction also. *Potato blight*, or *rot*, and *grape blight* are due to other closely related forms.

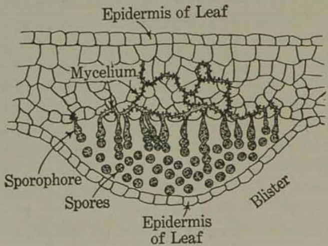

FIG. 22.—Albugo.

2. *Rhizopus* (Fig. 23) is the common black mold which grows on bread. Damp bread, kept under a glass jar, will exhibit a luxurious growth of black mold in a few days. The spores are in the air everywhere. The mycelium is a syncytium. The branching hyphae present a woolly appearance. Long vertical stalks, sporangiophores, end in round black sporangia, in which a great number of spores are produced. This black mold possesses a sexual method of reproduction also. Rhizopus is dioecious — *i.e.*, male and female mycelia occur. If two near-by hyphae of opposite sex occur near each other and touch, short side branches from each grow toward the other. The ends unite. The united part becomes separated from the two hyphae by cross partitions. This

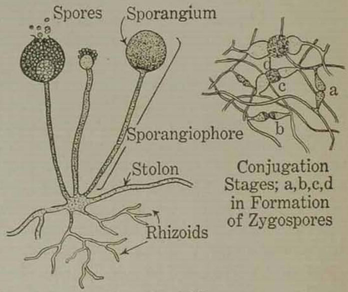

FIG. 23.—Rhizopus.

cell is virtually a fusion of two cells, forming a zygote by the conjugation of the two gametes. The zygote develops a thick wall. After a time it germinates, forming a small mycelium, with a sporangiophore and sporangium.

The great famine in Ireland, in 1846–47, was caused by the destruction of the main food supply, the potato, by a Phycomycete, *Phytophthora infestans*. Our own federal government employs many inspectors to maintain a strict quarantine against the introduction of plant diseases from foreign countries. No sensible person can object to keeping out such undesirable immigrants. Moreover, each state is constantly on the watch to prevent the introduction within its borders of plant diseases that might enter in the course of interstate commerce.

The Phycomycetes resemble the Green Algae in the formation of oospores and zygospores.

Class 4. The Ascomycetes. Most of the Fungi belong to this group and the next. The mycelium consists of filaments in which the cells are separated from one another by walls. Sex organs are reduced or absent. The characteristic of this group is the possession of the *ascus* or sac in which the spores (ascospores) are produced.

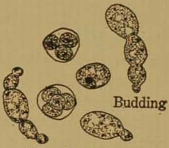

Fig. 24. — Yeast.

1. *Yeasts* (Fig. 24) are simple Ascomycetes. There are about forty varieties of these microscopic yeasts. The form used in bread making is called *Saccharomyces cervisiae*. It consists of ovoid-shaped, colorless cells with a nucleus and a sap cavity in the cytoplasm. The cells feed on sugar solution. The products of their metabolism are carbon dioxide and alcohol. The carbon dioxide "raises" bread dough. Yeast can reproduce by forming a bud. This remains attached to the parent cell and grows. The bud cell may also form a bud. Chains of yeast cells are thus formed. Yeast also forms spores. If food is scanty, the cell divides twice, forming a sac (ascus) with four spores. The wall is hard and resistent. . Later, when favorable conditions return, the wall ruptures, releasing the spores. These are driven about by wind and may reach a favorable medium for further growth.

The yeast cell contains an enzyme, zymase, which changes a simple sugar, glucose, to carbon dioxide and alcohol. The formula is $C_6H_{12}O_6 = 2(CO_2) + 2(C_2H_5OH)$. It is a process of fermentation. Pasteur pointed out that the power was dependent on the ability of the yeast cell to secure energy for its life processes from disintegration of sugar and without the use of the oxygen in the air. Yeast is on this account anaerobic — it can live without air — *i.e.*, without free oxygen. The alcohol produced is the result of an incomplete oxidation. If the process were completed as in ordinary combustion, the end products would be CO_2 and H_2O. When the percentage of alcohol increases to about 15%, the fermentation ceases, due to the formation of such substances as succinic acid and glycerine. Yeast was used empirically for ages before it was really understood. About 1830 it was found to be a plant and the genus, Saccharomyces was established in 1839. The chemical processes involved in this case of fermentation were reported by Pasteur in 1861. In modern commercial bread making the greatest care is taken to use only pure cultures of a particular kind of yeast, and to avoid contamination with wild yeasts.

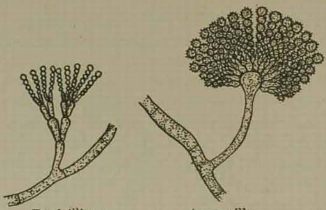

FIG. 25. — Penicillium and Aspergillus.

2. *Penicillium* (Fig. 25) is a Blue Mold. The mycelium grows on various substrata. The hyphae are septate, and possess an enzyme that can change bread to carbon dioxide and alcohol. Erect branches grow here and there and divide at the apex. The upper end of each terminal branch develops chains of spores. If grown where there is a poor supply of oxygen or none at all, certain short hyphae fuse and form a spherical body called an ascocarp. Within this, spore sacs or asci develop. Each ascus produces eight spores. In due time the spores are liberated and form new filaments. Penicillium produces a number of types of enzymes and so can digest many types of food, and this probably explains why it is so widespread. It imparts the green color and some of the flavor to Roquefort cheese. It is also present in other varieties of cheese (Stilton and Camembert). *Aspergillus* is another common form.

3. *Ergot* (Fig. 26) is a black substance that is produced by an Ascomycete, *Claviceps*, infecting rye. A head of rye may contain a number of such *ergotized* grains. Flour made from such grains is poisonous. Extract of ergot is a powerful drug used in medicine to contract blood vessels and so arrest hemorrhages.

Fig. 26. — Head of rye infected with ergot.

4. *Chestnut blight* is another Ascomycete that appeared in New York about 1904. By 1911 it had destroyed about twenty-five million dollars worth of chestnut trees within a radius of two hundred miles of New York and since then has extended much further.

5. *Black knot* is a fungus disease attacking the branches of plum and cherry trees.

6. *Truffles* and the *Morel* are examples of edible Ascomycetes.

7. The *Lichens* (Fig. 27) comprise a unique group. They are the familiar grayish dry growth on old fences, trees or rocks and are composed of an Ascomycete or Basidiomycete, in the mycelium of which live simple Green or Blue-green Algae. This association of two kinds of organisms is called *symbiosis*. Litmus, used to test the alkalinity or acidity of solutions, is derived from a lichen. Iceland moss, a lichen, is used as food by natives of northern countries. Reindeer Moss (Cladonia) grows on very poor soil in the far north and is eaten by reindeer. Lecanora, another lichen, grows in the deserts of northern Africa and is thought to be the "Manna" referred to in the Bible. From the lichen Rocella was obtained a purple dye once used in dyeing silks and woolens.


Fig. 27. — Lichen. (Photo by Schechter.)

Class 5. **Basidiomycetes.** Basidiomycetes are usually larger than Ascomycetes. The spore-producing organs are more prominent. The distinctive feature explaining the name is a special structure, the *basidium*, which produces basidiospores.

An example of a saprophytic form is the common edible mushroom, *Agaricus campestris* (Fig. 28), which grows in meadows under natural conditions, and is now a food product cultivated extensively in mushroom cellars and caves. It should not be called a toadstool — a name popularly given to somewhat similar forms which are inedible. The word *toadstool* is probably a popular derivation from the German words "Todt" and "Stuhl" meaning "death stool." The deadly *Amanita*, which is sometimes mistaken for Agaricus, is a true "todtstuhl."

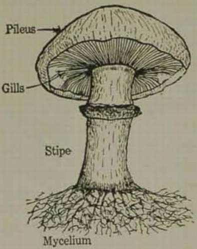

Fig. 28. — Agaricus.

Agaricus campestris has a short, upright stalk or *stipe*, at the upper end of which is the umbrella-like *pileus*. On the under surface of this are seen the radiating lamellae or *gills* (Fig. 29). The "mushroom" grows from a tangled *mycelium* in the earth. The stipe and pileus are composed of hyphae. The hyphae of the gills superficially merge into short, thick, club-shaped bodies, the *basidia* (Fig. 30). At the tip of each basidium are two or four small projections, at the end of which basidiospores are produced. Germinating *basidiospores* develop into mycelia which produce other "mushrooms."

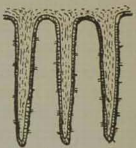
Fig. 29. — Gills of Agaricus.

There are hundreds of basidia, some old, some producing spores and some as yet immature. The spores are very light and can be carried long distances by air currents. It has been estimated that one mushroom can produce two billion spores. Bracket Fungi, found attached to trees, have a mycelium that ramifies into the trunk, destroying the living tissues. In some toadstools the underside of the pileus is toothed, in others it is porous. Puff balls (Fig. 31) are large, round, edible forms. It has

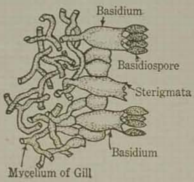

Fig. 30. — Reproductive organs on gill of mushroom. From Gager, *General Botany*, copyright 1926, P. Blackiston's Son & Co., reprinted by permission.

been estimated that one of the larger types may produce ten billion spores.

Gager states that there are over a thousand edible Fungi available. He also says that the only criterion of edibility is determined by experiment, *i.e.*, eat and find out. This, however, is not recommended, but it is suggested that the experienced mycologist be consulted.

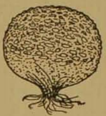

Fig. 31. — Puff ball.

Some of the most destructive plant diseases are produced by other Basidiomycetes. One of these, still unconquered, is wheat rust. During the years 1919 to 1923 it is said that this disease caused a loss of thirty million bushels of wheat. Stinking smut occasioned the loss of eighty million bushels of corn between the years 1917 and 1920. The white pine blister rust threatens the destruction of over a quarter billion dollars worth of pine trees. Some idea of the great economic loss caused by Basidiomycetes has been indicated above. One reason for making it difficult to eradicate these fungous diseases is that so many spores are produced. They are very light and are carried afar by air currents. They are very small and cannot be easily detected. They are also very resistant.

Endothia, the Ascomycete which is the cause of chestnut blight, probably came from Japan, where the native chestnuts are practically immune to it. There are thousands of Fungi. De Bary in 1872 *estimated* 150,000 kinds. There are many whose life histories are not as yet completely known. Some recognized plant diseases are caused by certain forms of these.

Summary of Thallophytes

The plant body consists of single cells, filamentous arrangements of cells or cells in masses with little differentiation into tissues for special physiological functions. Morphological differentiation into tissues so characteristic of higher groups *begins* here. The principal method of reproduction is by means of spores. Contemporary Thallophytes are representative of the earliest plants to appear on the earth. The Algae are typically aquatic as were also probably the first plants. The Cyanophyceae are the simplest from the point of view of structure and reproduction. The Chlorophyceae, whose cells exhibit an organization similar to those of higher groups, are the simplest and more closely approximate the hypothetical ancestors of the Bryophytes. Among the Phaeophyceae are found the largest Thallophytes. The Rhodophyceae are the most specialized. They exhibit alternation of generations so characteristic of higher groups. The Fungi include a miscellaneous collection of dependent forms. While reproduction is chiefly by spores, yet sexual reproduction by isogametes and heterogametes is present in some forms. The Bacteria and Blue-green Algae are similar in many respects. The Phycomycetes are regarded as degenerate forms of a certain type of Green Algae. The relation of Ascomycetes and Basidiomycetes to the other Algae is not at all clear. It is thought that Basidiomycetes were derived from the Ascomycetes.

Apart from such theoretical considerations as to the origin and relationship of the various groups of the Thallophytes, the fact is that one should have an acquaintance with their biology on account of the vital ways in which they affect mankind. The Fungi and the Insects are probably the most formidable contenders with Man for dominance on this earth. The Algae are of some economic importance. Moreover the occurrence among them of single-celled forms, linear arrangements of cells, sheets of cells and masses of cells has an evolutionary significance. We also find the transition from reproduction by fission to that type involving an alternation between reproduction by spores and reproduction by gametes.

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