University Extension Series

THE EVOLUTION OF PLANT LIFE

LOWER FORMS

G. MASSEE

METHUEN

UNIVERSITY EXTENSION SERIES

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BY

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Methuen & Co.

18, BURY STREET, LONDON, W.C.

1891

Richard Clay & Sons, Limited,
London & Bungay.

PREFACE.

THE aim of the present book is to briefly indicate, in a broad sense, the most pronounced features—structural and physiological—that characterize plant life as manifested at the present day, coupled with an attempt to trace the evolution of existing forms from primitive types, and to illustrate the inter-dependence between plants, animals, and inorganic nature.

Grateful acknowledgments are offered to the authors of works that have been made use of in the preparation of this little book.

GEORGE MASSEE.

KEW, SURREY,
August, 1891.

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CHAPTER I.

GENERAL IDEAS OF PLANT LIFE.

FROM the present standpoint of knowledge a concise and intelligible definition of life is not possible. This statement must not be interpreted as implying the absolute impossibility of ever attaining to this point; on the other hand, every new discovery strengthens the idea that the existence and continuance of life is governed by natural laws. For example, the manifestation of life depends on the presence of a definite substance called *protoplasm*, the existence of which in turn depends on surroundings; in other words, so long as protoplasm retains its individuality life is manifested, whereas the moment this individuality is destroyed, due to the predominance of antagonistic forces, life is no longer present. Heat above a certain degree, as also electricity, can bring about this change in protoplasm, and consequently indirectly destroy life, inasmuch as the protoplasm has lost its individuality, due to a chemical or physical change having taken place in its composition. From what has been said it will be seen that life is a force that can only manifest itself through matter, and in so far agrees with chemical and physical forces. Differences of degree are observable in the manifestation of the various known forces; for example, the attraction of mass for mass, or gravitation, acts universally on all matter regardless of its chemical or physical condition; magnetism, on the other hand, is more restricted, and its peculiarities are more readily demonstrated through iron than through wood; whereas life, as already stated, only manifests itself through one substance, protoplasm.

The reason why life is met with under such varied and extreme conditions depends on the fact that protoplasm possesses the power of retaining its individuality under extreme conditions. Taking the case of temperature, it has been proved by experiment that the spores of a fungus germinated after being exposed for two hours to air at a temperature of 80° C. (= 176° F.); germination or sprouting of wheat and barley takes place at 5° C. (= 41° F.), and between these two extremes, various forms of life in an active condition are to be met at every step. Cessation of active functions in protoplasm usually cease when either of the above extremes have been reached, but death does not necessarily result; when active life ceases, protoplasm often possesses the power of entering a passive condition in which it can remain until a favourable change in surroundings enables it once more to assume the active condition. In the passive condition protoplasm in many instances survives exposure to greater extremes of temperature than those given above; many forms of fresh-water algæ, common in our ponds and ditches, are sealed up in ice during the winter, and on the return of spring at once resume the active condition. In relation to pressure we find an equal range, life extending from an altitude of 20,000 feet above the sea-level, and down to as far below that point. Finally, relating to moisture, some of our common fresh-water algæ that flourish in water or in damp situations retain their vitality after being blown about as dry dust for a considerable length of time. The above remarks illustrate the extremes under which life in the broader sense can exist, but it must be remembered that the range of life of any one kind of organism is usually restricted within much narrower limits in relation to all forces acting on it. As a rule, the lower the organism stands in the scale of development, the greater its power of successfully overcoming extremes. The above-mentioned property of protoplasm in being capable of passing from the active to the passive condition, which means the power of acting differently under different conditions of environment, is not unique, but may be compared with the behaviour of iron under different conditions: at ordinary temperatures iron is a good conductor of electricity, but when heated to a certain temperature, this peculiar property ceases, yet the chemical condition of the iron is unchanged at the higher temperature, consequently its different behaviour is attributed to a physical change induced by surroundings; so with protoplasm.

From amongst the several characteristics of living matter, the two following may be considered as typical and universal.

(1) **Growth.**—All living organisms agree in growing or increasing in size, more especially during the early period of their existence, and the peculiar manner in which this is

effected constitutes growth as scientifically understood. Food has not the same chemical composition as the organism feeding on it, but the latter possesses the power of chemically breaking up its food, and retaining those portions that are suitable for becoming chemically transformed into its own substance, the surplus passing away as a by-product. Thus it is seen that increase in size is not necessarily synonymous with growth, as when expansion of a substance takes place on the application of heat, or when a piece of alum increases in size when placed in a solution of its own substance. In the last example the alum, in common with all minerals, possesses the power of attracting to itself matter having the same chemical composition when dissolved in water, but differs from the action of living matter in not being able to induce chemical changes; that is, no mineral can cause a chemical change to take place in a substance in solution with which it is in contact, even when all the elements it requires are present, appropriate these, and thus add to the bulk of its own substance and retain its original chemical composition. Consequently, although minerals increase in size under favourable conditions, and according to definite laws, they do not grow.

(2) **Reproduction.**—No living organism retains its individuality and continues to live under equally vigorous conditions for an indefinite period of time. To realize this statement, it is important to remember that life is not the all-dominant force, as considered by some, but rather that its manifestation depends as much on complying as exacting, in its relations with the other forces. Every change means the predominance for the time being of some force previously passive or in abeyance, and life shares these ebbs and flows in common with the other forces; consequently, leaving out of consideration the

loss of precedence in life that favours some antagonistic force, whose predominance results in premature death, we know, without at the same time being able to give a satisfactory explanation of all the concurrent phenomena, that under prevailing conditions there is a limit to the existence of every living organism, that can be predicted within measurable limits. Under normal conditions, before this period arrives, certain portions of the living organism possessing all its vital properties have become specialized, and eventually separate from the parent form; such bodies in the vegetable kingdom are known in the broader sense as seeds or reproductive bodies. Leaving out of consideration for the present certain transition forms and complications, the germination of a seed is considered as the commencement of a new individual of the same *species* or kind as its parent or the individual that produced it. The idea of an individual as defined above is a convenient one, if at the same time we clearly realize the actual condition of things. There is not the slightest reason for believing in so-called *spontaneous generation;* in other words, in the conversion of inorganic matter into a living organism by any other agency than that exercised by a previously existing form of life; hence we are constrained to assume the existence of a parent form as the progenitor of every living organism that exists at the present day. At the same time it is well known that plants and animals vary in their structure and habits to a greater or less extent from time to time, consequently it is not necessary to assume that all the progenitors of any given plant existing at the present time were in all respects similar to the latest product. In speaking of a seed as the commencement of a new individual, we do so only in a restricted sense, remembering the fact that the seed once formed an integral portion of the parent plant, and although eventually it becomes quite free and independent, yet it is none the less a living portion of the parent plant, destined under favourable conditions to pass through the same phases of development as its progenitor. From this point of view we observe that there is no break in life throughout the sequence of so-called individuals of any given species, but that life advances in recurring cycles, each cycle being represented by one individual, or in those various phases included between seed and seed. It has been already stated that each succeeding cycle does not necessarily reproduce the parent form in every particular, a fact expressed in popular language by the term "sport," and further if such a "sport" or unusual form continues to deviate from the parent type of structure, we eventually drift into a new cycle of life forms possessing characteristics more or less marked of its own. In this way we may and do get various cycles of individuals which in the end agree only with the primitive form from which they originated in those characters that are common to plant-life in general.

Remembering the indispensability of protoplasm in connection with life, it is necessary to enter somewhat into detail respecting its chemical and physical properties.

(*a*) **Chemical.**—Protoplasm belongs to the class of substance known as *proteids* or *albuminoids*, and contains also a varying amount of water and a very small quantity of mineral matter. In addition to its own complex constitution, being the seat of all vital actions, protoplasm at most times contains certain other substances which it secretes, in fact at one time or another it must contain all the very varied substances entering into the composition of plants, inasmuch as it is the only portion of a plant that can exercise the capacity of chemically building up material for its own use from the food taken in. Protoplasm has an alkaline reaction, is readily dissolved by a weak solution of hydrate of potash (KHo), but not by a concentrated solution.

(*b*) **Physical.**—A peculiar and universal property of protoplasm is its power of movement. In the case of naked protoplasm, that is, protoplasm that has not enclosed itself in a more or less rigid protective external coating or cell-wall, spontaneous movement is often very marked, as illustrated by the antherozoids or fertilizing bodies of the mosses and ferns, which consist of a minute mass of protoplasm furnished with one or two cilia or slender hair-like prolongations which act as organs of locomotion, propelling the antherozoid through water at a rapid rate, or in the more sluggish movement of the organism known as "flowers of tan" (*Fuligo varians*), one of the *Myxogastres*, the protoplasm of which is frequent amongst the tan in conservatories, resembling rather thin mustard in colour and consistency as it creeps about. Protoplasm even when enclosed within a rigid membrane can be shown in many instances to possess the power of movement; as seen in the cells of stonewort (*Nitella*), American water-weed (*Anacharis canadensis*), &c. If watery protoplasm is heated to above 50° C. (=122° F.), coagulation or stiffening takes place and death is the result, in this respect agreeing with albuminoids, as white of egg for example. Dilute mineral acids and alcohol also cause coagulation in protoplasm.

Electric shocks of moderate strength cause protoplasm to contract at once; this contraction may be considered as the commencement of coagulation from which the protoplasm recovers. Strong shocks induce permanent coagulation, and consequently, death. Living protoplasm does not readily absorb colouring matters, consequently in this state is not easily stained. Bismarck brown, a colouring matter soluble in water, if added in very small quantities,

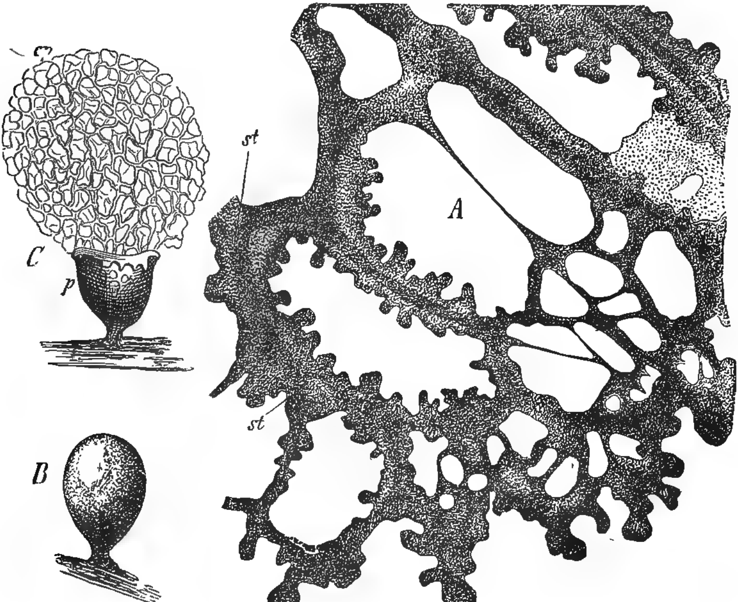

Fig. 1.—*A*, part of the naked protoplasm of *Didymium leucopus*, a Myxogaster in the motile condition during the vegetative state; the strands of protoplasm are continually changing their form, and the whole mass also moves (× 300). *B*, a closed sporangium of another species of Myxogaster, *Arcyria incarnata*; *C*, the same after rupture of wall of sporangium *p*; *cp*, the expanded capillitium (× 20). (After Cienkowski, from Prantl.)

will however stain the protoplasm of living organisms without in any obvious manner interfering with the usual routine of life, at least for some time. Dead protoplasm, on the other hand, greedily absorbs colouring matters, and usually becomes much more intensely coloured than surrounding structures. Owing to the varying composition of actively living protoplasm, no reliable chemical test for it is known, in fact, the tests usually given depend on the presence of various substances which are assumed to be constantly produced by the activity of living protoplasm. It becomes *blackened* after having been in contact for some time with a very dilute solution of nitrate of silver (even one part in 1,000,000 parts of water); this test proves the presence of living protoplasm, the reduction of the silver-solution being due to the reaction of the albumen of living cells, the failure of this reduction in dead cells is due to a chemical change having taken place in the albumen. Molybdic acid gives to dead protoplasm a deep blue colour. Very little is known respecting the structure of living protoplasm. It has recently been described as consisting of very delicate, spirally twisted, hollow tubes, composed of a colourless, unstainable, somewhat gelatinous substance, that easily swells up in water. These threads are in turn spirally coiled and form the walls of hollow cylinders; the hollow tubes and the cylinders formed by them are filled with the so-called granular protoplasm, in which the streaming or movements take place. The spiral threads and the cavities they form are the portions of physiological value, and these are not isolated in each cell of the organism, but continuous from one cell to another throughout the entire structure.

The relation of life to surroundings has to some extent been already demonstrated, nevertheless other far-reaching or universal dependencies on the nature of the environment require attention.

(*a*) **Food** is the only source of material by which a living body is enabled to add to its bulk, or grow, and at the same time to replace those portions of its own living substance that disappear in proportion to the amount of work done, chemical and physical, collectively known as vital energy. Hence it follows that one important factor in determining the presence or absence of life at any given spot, would consist in the presence or absence of food material under a form suited to the requirements of life. Keeping in view the well-known fact that different forms of life require different kinds of food, chemically considered; and further, that the physical condition of the food is also of importance, we gain a further insight as to the conditions that determine the presence of a given group of organisms at any particular spot. As an illustration of the above statement, assuming for the moment food to be the only factor in determining the distribution of life, we should find that a moss could live under conditions where it would be absolutely impossible for a fungus to do so for the following reasons. The food of a moss plant consists of *inorganic matter*, that is, matter whose existence in its present condition is not directly due to life; carbonic dioxide, derived from the atmosphere, and water along with small portions of various substances derived from the soil dissolved in it, and absorbed by the root of the moss, furnish it with all the chemical elements which its own vitality enables it to rearrange and convert into its own substance. A fungus, on the other hand, does not possess the power of decomposing and utilizing inorganic matter as food, but can only feed on *organic matter*, that is, matter that owes its present chemical composition to the direct action of life; consequently, other things being equal, the moss has the choice of a much wider range in which to establish itself, on account of the almost universal presence of its food, than is the case with the fungus. In the nature of its food the moss may be regarded as typical of the great majority of plants, in fact of all those that are green; this colour, called *chlorophyll*, being inseparably connected with the assimilation of inorganic food; but it is important to bear in mind that although all green plants agree with the moss in requiring carbonic dioxide as one food constituent, yet all are not equally indifferent as to the nature of the food substances absorbed in solution in water, an unusual and sparsely-distributed substance being in some instances an indispensable food constituent, consequently we find that the nature of the soil, or the geological formation of a given district, determines to a great extent the nature of its own flora. The fungus, in the nature of its food, is characteristic of all those plants not furnished with chlorophyll, agreeing with the members of the animal kingdom in requiring organic matter as food. But in the fungi we find that food determines to some considerable extent the distribution of the species. Many kinds of fungi, so far as can be ascertained, have no marked partiality for any particular kind of food; other conditions being favourable, so long as organic matter is present, such fungi generally appear. On the other hand, some kinds of fungi are so restricted in the matter of food that they are confined to being parasitic on the leaves of one particular species of plant; consequently, in such instances the limits of distribution of the fungus is necessarily influenced by the range in space of the plant upon which it is dependent for food.

(*b*) **Moisture.**—The manifestation of life in the active state is absolutely dependent on the presence of water in the liquid condition. The following, amongst other reasons, explains this statement: the various substances constituting plant food are brought into contact with the protoplasm through the agency of water in which they are held in solution; this substance also conveys assimilated food from its point of origin to those portions of the plant that require food, but cannot prepare it directly for themselves. In the passive condition of plant life, the amount of water present is reduced to the minimum, but is probably never entirely absent.

(*c*) **Temperature.**—The vital functions of plants appear as a rule to be confined between the temperatures 0° C. (=32° F.) and 50° C. (=122° F.); but the same functions have very different limits between these two extremes in different plants, and even in the same individual different functions have different limits. Gourd seeds will not germinate at a temperature below 13° C. (=55·4° F.), nor at one above 42° C. (=107·6° F.), whereas in barley the limits to germination are 5° C. (=41° F.) and 37° C. (=98·6° F.). Between the two extremes of temperature at which any function can be exercised there is one point, the *optimum temperature*, at which that function is performed with the greatest activity, and any departure from this point in the direction of the maximum or minimum becomes less and less favourable for the performance of that function.

(*d*) **Light** is an indispensable factor in connection with green plants, inasmuch as the development of chlorophyll is dependent on light; and further, the work done by chlorophyll can only be exercised under the influence of light. Various other forces less general in their influence on plant life do not call for special notice at present.

It must be clearly recognized that favourable conditions in relation with any one of the forces enumerated is not alone sufficient to enable a plant to perform all the functions requisite for its well-being; a plant may have a sufficient supply of light and moisture, but if the temperature is not favourable, life in the active stage does not predominate. On the other hand, as previously stated, life is not rigid in the sense of running in one narrow groove or disappearing; but rather, when placed under adverse conditions, if the change is not too extreme and abrupt, a certain amount of elasticity is manifested which in many instances results in life becoming so adjusted as to perform its functions under new conditions of environment. At this stage it may be necessary to state that all the various organs possessed by a plant, as hairs, scent, colour, wood, nutritious seeds, fruits, etc. are developed for the use and benefit of the individual producing them, and not, as imagined by some, for the benefit of other forms of life. Now if we imagine a plant having survived a change of conditions, we may be certain that the proportion of work done by the various organs cannot be exactly the same under the two sets of conditions; and if we also remember that the structure of a plant is that which enables it to do the necessary amount of work with the least expenditure of energy under existing conditions, then under altered surroundings we should expect a change of form, more or less pronounced, in responsion to the relative amount of internal change, and this is what does actually take place; consequently in proportion to the number of changes in the above sense a plant passes through, the greater will be its divergence in structure and function from the parent type. This condition of things may continue until eventually the various functions of life are manifested through organs so dissimilar in form from those of the parent, that in the absence of transitional forms, the evolution of one from the other is difficult to prove.

Recent experiments made with the spores of the *Fucaceæ* or brown sea-weeds, for the purpose of determining the relative influence of external agents in determining their *polarity*, that is, the determination of those points on the surface of the spore where the rhizoids and apical point, or in popular language the root and stem, respectively first appear on germination, revealed the following points. Light determined the polarity of all spores experimented upon except those of *Fucus serratus;* the apical point, that directly develops into the thallus, always appearing on that side of the spore on which the light fell, the rhizoids appearing on the opposite and shaded side. In such cases the *orientation* or direction of the plane of the first septum in the germination of the spore is at right angles to the incident ray of light. When the amount of light was insufficient to induce polarity, it was found that a difference in quantity of oxygen on the different sides of the spore produced this effect, rhizoids developing from the side in contact with the least amount of oxygen, the apical point originating from the opposite side. Neither gravitation nor contact with a solid body exercised any influence on the polarity of the spores. The polarity of germinating *Equisetum*, or Horsetail spores, can also be determined by light, the side farthest away from the light producing the root-cell, that nearest the source of light giving origin to the prothallium-cell. In all the species mentioned the polarity could be determined entirely by internal causes that could not be formulated other than by stating them to be due to life, and probably this last cause of polarity and orientation is the one followed under normal conditions; that is, when germinating in a subdued, equally diffused light, or in darkness, the spores always develop rhizoids and apical growing points at opposite poles, but these points of growth bear no definite relation to surroundings as indicated by direction; whereas when germinating under new conditions, as when exposed to a strong side light, it may be presumed that the internal causes continue to determine polarity to the extent of rhizoids and apical-cell appearing at opposite poles, and that the new factor, light, determines the orientation or direction, causing all the rhizoid poles to point away from it. Finally the manifestation of spontaneous movements in plants is almost entirely dependent on light and temperature. This does not necessarily mean that the proper combination of temperature and light is the fundamental cause of such movements; but one thing appears to be certain: admitting the existence of some additional internal factor, this hypothetical factor is regulated in its working by external agents.

Protective organs in the broader sense are characteristic of life, and *adaptation to circumstances* depends, not entirely, but to a considerable extent on the power of certain organisms to become so modified in their structure and functions as to overcome conditions that would prove fatal to the unmodified organism. As an illustration of the above on a broad scale we may briefly trace the gradual evolution of land vegetation from primitive aquatic forms. Water is the medium in which the greatest amount of vital activity can be manifested with the least amount of specialization and expenditure of energy, hence the simplicity of structure characteristic of aquatic plants. In the case of land plants, provision against dessication or the loss of an undue proportion of water from those parts growing in the air is an absolute necessity. It is generally admitted that the entire land vegetation originated from sea-weeds, and by various phases of evolution attained to the great variety of form and structure existing at the present day; and during the early attempts of seaweeds, the pioneers of the vegetable kingdom, to gain a footing on dry land, they were confronted with the unforeseen difficulty of counteracting the grave danger resulting from dessication.

Primitive attempts to overcome this difficulty are seen in such microscopic aquatic forms as *Palmella*, *Glœocystis*, and

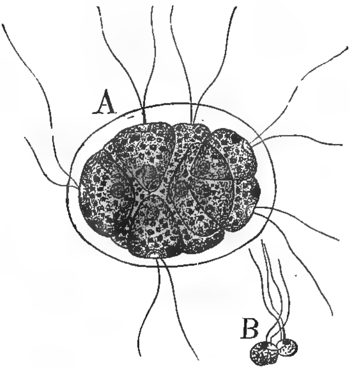

Fig. 2.—*Pandorina morum* (× 400). *A*, a motile colony (or cœnobium). The individual cells have their cilia protruding through the gelatinous envelope of the colony. *B*, two zoogonidia, formed by the division of the cells of *A*, in process of conjugation. (From Prantl.)

Nostoc, where numerous individuals become agglutinated together by a secreted substance very retentive of water, thus forming colonies frequently of considerable size; other kinds form dense felt-like masses, as *Spirogyra* and *Conferva*. Such collections of individuals present no approach to anything like specialization of parts or division of labour, each component plant retaining both its physiological and morphological individuality, and the explanation of this colony-forming idea that naturally suggests itself is—resistance to drought; on the principle that a given amount of matter in one piece, especially when surrounded by a substance very retentive of moisture, takes a longer time to become dry than an equal amount of the same kind of matter broken up into numerous pieces. The correctness of this view is supported by the fact that the colony-forming species have a much wider range than their non-colony-forming relations, owing to being able to survive a wider range of surroundings, being equally at home when completely submerged, or in swampy places exposed to the air. The amount of difference between the two last-named habitats may not at first sight appear to be very pronounced, but it is a step in the right direction, and illustrates the slow process of evolution. This difference of habit, or relative faculty on the part of living organisms to adapt themselves to circumstances is often very marked in different species of the same genus. *Conferva tortuosa* forms fleecy tufts on rocks which retain a sufficient quantity of water to prevent dessication during low tide, thus enabling the plant to continue its work under varied conditions, a circumstance in favour of life, whereas *Conferva melagonium* consists of isolated filaments, hence never flourishes above low-water mark, and consequently is confined to one set of conditions. The former has a wide distribution, the latter is not common anywhere. Some of the large brown seaweeds store up a certain amount of water in their tissues which enables them at least to resist the injurious effects of dry air on their tissues during exposure between tides, possibly it may enable them to do more than this. In spite of the progress made by aquatic plants in their attempts to gain a footing on dry land, favoured by the method for preventing dessication described above, this idea was replaced by a second, which proved so successful that it has never been superseded, and is at the present day the universal method adopted by all forms of terrestrial vegetation. This successful effort depended on *division of labour*, the one idea more than all others that has enabled life to reach its present phase of development, and consisted in the external cells of those portions of plants growing in the air becoming converted into a waterproof *epidermis* or skin, the various structural peculiarities of which will be explained at a later stage. The protective organs of plants may be conveniently referred to under two headings.

(*a*) *Protection against climate.* Under this heading may be mentioned hairs, movements (as the closing up of leaves and flowers), colour, etc.

(*b*) *Protection against living enemies.* Stings, spines, bitter tastes, colours, &c. It is important to remember that the above divisions are not sharply marked in nature; for example, colour may be protective against both climate and living enemies; the same is true of various scents and secretions. Flowers may close during a rainy day to prevent their pollen being washed away, or the closing may take place at certain periods to prevent the entrance of insects not adapted to effect fertilization of the young seeds. Many contrivances evolved obviously for protective purposes by plants are rendered more or less useless by the cunning of living enemies; for example, the common wayside weed, *Glechoma hederacea*, or Ground Ivy, has a corolla prolonged behind into a tube which secretes honey for the purpose of attracting insects in connection with cross fertilization.

Owing to the length of the corolla-tube, which is furnished inside with a ring of hairs pointing towards the centre, only long "tongued" insects, as some kinds of bees, can reach the honey; in other words, the arrangements are such that only those insects that are adapted for effecting fertilization by removing the pollen from one flower and depositing it on the stigma of another can obtain the honey by legitimate means. But certain insects that could not effect the fertilization of the plant are conscious of the existence of honey, and not being able to reach it by the usual channel, bite through the corolla-tube from the outside at the point where the honey is secreted, and thus obtain a meal by surreptitious means. On the other hand, instances of protection afforded by members of the animal kingdom to certain plants has gradually evolved into *mutualism*, or that condition of things where two living organisms, originally independent of each other in every way, become so modified as to live in each other's society with mutual advantage.

A striking illustration of mutualism is described by Belt (*The Naturalist in Nicaragua*) as follows. "A species of *Acacia*, belonging to the section *Gummiferæ*, with bi-pinnate leaves, grows to a height of fifteen to twenty feet. The branches and trunk are covered with strong curved spines, set in pairs, from which it receives the name of 'Bull's-horn Thorn,' they having a very strong resemblance to the horns of that quadruped. These thorns are hollow, and are tenanted by ants, that make a small hole for their entrance and exit near one end of the thorn, and also burrow through the partition that separates the two horns, so that the one entrance serves for both. Here they rear their young, and in the wet season every one of the thorns is tenanted, and hundreds of ants are to be seen running about, especially over the young leaves. If one of these be touched, or a branch shaken, the little ants swarm out from the hollow thorns and attack the aggressor with jaws and sting. They sting severely, raising a little white lump that does not disappear in less than twenty-four hours. These ants form a most efficient standing army for the plant, which prevents not only mammalia from browsing on the leaves, but delivers it from the attacks of a much more dangerous enemy—the leaf-cutting ants. For these services the ants are not only housed by the plant, but are provided with a bountiful supply of food; and to secure their attendance at the right time and place, the food is so arranged and distributed as to effect that object with wonderful perfection. The leaves are bi-pinnate. At the base of each pair of leaflets, on the mid-rib, is a crater-formed gland which, when the leaves are young, secretes a honey-like liquid. Of this the ants are very fond, and they are constantly running about from one gland to another, to sip up the honey as it is secreted. But this is not all; there is a still more wonderful provision of more solid food. At the end of each of the small divisions of the compound leaflet there is, when the leaf first unfolds, a little yellow fruit-like body united by a point at its base to the end of the pinnacle. Examined through a microscope, this little appendage looks like a golden pear. When the leaf first unfolds the little pears are not quite ripe, and the ants are continually going from one to another, examining them. When an ant finds one sufficiently advanced it bites the small point of attachment; then, bending down the fruit-like body, it breaks it off and bears it away in triumph to the nest. All the fruit-like bodies do not ripen at once, but successively, so that the ants are kept about the young leaf for some time after it unfolds. Thus the young leaf is always guarded by the ants, and no caterpillar or larger animal could attempt to injure them without being attacked by the little warriors. The fruit-like bodies are about one-twelfth of an inch long, and are about one-third the size of the ants, so that the ant bearing away one is as heavily laden as a man bearing a bunch of plantains. I think these facts show that the ants are really kept by the *Acacia* as a standing army to protect its leaves from the attacks of herbivorous mammals and insects." The above detailed account will give an idea as to the amount of specialization entered into by some plants in their endeavours to insure protection. Several other plants belonging to widely separated families have arranged on mutual terms with ants for protective purposes, suggesting that the idea has originated independently in different groups of plants.

The substance of plants is not homogeneous, but consists of minute portions, for the most part invisible to the unaided eye. These minute fundamental parts are called cells, and it is important to remember that every variety of form and texture, as also the various colours, secretions, scents, etc., depend entirely on division of labour and differentiation in cells. The term cell implies a closed vesicle, and consequently clearly expressed the idea entertained by the early botanists as to the structure of this organ, but at the present day many fundamental parts are known that are not covered by the older definition; nevertheless the old name is retained.

A typical cell presents the following structure: (*a*) an external protective membrane called the *cell-wall*, which is composed of a substance formed by the protoplasm, and having, at least when young, a constant chemical composition. This substance is known by the name of *cellulose*.

(*b*) Enclosed within the cell-wall is the *protoplasm*, which in the young condition almost entirely fills the cavity. (*c*) In the protoplasm of all young cells of the higher plants, and in most of the simpler forms also, there lies imbedded a more or less spherical body called the *nucleus*.

When quite young all cells agree in general structure and appearance; but owing to the division of labour already alluded to, the mature cells differ very much from each other both in structure and function.

In young cells the wall is very thin, but owing to the continued secretion by the protoplasm of the substance of which the cell-wall is formed, the latter continues to increase in area and thickness. The growth of the cell-wall is entirely dependent on the contact of the contained protoplasm with its inner surface, consequently cells from which the protoplasm has disappeared cease to grow, and as all vital functions emanate from protoplasm, such cells can only perform mechanical functions, as giving strength or rigidity. This is clearly seen in the case of hollow trunks, the heart-wood or central portion is the oldest, and in old trees the protoplasm has almost entirely disappeared from the thick-walled cells of this part, and their decay and total disappearance does not at once cause the death of the tree, the necessary communication between the root and the leaves being carried on by the young wood lying just below the bark.

In young cells the thin wall consists mostly of cellulose, a substance having the same chemical composition as starch ($C_6H_{10}O_5$), in addition there is always a considerable quantity of water, and a varying but always very small proportion of mineral matter which remains as ash when the cell-wall is burnt.

Cellulose is colourless when pure, but is *coloured blue* when treated with sulphuric acid and iodine. This reaction is known as a test for cellulose.

During the increase in size of the cell-wall growth is rarely uniform at all points, but certain portions of the surface grow at a much quicker rate than others, which results in the originally spherical cell presenting an irregular outline at maturity. This unequal rate of development is known as *local growth.* As examples of the result of local growth may be mentioned the *stellate* or star-shaped cells of the pith of some rushes, the spines and warts on the walls of pollen, and the spores of many ferns, mosses, and funguses. Very much branched cells are to be found mixed with the dense powdery mass of spores in the puff-balls, but the most remarkable forms assumed by single cells are met with in the *unicellular* or one-celled members of the seaweed family (*Algæ*), where the species of *Caulerpa* inhabiting tropical seas are often two feet in length, and possess portions resembling root, stem, and leaf respectively. Such gigantic cells are exceptions to the rule previously stated, that cells are usually so minute as to be invisible to the naked eye. The last example illustrates the great amount of differentiation and division of labour that a single cell is capable of

Fig. 3.—(× 240).
A cell from the hair on the *filament* or stalk of the stamen of Virginian Spiderwort (*Tradescantia virginica*). The outside black line is the cell-wall, lined by a thin, unequal layer of protoplasm, from which proceed strands of protoplasm into the sap-cavity; in the centre of the cell the large spherical nucleus is seen lying in the protoplasm. (From Strasburger.)

undergoing. From geological evidence it would appear that these very large cells constituting individuals were much more general in long bygone times than at the present day; in fact during the early geological periods, so far as algæ are concerned, it appears that the morphological difference between very minute and very large seaweeds consisted in the relative size and differentiation of a single cell rather than in the aggregation of numerous individually minute cells as is usual at the present day; although we have yet a small remnant of this antiquated group of large unicellular forms. Undoubtedly many fossils or impressions in the rocks that were at one time considered as the remains of gigantic unicellular algæ have been proved to be due to other causes; yet there appears to be distinct evidence of the existence of such in early geological times.

Contemporaneous with the development of the configuration of the cell due to local growth of the cell-wall, the latter usually also increases in thickness, and in some cases to such an extent as to almost completely fill up the cavity of the cell. Increase in thickness takes place by additions to the inner surface of the cell-wall, and again this thickening matter is very rarely uniformly deposited, certain portions of the original thin wall being left unthickened. As the local deposition of secondary thickening matter is constant within narrow limits in corresponding groups of cells in all the individuals of a species, or even in large groups of plants, it follows that the configuration produced by the secondary thickening of the cell-wall is a factor of some importance in indicating affinity, and is especially useful in the case of fossil plants, where the identification of the fragmentary remains depends to a very great extent on their microscopic characters. Amongst the characteristic patterns presented by the cell-wall due to internal thickening may be mentioned the following: *spiral*, when the thickening matter is deposited in the form of a continuous spiral band; *annular*, when arranged in the form of closed rings. Transitional forms unite the two preceding arrangements; thus it is not unusual to see a cell with spiral markings passing over into the annular condition due to the breaking up of the spiral to form rings; in these two forms the thickening matter often becomes detached from the wall and lies perfectly free in the cavity of the cell, and being more or less elastic, protrudes in the form of a loose spiral coil when the cell-wall is torn; if a leaf or flower-stalk of the common hyacinth or rhubarb is notched all round with a knife through the epidermis or skin, and the central portion then gently drawn asunder, a mass of very fine cobweb-like glistening threads are drawn out, which are collectively strong enough to support the weight of the broken portion. These threads are the loose spirals that have been drawn out of the broken cells. In the two foregoing examples the ornamentation is due to the deposited matter, which covers but a comparatively small portion of the area of the cell-wall, whereas in the following cases, where the thickening usually covers the greater portion of the surface, the unthickened portions form the pattern observable from the outside. *Scalariform*, when the unthickened portions consist of rows of parallel bands arranged like the steps of a ladder. This form is characteristic of certain tissues of the fern group, without at the same time being entirely confined to that group. *Pits*, or pitted cells, are very general, and depend on the thickening matter leaving small circular portions of the primary cell-wall unthickened. These thin portions were considered by the early observers as actual pits or perforations in the cell-wall, hence the name, which has been retained, although the apparent pits are now known to be due to the different appearance of the circular unthickened portions of the cell-wall. In ordinary pitted cells the opening through the secondary thickening is everywhere uniform in shape and size with the unthickened portion of the primary wall, hence cylindrical; but in a special form of pitted cells, characteristic of the *Coniferæ*, including fir-trees, yews, etc., the pits are termed *bordered pits*, and originate as follows. The unthickened portions of the primary cell-wall are circular in outline as before, but as the thickening increases the cavity becomes smaller and smaller, consequently in a section of the cell-wall the cavities are conical, widest at the outside, so that a surface view of such a pit shows two circles, one large and corresponding to the large outermost ring, and enclosing a smaller ring corresponding to the innermost portion of the pit; in fact, exactly the same appearance as presented by looking down a funnel. The thickening matter, deposited by the protoplasm, consists at first, like the primary cell-wall, of cellulose, but sooner or later chemical changes take place, either partially or entirely; for example, the cellulose may be converted into a substance called *lignin*, as in the wood of ordinary forest trees, for the purpose of giving additional mechanical strength to the structure—such modified cell-walls are yet easily permeable by water; or the cell-wall may become partially or entirely converted into *cork*, characterized by its elasticity and water-proof nature—such changes occur in the external cells of leaves, branches, etc., which are growing in the air, the object being to prevent the loss by evaporation of the water contained in the tissues of such structures;

finally, the whole, or a portion of the originally cellulose wall, may become converted into mucilage. This change is very general in the algæ, also in some fungi, and portions of the tissues of flowering plants. It is due to this mucilage that the majority of algæ, especially the youngest portions, adhere so firmly to paper when dried. Mucilaginous tissues become hard and horny when dried, but swell up very considerably when soaked in water.

The primitive thin cell-wall, although not perforated, readily admits the passage of water through its substance to the protoplasm in its interior, and one reason why the internal thickening matter is locally deposited is obviously for the purpose of securing the interchange of liquids and gases necessary for the vital activity of the cell through the unthickened portions of the wall. Another object of pits is to allow of the contact of the protoplasm contained in adjoining cells. The early conception of a cell was that of a portion of protoplasm completely surrounded by a cell-wall, and entirely isolated from the protoplasm of adjoining cells. This is now proved to be incorrect; the pits, or unthickened portions of the walls of adjoining cells, are placed exactly opposite to each other, and at these points the protoplasm of the adjoining cells is brought into contact, this connection between the protoplasm of adjoining cells is known as the *continuity of protoplasm.* In the case of a single row of superposed cells, as in many of the simpler red sea-weeds, the protoplasm of adjoining cells is usually in contact at one point only, situated in the centre of the transverse wall separating the two cells; in other examples where the cells form a solid tissue, continuity of protoplasm between adjoining cells usually takes place at several points. The protoplasm of a more or less spherical cell, with thickened, pitted walls, would consist of a central mass lining the cavity of the cell and giving off rays of protoplasm filling up the cavities in the thickening layer; these rays extend to the outer unthickened portion of the wall, and meet similar rays of protoplasm from adjoining cells. Two such rays meeting each other do not usually form a continuous ray, but are separated by an exceedingly thin film of wall at the point of contact.

The demonstration of the continuity of protoplasm is undoubtedly one of the most important of recent discoveries in plant morphology, and renders possible an intelligible explanation of many phenomena in plant-life that previous to this discovery appeared unfathomable. For example, the communication of impulses from one part of a plant to another resulting in movements, as the closing of the leaves of so-called sensitive plants, or the similar movements for a widely different purpose in some carnivorous plants, appears to depend to a great extent on the continuity of protoplasm; or this same arrangement renders possible in such structures as sieve-tubes, where actual perforations exist, the transference of solid food-materials from one part of the plant to another.

Owing to a partial or entire change in the composition of cell-walls, various substances of economic importance are produced; these are known as *degradation-products*. As illustrations of such may be mentioned, cherry-tree gum, gum-arabic, gum-tragacanth, along with several resins, as myrrh, &c.

Although the use of cellulose for cell-walls is almost universally adopted by plants at the present day, yet there is evidence to show that other substances were experimented with for this purpose by some of the pioneer groups of the vegetable kingdom; for example, in diatoms, a group of microscopic algæ, the cell-wall is rendered rigid with *silex* or flint, and it may be partly owing to this selection that diatoms at the present day form the terminal members of the group that adopted this speciality, the disadvantages connected with a perfectly rigid wall of flint as compared with the yielding wall of cellulose, other things being equal, is sufficiently obvious. It would appear that the adoption of flint for the cell-wall must have been in connection with protection, and it has recently been suggested that in the diatoms it is an acquired character, and for the purpose of protecting these organisms in their passage through the alimentary canal of such aquatic animals as frogs, which swallow large quantities along with their food. A considerable quantity of silica is present along with cellulose in the outside cells of the stem and branches of the various species of "horsetail" (*Equisetum*), also on the surface of bamboo and cane (palm) stems; the cutting action of blades of grass when drawn between the fingers is also due to particles of flint in the cell-wall.

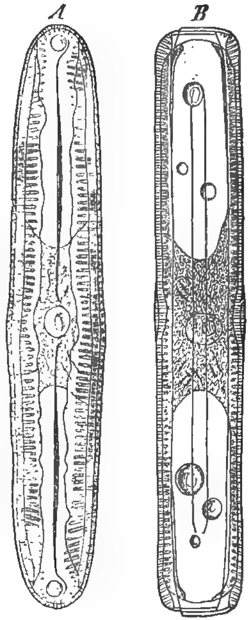

Fig. 4.—(× 540). *Pinnularia viridis*, a diatom furnished with a siliceous cell-wall. *A*, side view; *B*, edge view. The central shaded portion is the protoplasm enclosing a nucleus. (From Strasburger.)

In young cells the protoplasm, along with the nucleus, respecting which more will be said later on, almost completely fills the cell cavity. The differentiation usually commences by the formation of an external, firmer, very thin layer, which is in intimate contact with the central mass; the cell sap, that is, water containing substances in solution which permeates the entire substance of the cell, then collects in minute drops known as *vacuoles* in the central mass of protoplasm. As the cell grows these vacuoles increase in size, until eventually the protoplasm forms a sac or layer, lining the cell-wall, and filled with watery sap. The central cavity bounded by the protoplasm is called the *sap-cavity*, which is usually traversed by strands of protoplasm in contact with the peripheral portion. These strands are not permanent, but exhibit movements distinguished as *Circulation*, and consists in the accumulation or diminution of protoplasm forming the outer layer, or the irregular contraction and protrusion of the strands of protoplasm passing from the outer layer across the cell cavity, whereby these latter are constantly changing their number and arrangement. The term *streaming* is applied to currents which occur in the above-mentioned outer layer or strands of protoplasm, and is rendered apparent by the movements of enclosed granules; such currents often move in opposite directions in the same slender strand. The term *Rotation* is applied to those cases where the entire mass of protoplasm contained in a cell circulates in a rotatory manner; this movement is not always in the same direction, but rotates for an irregular period of time in one direction, when the action becomes reversed. Rotation can be clearly seen in the stem of species of *Nitella*, an aquatic flowerless plant; also in the root, hairs, and other portions of some aquatic flowering plants. In many instances the layer of protoplasm lining the cell-wall is so thin and closely applied to the latter as to be almost indistinguishable; its existence, however, can be clearly demonstrated when the cell is treated with some water-extracting substance, such as a solution of salt, sugar, or glycerine, which causes the protoplasm to leave the cell-wall and become contracted. This is known as *plasmolysis*.

The *nucleus* is a product of the differentiation of protoplasm, in which it always remains enclosed. It is at first a roundish mass; eventually its surface becomes firmer without developing a distinct wall, as in the case of the cell, and in its interior there usually appear one, two, or several granule-like portions or *nucleoli*. When fully formed, the resting nucleus appears finely granular under a moderate power of the microscope; but when sufficiently magnified it is seen that the granules are not irregularly scattered, but arranged in rows forming exceedingly fine threads, which are very much contorted and interwoven, and enclosed in a delicate membrane. During the division of the nucleus the coiled threads undergo various complex arrangements. A nucleus is present—at least during the young condition of every cell belonging to the higher plants; but was at one time considered to be absent from the cells of the simpler algæ and fungi. Recent researches, however, have demonstrated the presence of nuclei in many of these simple forms of plant life, and in all probability nuclei in a primitive state of differentiation are present in all plant cells. The exact function of the nucleus is not known, but judging from its almost universal occurrence, and its behaviour in connection with the formation of new cells, it must be supposed to perform some important function.

In addition to the typical form of cell described above, certain modified forms of cell occur, the most remarkable being the *primordial* or *naked cell*, so called on account of the entire absence of the cell-wall. Such cells are only met with in the simplest of the two primary divisions of plants called *Cryptogams*, and are usually connected with reproduction. The movements of the protoplasm constituting primordial cells are generally much more marked than when enclosed within a cell-wall, and may be conveniently described under two headings. The first is when the whole cell moves rapidly, due to the presence of a varying number of cilia or exceedingly fine hair-like prolongations of the outermost hyaline layer or *ectoplasm* of the protoplasm. In the second type the movement of the cell depends on its constantly changing form; a few rather stout prolongations of its substance are protruded and then withdrawn, similar prolongations or *pseudopodia* being protruded from fresh points of the surface of the cell; the movement, being effected in a similar manner to that of the simple animal organism known as *Amœba*, is called *amœboid.* It will have been observed that in the last described movement the organs of locomotion are temporary, whereas cilia are permanent.

Light, heat, and free oxygen appear to be indispensable factors in connection with all protoplasmic movements.

Formation of New Cells.—The origin of new cells always depends on various modifications undergone by previously existing cells, and may be referred to under two headings: (*a*) *Vegetative*; (*b*) *Reproductive.*

The vegetative parts of a plant include all structures collectively administering to the well-being of the individual, as root, stem, leaves, etc., and in such parts the almost universal method of new cell formation is by *division*; the original nucleus of the cell disappears and in its place two closely-apposed nuclei appear, the protoplasm divides into two equal or unequal portions, the plane of division passing between the two nuclei, and along this plane a new wall is formed. In the higher plants the division-wall between the two new cells is formed simultaneously at every point, but in some of the fresh-water algæ it commences as a ring from the previously existing cell-walls, and grows inwards. The above changes result in the formation of two cells out of the one previously existing, each furnished

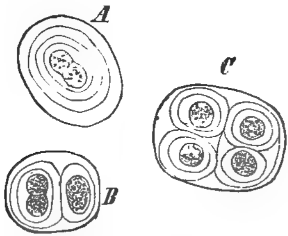

Fig. 5.—(× 540). *Gleocapsa polydermatica*, a minute fresh-water alga, showing stages in the formation of a colony or cell-family In *A* the protoplasm (shaded portion) of an individual is becoming elliptical with a slight constriction in the centre, preparatory to dividing into two individuals; the thick mucilaginous cell-wall is lamellated. In *B* the division is complete, and the two daughter-cells or individuals have become elongated preparatory to further division. In *C* the four individuals forming the colony are spherical and in the vegetative condition. (From Strasburger.)

like the original with protoplasm, nucleus, and cell-wall. At first the two cells are only half the size of the parent cell, but eventually grow to the same size. In this method there is no contracting or rounding off, and only one of the six sides of the wall of the cubical or oblong cell is new, the remaining five having belonged to the parent cell.

The reproductive portion of a plant includes all those structures directly or indirectly concerned with the production of seeds or spores, which are for the purpose of producing new individuals, and thus providing for the continuance of the species in time. Such structures do not in any way assist the plant producing them, as an individual, but on the other hand are a great tax on its energies. The division of labour as illustrated between the vegetative and reproductive portions is usually sharply marked in the case of the higher plants. Taking the apple tree as an illustration we may say in general terms that the root, trunk, branches, and leaves constitute the vegetative part, or all that is required for the life of the individual tree; whereas the flowers or reproductive portions are, even to the casual observer, abruptly different in general appearance, and suggest the idea of being as it were something tacked on to the older vegetative part, and this idea is correct in the sense of the sharply differentiated sexual parts when compared with older and simpler types of plants. In the majority of flowering plants living at the present time, the very varied contrivances presented by the flower as popularly understood, for securing cross-fertilization, protection, dispersion of the seed, etc., are evolved characters and not contemporaneous with the vegetative parts producing them at the present day. The vegetative portions of plants have also undergone marked changes from time to time, but not perhaps equal to those connected with the sexual method of reproduction alluded to above, which in flowering plants has, owing to its many advantages, almost entirely and in numerous instances altogether superseded the old asexual or vegetative mode of reproduction.

Cell-formation in the reproductive parts of plants is characterized by the contraction and rounding of the protoplasm, and by no portion of the cell-wall of the parent-cell being used by the new or *daughter-cells.* The following are the most important methods.

Division.—When the nucleus of a mother-cell disappears and four nuclei appear, round these nuclei the whole of the protoplasm accumulates, forming four new cells, each of which secretes its own cell-wall, the cell-wall of the mother-cell then disappears, and the daughter-cells are free. In this way are formed the spores of mosses and the higher Cryptogams and the pollen grains of flowering plants. In other cases, as in many seaweeds and fungi, the protoplasm becomes divided into several daughter-cells, which escape from the mother-cell as primordial cells, and exhibit spontaneous movements due to the presence of cilia. Such cells, if possessed of sexual functions, either always remain naked or without a cell-wall, or after moving about for some time the cilia contract and a cell-wall is secreted.

Free-cell Formation.—A portion of the protoplasm of a mother-cell become rounded and form cells which form walls of their own; the rest of the protoplasm remains in the mother-cell, which lives for some time after the change. The spores of some groups of fungi and certain cells in the young seeds of flowering plants are formed in this way.

Conjugation.—The protoplasm of two cells, usually belonging to distinct individuals, unite together to form one cell which secretes a thick cell-wall, and is known as a *zygospore.* Zygospores are always reproductive cells, and as they do not grow into a new individual at once, but remain during the winter in a passive condition, protected by the very thick, usually warted or spinulose cell-wall, are known as *resting-spores.* The fact of two cells belonging to distinct individuals of the same species becoming blended together to form a reproductive cell or spore, illustrates what is meant by the term *cross-fertilization*, and the present type illustrates a primitive form of sexual reproduction, characterized by the two conjugating cells being almost or completely alike morphologically or in structure; yet there is evidence for supposing that the two cells are of different functional values, as in the case of *Spirogyra*, a fresh-water alga common in our ponds and ditches, a plant consisting of a single row of cells placed end to end, and at the period of conjugation two such plants lie parallel to each other; opposite pairs of cells, belonging to the two individuals respectively, send out on the side nearest each other, a finger-like extension of the cell-wall due to local growth; these extensions of the two cells eventually meet, the cell-walls become absorbed at the point of contact, thus effecting an open communication between the two cells; through these connecting channels the protoplasm from all the cells of one of the two plants—the male

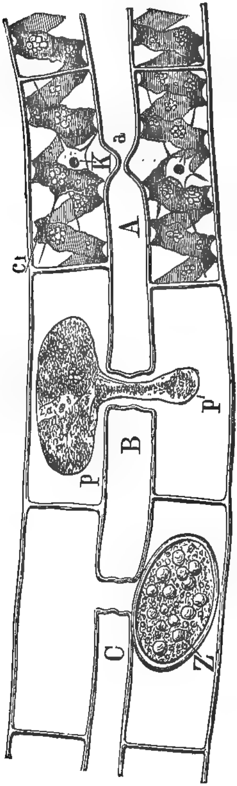

Fig. 6.—(× 400). Conjugation of the cells of two individuals of *Spirogyra*, a fresh-water alga. *A*, two cells prepared for conjugation; at *a* the filaments have begun to swell towards each other; *cl*, spiral bands of protoplasm; *K*, nucleus. At *B* the protoplasm of the cell *p* is fusing with that of the cell *p'*. *Z* is a perfectly-formed zygospore which has secreted a cell-wall. (From Prantl.)

plant—passes and blends with the protoplasm that has not moved from the cells of the other—female plant; the two originally independent masses of protoplasm combine to form one cell, the zygospore. In other examples the zygospore is formed at the point of contact of the two cells, thus indicating less differentiation between the presumably male and female elements. Conjugation only takes place in certain groups of algæ and fungi.

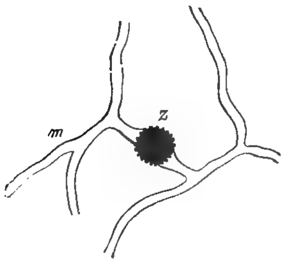

Fig. 7.—*z*, Zygospore of *Mucor*, a minute fungus; *m*, the mycelium (mag.). (From Prantl.)

Rejuvenescence. — In this method the entire mass of protoplasm of a mother-cell contracts as a primordial daughter-cell, which eventually secretes a cell-wall. The zoospores of many of the simpler forms of algæ are formed in this way, as are also the oospheres of Cryptogams.

From the above examples it will be seen that the formation of new cells does not necessarily imply the production of a greater number of cells than existed previously. This is the case in vegetative and reproductive cell-formation by division, also in free-cell formation. In rejuvenescence the number of cells remains unaltered, whereas in conjugation the actual number of cells is diminished.

Substances contained in Cells.—Various specialized structures are met with in cells, amongst the most important being chlorophyll and starch.

In some of the simpler forms of algæ the green colouring matter or chlorophyll is equally diffused throughout the protoplasm, in all other plants it exists in the form of minute particles called chlorophyll grains. A chlorophyll grain consists of two parts: a solid, colourless portion consisting of modified protoplasm, having a spongy texture called the *chromoplast*, and the green colouring matter or chlorophyll which fills the cavities of the chromoplast. The latter becomes differentiated while the cell is quite young and in total darkness, and in this condition becomes coloured yellow. At this stage development is retarded until the cell is exposed to light, which is necessary for the production of the green chlorophyll, as is also the presence of iron in solution, although this substance does not enter into the composition of chlorophyll. Its presence is probably necessary for the purpose of aiding in the chemical changes that result in the formation of chlorophyll. From what has been said as to the necessity of light for the formation of chlorophyll, it will be understood why this substance is only present in the superficial parts of plants exposed to light; and further, its most important function can only be exercised in the light. Nevertheless chromoplasts exist in structures that are normally developed in darkness, and on being exposed to light become green, as is often seen in potatoes that become exposed during growth. Exceptions to the above statement respecting the importance of light in connection with the development of chlorophyll are not unknown: the prothallus in ferns and the cotyledons or seed-leaves of Conifers become green in total darkness. The significance of this exception is not understood. In some plants, as red and brown seaweeds, the purple beech, etc., the green colour of the chlorophyll is masked by the presence of an additional colouring matter present in the cells.

The important work done by chlorophyll consists in the absorption of carbonic dioxide, the evolution of oxygen, and the formation of starch, which first manifests itself in the form of minute solid particles—starch grains—within the chlorophyll corpuscles. The formation of starch grains is a rapid process under favourable conditions, especially in the lower plants, appearing after five minutes' exposure to bright sunlight in *Spirogyra*, a minute fresh-water alga, and after about two hours in the Screw moss, *Funaria hygrometrica.*

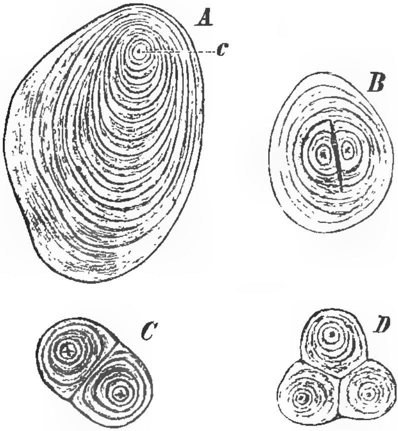

Fig. 8.—(× 540). Starch grains from a potato tuber, *A*, a simple grain showing the lines of stratification and the nucleus or hilum at *c*. *C* and *D*, compound grains, formed by the development of new hila in an ordinary grain, each hilum being surrounded by its own layers. (From Strasburger.)

Starch is very widely distributed in all plants except fungi, in which group it is entirely absent. It appears under the form of minute colourless grains, varying in shape, but constant in each species; usually oval, sometimes spherical or lenticular, and marked with concentric or eccentric lines or striæ, which originate from a point called the *hilum*, itself the starting-point of the formation of the starch grain. The lines of stratification are due to the alternation of more and less watery layers of starch. The grains consist of starch, water, and a very minute proportion of mineral matter. The starch has the same chemical composition as cellulose, $C_6H_{10}O_5$, and consists of two substances, *granulose*, and *starch-cellulose;* the latter forms only a very small percentage of the structure. Starch becomes blue when treated with a solution of iodine; this change is used as a test for its presence. In reality the granulose is only coloured blue by the iodine.

Although it has been stated that chlorophyll grains form starch from carbon dioxide and water under the influence of light, yet it is not considered that the conversion of these two substances into starch is direct, but that this substance is in all instances formed from protoplasm. In the internal dark parts of plants starch is formed by *amyloplasts.* These bodies closely resemble chromoplasts, in fact the conversion of the former into the latter under the influence of light has been directly observed. The difference in function between the two may be stated as follows. In both cases the starch formed is the product of decomposed protoplasm; in the chlorophyll grain exposed to light, the process begins with chemical changes produced on inorganic substances, as water, carbonic dioxide, and salts; whereas in amyloplasts it begins with organic substances, and light is not essential.

Cell-sap is always present in young cells, and remains so long as the cell is doing physiological work. Many organic substances formed by the protoplasm remain in solution in the cell-sap, as vegetable acids, malic ($C_4H_6O_5$), citric ($C_6H_8O_7$); cane-sugar ($C_6H_{10}O_5$), grape-sugar ($C_6H_{12}O_6$);

tannin ($C_{34}H_{28}O_{22}$); inulin ($C_6H_{10}O_5$); glucosides, colouring matters, etc. In addition to the above certain mineral salts taken up in solution in water remain in that condition in the cell-sap.

Crystals, consisting of oxalate of lime (CaC_2O_4) are common in cells, and sometimes also in the substance of cell-walls in *Coniferæ* and *Gnetaceæ*. The crystals occur in the form of regular octohedra or needle-like crystals, sometimes called *raphides*. Crystals of phosphate of lime ($Ca_3 2PO_4$) and carbonate of lime ($CaCO_3$) are rare.

Metabolism.—The process of *Assimilation* or the elaboration of the elements contained in carbonic dioxide and water into a carbohydrate, usually starch, rarely cane-sugar or fat, has already been explained. These substances do not remain where they are first formed, but change their position to other parts of the plant, and the change of locality is usually preceded by a change in chemical composition. This process is called Metabolism.

Substances contributing to form cell-walls and protoplasm are called *plastic substances*. The plastic substances forming the cell-walls are mostly starch, sometimes cane-sugar, inulin, or fatty matters. These are always changed in part into grape-sugar, which passes in solution through parenchymatous cells to those points where cell-formation is going on, for the purpose of supplying the cellulose. The plastic substances going to form protoplasm consist of albuminous bodies containing nitrogen and sulphur. Assimilated material is usually produced in excess of the quantity required at the time of its formation, the surplus being stored up for future use and known as *reserve-material*. Thus the starch formed in leaves is removed and re-formed as starch in other parts of the plant. Seeds and tubers contain supplies of reserve-material ready for use when growth commences.

During the chemical changes that take place in reserve-material previous to its being used up in the formation of new parts, certain substances are formed that are of no use to the plant in the formation of cells; these are called by-products of metabolism. Amongst others may be mentioned volatile oils, tannin, oxalate of lime, etc. Such substances are often used for attractive and protective purposes. A prevalent idea in connection with the processes of plant life is that plants purify the atmosphere, that is, from the animal point of view, by removing the carbonic dioxide and supplying oxygen, which is perfectly true, the mistake arising in usually connecting this function with respiration, which is not correct. The interchange between the gases of the atmosphere and those contained within the plant, also the chemical changes produced in them, are due respectively to two distinct functions, respiration and assimilation; and if this fact is thoroughly grasped the apparent contradictory statement, that in the performance of the first-named function oxygen is removed from the atmosphere and carbonic dioxide added, while in the second carbonic dioxide is removed and oxygen added, becomes intelligible.

Respiration or breathing in plants is a constant process, and quite independent of light, and as in the animal kingdom is for the purpose of purifying the organism. For this purpose oxygen is inhaled from the atmosphere and again exhaled in chemical combination with the refuse carbon under the form of carbonic dioxide, often spoken of as carbonic acid (CO_2). Again, as in the animal kingdom, a certain amount of heat is set free during respiration, which is a process of oxidation; but as respiration is usually comparatively feeble in plants, and the great amount of surface favours rapid cooling, no rise in the temperature is observable except under special conditions, as in the case of flowers at the time of fertilization, where a proper heat, that is, the amount above that of the surrounding air of from 4° to 10° C., has been observed.

Assimilation. — Inorganic plant-food consists of compounds usually containing a large amount of oxygen, and as the substances formed by the plant from these compounds contain very little oxygen, it follows that a large amount of the last-named element is liberated by the plant and restored to the atmosphere. The decomposition of carbonic dioxide by the green parts of plants under the influence of light is a rapid process, consequently the amount of oxygen liberated into the air by this process during the day is greatly in excess of the amount of oxygen removed during the same period in the act of respiration. As the assimilation of carbonic dioxide cannot be carried on by the plant in darkness, while respiration continues, it follows that during the night the vegetable kingdom produces the same effect on the atmosphere as the animal kingdom does, that is, takes away oxygen and adds carbonic dioxide. As already stated, all fungi, and some flowering plants that are destitute of chlorophyll, cannot assimilate carbonic dioxide, hence never restore oxygen to the atmosphere, although such constantly remove it in the act of respiration.

Although carbonic dioxide is the staple substance from which plants obtain the carbon and part of the oxygen required for the formation of starch, yet the interesting discovery has been made that the chlorophyllous cells of many plants, both Cryptogams and Phanerogams, can form starch from various organic compounds, such as cane-sugar, dextrose, and dextrin, and in some instances from glycerin mannite, etc.

Plant Tissues.—Those combinations of cells that originate from one common law of growth or cell-formation, and that are from the first organically united, are called tissues, as opposed to masses of cells that were originally independent becoming adherent, or to rows of cells becoming more or less interwoven and exhibiting a common growth, as in many fungi; such combinations are known as *spurious tissues*, or *pseudo-parenchyma*.

As already stated, a single cell may constitute an individual, many such unicellular or one-celled plants always remain isolated, in others the daughter-cells produced by the mother-cell remain in clusters of definite form, each daughter-cell retaining its individuality. Such collections of individuals are termed *cell-colonies*, and remain in mechanical contact, usually held together by a mucilaginous substance secreted by the members of the colony. Finally the individuals separate, each in turn being the mother-cell of a new colony. In other examples the individuals of a cell-colony are for some time organically united by strands of protoplasm, eventually becoming free, and in a sense forming a transition from cell-colonies to true tissues.

The following are the most important aggregations of cells to form tissues.

Filaments consist of a single row of superposed cells in contact by their contiguous ends only. Many of the simpler species of algæ consist of such unbranched cell-rows: the same arrangement of cells occurs in the hairs of some flowering plants.

Cell-surfaces.—The cells combine to form a continuous layer only one cell in thickness. Such membranaceous expansions are met with in some algæ, also in the leaves of most mosses and hepatics.

Cell-masses.—When the cells are in contact on all sides, thus forming solid masses of tissue frequently of large size, and including every form of tissue not falling under either of the preceding sections. Such masses of cells in the higher plants eventually become profoundly modified in form and function, thereby rendering possible division of labour.

The Common-wall of cells combined to form a tissue is at first thin and apparently homogeneous; but as it increases in thickness the central portion or *middle lamella* becomes differentiated as a thin plate which divides the common-wall into two layers, one belonging to each of the two contiguous cells. The chemical composition of the middle lamella is different to that of the remainder of the cell-wall, and as it is soluble in nitric acid and potassic chlorate—whereas the remainder of the cell-wall is not—its solution admits of the separation of the component cells of firm tissues.

Intercellular Spaces are cavities between the cells of a tissue, and originate in two different ways. The most usual method is by the splitting of the common-wall of contiguous cells along the line of the middle lamella (*schizogenous*) and generally commences at the angle where several cells meet; sometimes whole masses of tissue are separated from each other in the above manner, forming very large spaces called *air-chambers*, as in the tissues of most aquatic plants. The second or *lysigenous* type originates from the absorption of masses of tissue, the resulting cavities often containing the product resulting from the disintegration of the cell-walls, as cherry-gum, also various resinous, oily or fragrant bodies, such as those contained in the cavities of the rind of the orange. Such structures were formerly called glands. The hollow stems of grasses, hemlock, parsnip, also the hollow leaves of the onion, are formed by the present method. Schizogenous intercellular spaces often contain air, which serves in connection with food or respiration. In aquatic plants, the presence of air, in addition to the above functions, also enables the plants to float, and for this purpose the cavities are frequently very large and highly specialized; the large bladders of the common brown seaweed called "bladder-wrack" being entirely for this purpose. Amongst other contents may be mentioned resin, or balsam, a solution of resin in an ethereal oil; in fir trees and their allies, oils and gum-resins.

Cell-fusions take place when the partition walls of adjoining cells become absorbed, the large cavity formed being still bounded by the walls of the component cells. In this way true *vessels* are formed, by the absorption of certain of the transverse walls of superposed cells. *Laticiferous vessels* consist of straight or branched and often anastomosing rows of cells running in many cases through various tissues of the plant, having the transverse walls entirely or partially absorbed, and containing a milky juice called *latex* which escapes in considerable quantities when the plant is cut, as seen in the flower-stalk of the dandelion. Amongst economic products furnished by latex may be mentioned opium and india-rubber. The exact use of latex in plant economy is not known. Under the same heading may be placed *sieve-tubes*, having the greatly thickened transverse walls perforated by numerous small openings; these perforated transverse plates are called *sieve-plates.* Not unfrequently certain contiguous portions of the lateral walls of two sieve-tubes become similarly thickened and perforated. The object of this perforation of the walls is to facilitate the circulation of assimilated food-material contained in the cells. Sieve-tubes are present in the bast or *phloem* of most flowering plants, and also in the stem of some of the large brown algæ.

Differentiation of Tissues.—In many of the simpler multicellular plants the constituent cells are, during the vegetative phase, similar in structure and function, but in the higher Cryptogams and Phanerogams groups of similar cells occur, which differ in structure and function from other groups of cells that surround them, thus constituting a distinct form of tissue. Two such forms of tissue of primary importance may be distinguished.

Parenchyma: The cells are more or less isodiametric, or not much longer than broad, and are in contact by broad surfaces; intercellular spaces are usually present; pith, succulent parts of fruits, the entire tissues of many sea-weeds, etc., are examples.

Prosenchyma: The cells are very much longer than broad, the ends are tapering and overlap, and there are no intercellular spaces; bast and wood fibres are examples of this class.

When the cells of either of the above systems become much thickened, hard, and often dark coloured, the tissue is termed *sclerenchyma;* examples, plum-stone, shell of cocoa-nut, most kinds of wood.

Meristem, or generating tissue, is the name given to groups of cells that still possess the power of dividing, and is consequently always present at those points where growth due to the increase in number of cells is taking place, as the tips of roots, stems, etc., which are spoken of as *growing-points.* Meristem, a primitive form of parenchyma is homogeneous in structure, and is the tissue from which all other tissue-systems are subsequently differentiated.

Permanent Tissue is the name given to any tissue in which the cells have ceased to divide, and have assumed a permanent form.

In the higher or vascular Cryptogams and Phanerogams the various tissue-systems are present in the following order.

Epidermis, a tissue usually consisting of a membrane composed of a single layer of cells continuous over the exterior of every portion of the plant growing in the air.

Fibro-vascular System, present in the substance of the plant in the form of one or more comparatively firm strands.

Fundamental Tissue, forming a groundwork mostly of parenchyma, filling up the spaces between the fibro-vascular bundles and the epidermis.

Epidermis.—As already stated, the most important function of this tissue is to prevent undue evaporation of water from those portions of plants surrounded by air. In aquatic plants, and those portions of terrestrial plants surrounded by a damp medium, as roots, the epidermis is comparatively imperfect or absent.

In such simple terrestrial plants as Fungi and Lichen-fungi, we are introduced to more or less differentiated structures, which fulfil functionally to a certain extent the work of a true epidermis. In many of the large fungi of the "toadstool" type, the outermost layer of the "cap" or *pileus*, which consists of densely compacted filaments, due to partial gelification of their walls, become cemented together and form a thin, frequently separable skin, whereas in many Lichen-fungi, the filaments of the fungal portion combine towards the exposed surfaces to form a compact structure called the *cortex*, resembling a parenchymatous tissue, but as this is formed by the anastomosing and mechanical adhesion of originally independent filaments, and not produced by cell-division, it is called *pseudo-parenchyma.* A similar structure is formed by many fungi.

True Epidermis is first shadowed in amongst the *Muscineæ*, including the Liverworts, Bog-mosses, and true Mosses, and curiously enough in the Liverworts or *Marchantieæ*, a primitive group, we suddenly come upon an epidermis perfectly developed and furnished with complex *stomata;* whereas in other divisions of the *Muscineæ* much more highly organized, the epidermis is very rudimentary, or confined to certain portions only. In vascular plants the epidermis consists at first of a single superficial layer of cells differentiated from the meristem. Eventually this layer sometimes splits into two or more by cell-division taking place parallel to the surface; however, the outermost layer always forms the epidermis proper. The cells of the epidermis are at first in contact on all sides, consequently without intercellular spaces. The contour of the epidermal cells varies, being elongated in the direction of growth in long leaves and stems, and more or less quadrate in structures with a broad surface; very frequently the side walls are more or less waved. The free or outside walls of epidermal cells become very much thickened and cuticularized. As a rule, epidermal cells do not contain chlorophyll or starch; these are, however, present in the epidermal cells of Ferns and some aquatic plants. At an early period of development *stomata* or openings through the epidermis are formed. The preliminary for this is the formation of a mother-cell, formed by the division of an ordinary epidermal cell, one-half of which constitutes the mother-cell. This mother-cell is then divided by a wall into two equal parts or cells, termed the *guard-cells* of the stoma.

Finally the wall formed between the two guard-cells splits, and under certain conditions the two guard-cells become

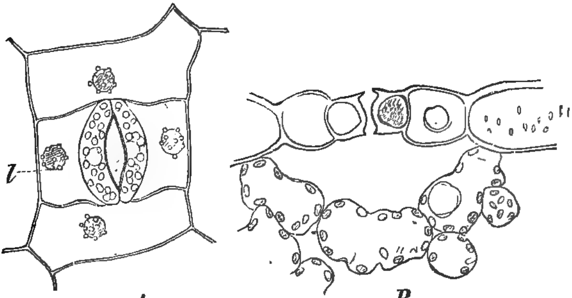

Fig. 9.—Epidermis of under side of leaf of Virginian Spiderwort (*Tradescantia virginica*). *A*, seen from the surface; *B*, in cross section through the leaf (× 240). (From Strasburger.)

concave towards the median split, thus forming an opening through the epidermis which opens into a large air-cavity, situated in the fundamental tissue below. The opening between the two guard-cells is the *stoma.* The details connected with the formation of stomata are often much more complicated than described above. Stomata are often very numerous on the green parts of plants, as leaves, and are for the purpose of effecting an interchange between the gases contained in the plant and the external air. Carbonic dioxide, as a food constituent, is taken in through the stomata, as is also oxygen for respiratory purposes, and the carbonic dioxide is exhaled; a portion of the water containing required substances in solution taken in by the plant also escapes into the air through the stomata; this last act is termed *transpiration.* Water required by the plant does not enter through the stomata. In addition to stomata, certain cells of the epidermis give origin to structures known as *epidermal appendages*, such as hairs or glands, which are outgrowths originating from one or several epidermal cells. Amongst the most highly differentiated of such structures may be mentioned the *sporangia* or spore-producing organs of ferns.

The Fibro-vascular System is present in the higher Cryptogams and Phanerogams under the form of one, or usually several, strands called *fibro-vascular bundles*. As examples of such bundles may be mentioned the veins of leaves, and the wood and bast of stems. Owing to the thickening of the cell-walls of most elements constituting a fibro-vascular bundle, these structures remain after the parenchymatous portions of the structure have decayed, as illustrated by a "skeleton leaf," which consists entirely of fibro-vascular tissue, the parenchyma having been removed along with the epidermis. In aquatic plants as a rule, however, the fibro-vascular bundles are softer than the surrounding parenchyma or fundamental tissues. The structure and arrangement of the fibro-vascular bundles is constant in the same species, and in addition, depending on its origin, increase, and detailed structure, is of great value in classification. In leaf-stalks or *petioles*, and stems, and all organs that grow especially in length, the fibro-vascular bundles run longitudinally, or in the direction of the long axis of growth; and as a rule the bundles of the leaves are continuous with those of the stem, in other words the bundles from the leaves pass continuously into the stem and coalesce with older bundles; such are termed *leaf-traces* or *common bundles*, in the sense of being common to leaf and stem. In rare instances in flowering plants certain bundles, called *cauline bundles*, originate exclusively in the stem, and consequently are not leaf-traces or prolongations of the leaf-bundles. The course followed by bundles in the stem is various, but may be reduced to three types. (1) The leaf-traces combine in the stem to form a single axial or central bundle; this is the least usual arrangement, occurring in a few ferns and aquatic flowering plants. (2) The numerous bundles of each leaf on entering the stem remain isolated at first, grow towards the centre and downwards for some distance, then become thinner and bend outwards; finally coalescing at a point considerably below that at which they entered the stem. This arrangement is characteristic of the group of flowering plants called *Monocotyledons*, and is most highly developed in palms. (3) The comparatively few bundles from each leaf bend downwards soon after entering the stem, and grow downwards parallel to each other, forming a broken ring about equidistant from the centre and the circumference of the stem, thus separating the previously existing fundamental tissue into two portions: that included within the ring of bundles is called *pith* or *medulla*; the portion exterior to the ring is the *cortex*, which is bounded on the outside by the epidermis. Those portions of fundamental tissue lying between the isolated fibro-vascular bundles forming the ring are called *medullary rays*, and are continuous with the pith and cortex. This mode of arrangement is characteristic of the two groups of flowering plants called *Gymnosperms* and *Dicotyledons*. The above types are not sharply defined, but connected by intermediate forms.

A typical fibro-vascular bundle consists of two kinds of permanent tissue; the wood or *xylem*, and the bast or *phloem*; and in the greater number of cases they are arranged in a *collateral* manner, that is, the phloem and xylem of

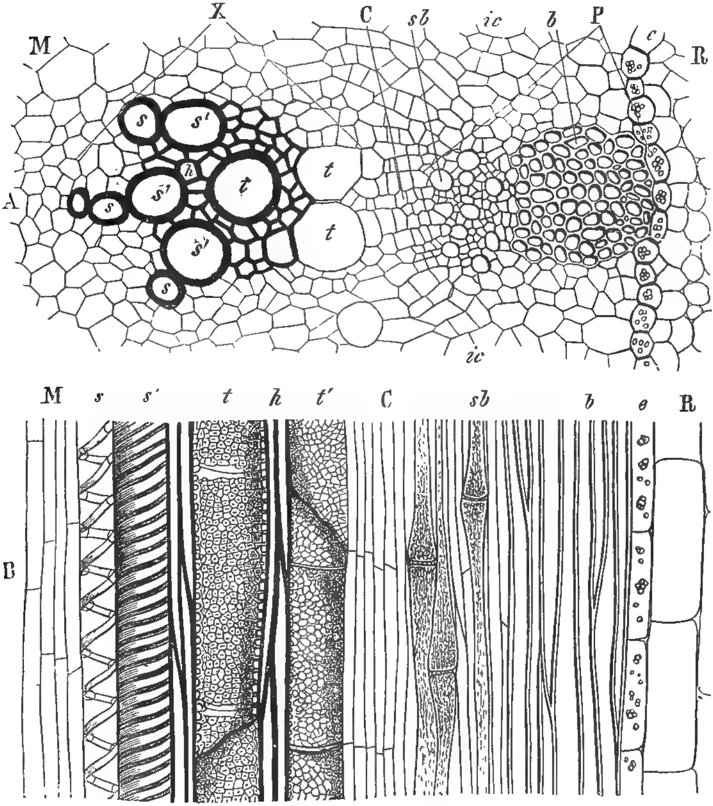

Fig. 10.—A tranverse section of an open fibro-vascular bundle in the stem of the sun-flower. *M*, pith; *X*, xylem; *C*, phloem; *R*, cortex; *s*, small, *s′*, large spiral vessels; *t*, pitted vessels; *t′*, pitted vessels in course of formation; *h*, wood-fibres; *sb*, sieve-tubes; *b*, bast-fibres; *e*, bundle-sheath; *ic*, inter-fascicular cambium. *B*, radial vertical section through a similar bundle (somewhat simplified) lettered as in the transverse section (highly mag.). (From Prantl.)

a bundle lie one behind the other in the same radial line, the xylem innermost, the phloem nearest the circumference of the stem. In most ferns, however, the arrangement of the two elements of the bundle is *concentric*, the phloem completely enclosing the xylem in a ring-like manner. The fibro-vascular bundles of cryptogams and monocotyledons never increase in size after their first formation, and are said to be *closed;* whereas the bundles of dicotyledons which possess a layer of meristem or *cambium* between the xylem and phloem, continue to increase in size from year to year, due to certain of the new cambium cells becoming differentiated respectively into xylem and phloem, such bundles are said to be *open.*

The various modifications of cells forming fibro-vascular bundles, also their relative number and arrangement, are very varied in different groups of plants. The following is the most general combination. Three kinds of cells are met with in xylem and phloem respectively.

In the *Xylem.*—(1) *Vessels* or cell-fusions having the walls thickened in various ways, spiral, annular, reticulated, scalariform, pitted, etc. True spiral and annular vessels are only met with in the first year's wood (*medullary sheath*) of open bundles; the vessels of the wood of all succeeding years being provided with pits on their longitudinal walls. In some instances the transverse walls of certain vessels are not entirely absorbed, but only pitted like the longitudinal walls; such are called *tracheides*, and closely resemble wood-fibres. The diameter of vessels is usually much greater than that of any other form of cell. Vessels contain air or water.

(2) *Wood-fibres* are very much elongated and of small diameter, and their pointed ends overlap, the walls become

thick and lignified; when pitted like vessels they are known as *tracheide fibres;* when unpitted or with small slit-like pits, *libriform fibres.* Water containing food-substances in solution taken in by roots, travels along the cells of the young wood-fibres to reach the leaves.

(3) *Wood-parenchyma.* The cells have thin walls furnished with large, simple pits, and still contain protoplasm; frequently absent.

Most frequently the wood-fibres constitute the greatest bulk of the xylem.

Phloem.—(1) **Sieve-tubes** with thin side walls, but thick transverse perforated septa, the sieve-plates already described. Contents: albuminous substances.

(2) *Bast-fibres*, usually much elongated prosenchymatous cells with tapering ends; walls very thick but remaining flexible; that is, not lignified.

(3) *Phloem parenchyma* consists of thin-walled parenchymatous cells.

In open vascular bundles new additions are made to both the phloem and xylem of the bundle by the cambium lying between the two. Cambium cells are elongated with oblique ends, and by the differentiation of their daughter-cells the vascular bundle increases in size, those on the inner side of the cambium being transformed into xylem elements, those on the outside into phloem; the central portion of the cambium remaining unchanged; and from its daughter-cells similar additions to the elements of the vascular bundle are made during every season of growth. From the above account it is seen that the xylem increases in size by additions to its outer surface, the phloem by its inner surface. The periodical additions to the phloem are very much thinner than those of the xylem. In temperate regions there is one period of active growth, consequently one portion is added by the cambium yearly to the xylem, and as these yearly additions of wood are usually clearly distinguishable they are called *annual rings;* in the trunks of some tropical dicotyledonous trees more than one ring is produced annually. The concentric rings observable in the trunks of our forest trees when sawn across correspond to annual rings of wood or xylem, and are produced as follows. During the spring, when the daughter-cells of the cambium first become transformed into xylem elements, the pressure of the surrounding cortex and bark is comparatively slight, consequently the cells of the newly-formed wood are large and thin walled, and consist to a considerable extent of large vessels. As the season advances the pressure of cortex and bark becomes much greater, consequently the new wood is more compressed, resulting in the cells having smaller cavities and thicker walls, and vessels are almost or entirely absent; hence the wood becomes gradually denser during its annual development. Next season the spongy spring wood commences abruptly upon the dense wood of the previous autumn, thus sharply differentiating each annual ring. In *Coniferæ*, an order including pines and yews, in the *secondary wood*, that is, all wood formed after the first year, vessels are entirely absent, the wood consisting entirely of wood-fibres with bordered pits. In this case the distinction of annual rings depends entirely on the relative size of the cells, and the thickness of their walls. The *primary wood* of Conifers, that is, the wood produced during the first year's growth, contains vessels.

In *roots* the fibro-vascular bundles are usually fewer in number than in the stem, and are also differently arranged;

thus the xylem and phloem bundles alternate with each other in one ring, and are not collateral as in stems. In the xylem bundles the spiral vessels, the oldest portions, lie nearest the periphery of the root, the opposite arrangement to that met with in the stem. In open bundles the cambium ring is outside the primary xylem and inside the primary phloem. The tissue immediately surrounding the fibro-vascular cylinder is called *pericambium;* the secondary roots originate in this pericambium, usually opposite to the xylem bundles, and during their development push through the cortex of the mother-root; for this reason roots are said to be *endogenous* in origin, and in this respect differ from branches.

Pericambium is absent from the roots in the species of *Equisetum* or Horsetails.

The appearance and gradual differentiation of the fibro-vascular system in plants is to a very great extent contemporaneous with their change of habitat from an aquatic to an ærial mode of life. In aquatic plants of a primitive type, at all events, the entire tissue consisted of parenchyma, and the absence of a waterproof epidermis from every part enabled every portion of the plant to absorb the required amount of water, consequently no internal arrangement was necessary for the transmission of this essential medium from one part to another; and as the water taken in contained in solution the gases required for food and respiratory purposes, special arrangements for this purpose were not required. On the other hand, when plants had succeeded in establishing themselves on land, as already explained, those parts that remained in the damp ground, as roots, were the only portions capable of taking in water, as in all plants above mosses those portions growing in the air are protected by a waterproof epidermis which prevents the absorption of water; consequently some means of supplying the above-ground portion with the required amount of water became necessary. This was effected by a further division of labour and differentiation of a portion of the stem tissue into fibro-vascular bundles. Other things being equal, the advantage of an erect stem to a plant growing on dry land is obvious; it removes those indispensable organs, leaves, beyond the reach of herbivorous animals, and at the same time places them in a favourable position with regard to light, which is necessary for the performance of their functions. The weak point in connection with the presence of a stem is the separation of the root, the only source of water to the plant, and the leaves and other parts requiring the water, and this difficulty was overcome, as already shown, by the conception and perfection of the fibro-vascular bundles, which, in addition to the functions already enumerated, are concerned in the diffusion of assimilated food-materials, giving strength, rigidity, etc.

Growing-points, as already defined, consist of primary meristem or cells capable of dividing, and it is out of these cells, originally all alike, that the most diverse tissue-systems are formed. The majority of leaves, for example, consist at first entirely of meristem; during their development the whole of this becomes differentiated into the various tissue-systems constituting a fully developed leaf, so that none of the generating tissue or meristem remains; hence leaves do not exhibit periodic growth. The same applies to fruits and many other organs. On the other hand, in organs that continue to increase in length for a considerable period, as most stems and roots, new meristem is being constantly formed at the tip or growing-point, which furnishes the tissue that eventually forms the differentiated stem. During the active period of growth the apical portion of such a stem or root

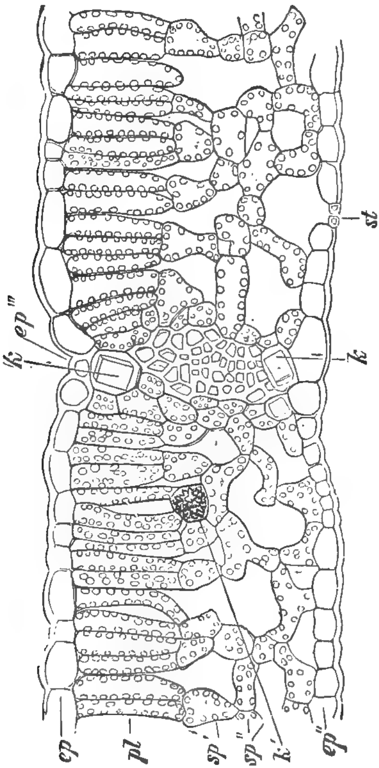

Fig. 11.—(× 360). Cross section through the leaf of the beech (*Fagus sylvatica*). *ep*, *ep'''*, epidermis of upper surface of leaf ; *ep''*, epidermis of under surface, bearing one stoma, *st* ; *pl*, palisade parenchyma, showing the cells placed end on to the upper surface of the leaf and closely packed ; *sp*, *sp''*, spongy parenchyma of lower portion of the substance of the leaf, showing numerous large, irregular, intercellular spaces ; *k*, cells containing crystals ; *k'*, a cell containing a cluster-crystal. (From Strasburger.)

may be divided into three zones, characterized as follows. At the extreme tip new cells are being formed by division; below this the newly formed cells rapidly increase in size; still further back, the meristem is undergoing differentiation to form the permanent tissue-systems of the complete structure.

In Cryptogams the meristem originates from a single cell situated at the apex of the growing organ; this is known as the *apical cell.* The meristem is formed from the apical cell in different ways, which will be noticed under the various groups. Exceptions to this method occur in a few members belonging to the fern group, where there is not a single apical cell, but several cells of equal value.

In Phanerogams there is no apical cell, but a number of cells are present at the apex which divide and form the meristem.

Cork or *Periderm* is best developed in *Gymnosperms* and *Dicotyledons*, where as a protective tissue it generally replaces the epidermis after the first year in organs that continue to increase in size, as stems and roots. Cork cells usually originate from the primary cortex, rarely from the inner layers of the epidermis when the latter divides. A layer of cells usually some distance below the epidermis divides tangentially or parallel to the surface, the outer row becomes converted into periderm, while the inner row remains alive and forms *phellogen* or cork-cambium, which forms cork annually on its peripheral side, and in addition often produces on its inner side a layer of chlorophyll-bearing cells called the *phelloderma*. Phelloderma is characterized by the oblong cells when seen in a transverse section, being arranged in radial rows with the sides parallel to the surface of the organ, and the absence of intercellular spaces. The walls of the cells undergo changes similar to those of the epidermis, and become flexible and elastic, through which water and air permeates with difficulty. The cells usually soon lose their protoplasm and become filled with air. In many cases periderm forms the permanent protective covering of trunks as in the beech and cork-oak, attaining in the latter instance a very considerable thickness; such rugged structures are popularly and erroneously called bark. When cork is formed in roots it originates from the pericambium, the outside primary cortex being gradually thrown off.

Bark differs from periderm in not being a specially differentiated tissue, and originates as follows. In many trees layers of periderm form at various depths in the primary cortex, and in some instances extend as far inwards as the fibro-vascular bundles. All tissues external to such plates of cork die on account of being cut off from their food-supply by the impervious layer of cork; such dead tissue becomes dry and hard, and surrounds the inner living tissues as a protective layer or bark, which is well developed in the Scotch fir and plane tree.

Shadowing in of the Vegetable Kingdom.—The conceptions embodied in the idea of plant and animal are not present in the simplest known forms of life, which for the most part consist of exceedingly minute particles of naked protoplasm, portions of which are usually prolonged as cilia or pseudopodia for purposes of locomotion or nutrition; such organisms present the minimum known amount of differentiation and division of labour, and constitute a group known as the *Flagellatæ.* The fact of the members of this group mostly requiring organic matter for food along with their aquatic habitat and very rudimentary differentiation suggest antiquity, without at the same time proving the *Flagellatæ* to represent the starting-point of life; in fact such expressions as primitive or primordial forms of life simply mean the oldest and most primitive types actually known, and not necessarily the earliest forms that ever existed.

From the *Flagellatæ*, as the earliest known starting-point of life, several types radiate; in other words, certain members of the *Flagellatæ*, by a series of slow changes extending over a long period of time, eventually become so far removed, morphologically and functionally, from the primitive stock, that the sum of evolved characteristics constitute at the present day the distinguishing features of animals and plants respectively. The weight of evidence does not support the idea that plants and animals have for all time existed as such, the relationship between the two being shown only in the common manifestation of life; but rather that from a common starting-point of life the specialities of plants and animals have been evolved, the individuality of each group becoming more and more emphasized the further it recedes from the starting-point. At the same time the two groups, plants and animals, become more and more unlike each other as the differentiation of each proceeds; whereas at the starting-point from the primitive *Flagellatæ* the two groups for some time possess many characters in common, and those evolved features which eventually gave individuality to plants and animals respectively were not unfrequently met with in the pioneers of both groups, and eventually discarded by the one and made a speciality of by the other. How it is that life, the junior member in the differentiation of forces on our globe, should in such a comparatively short space of time rise from obscurity and assert its equality, and even to a certain extent its supremacy over the previously existing forces, is not as yet formulated; and yet it is not difficult to understand why a mass of living organic matter should not possess more energy than an equal mass of typical inorganic matter from chemical and physical laws. It will be sufficient to allude to the chemical side only. The amount of energy liberated by matter is very much influenced by its relative chemical stability; inorganic matter is as a rule comparatively stable, that is, its chemical composition is not disturbed by the ordinary surroundings; whereas organic matter is exceedingly unstable or constantly changing within certain limits, as illustrated by the chemical changes constantly exercised by the protoplasm, chlorophyll, etc., on food, and the further chemical manufacture of the numerous organic substances present in plant and animal tissues. This incessant change, due to chemical instability, results in the generation of energy recognized as heat, electricity, etc. Whether the balance and mutual action of this energy, generated by the instability of organic matter, constitutes life is not known.

Hovering round the *Flagellatæ* are numerous groups of organisms that are considered as showing in a very incipient stage those special structures that in more highly evolved plants are considered characteristic of the Vegetable Kingdom. Amongst the earliest of differentiations observable is the formation of chlorophyll, which indeed is the key-note of plant life, inasmuch as the power of assimilating inorganic food by plants depends on the presence of chlorophyll; and this power of utilizing inorganic food, followed by the formation of starch, and the firm, permanent cellulose cell-walls, are the characteristics of plant life. It is however important to bear in mind that the three characteristic features of plant life just enumerated are not absolutely restricted to members of the Vegetable Kingdom. All three are met with in certain of the lower but unmistakable members of the Animal Kingdom; but while in the last-named group these features are most pronounced low down in the scale of differentiation of animal life, and completely arrested and superseded as development proceeds, in the plant world, on the other hand, these same structures become more and more specialized, and the whole structure of the vegetative parts of plants in general is so arranged as to facilitate the working of the chlorophyll, as illustrated by the flattening out of the substance of the plant into thin plates—leaves—for the purpose of exposing a great area of chlorophyll-bearing surface. In the case of many simple forms of animal life, that were at one time supposed to possess the power of forming chlorophyll, it has been shown that the chlorophyll belongs to minute algæ, that are incorporated in the soft substance of the animal; yet there are cases where animals appear in reality to possess the power of developing chlorophyll. In Fungi and some flowering plants chlorophyll is entirely absent; but in all such cases the plants at present without chlorophyll have degenerated from chlorophyll-producing ancestors. Starch is found in many, even if not in all, of the uncoloured forms of the *Protozoa*, a primitive group of animals, according to Bütschli.

In the simplest and most primitive of known plant forms, met with at the starting-point of the algæ, the mode of reproduction is asexual or vegetative, usually effected by division or fission of the generally unicellular organism. In such cases it will be observed that there is no definite provision for death; in other words, no provision, as in the higher forms of life, for the return of the mass of material appropriated from the inorganic world during the predominance of life, to that condition on the cessation of life in a given individual. It is not difficult to realize that this primitive mode of reproduction, by division into two equal parts, of an organism at the end of its vegetative phase, each portion growing to the size of its parent and then repeating the same process, could not possibly have become general, not even from the point of view of supply and demand; as by this method of reproduction there was a continual drawing from the available supply of plant food without any return, except the small amount of certain elements furnished by respiration. The change from this condition, and the gradual evolution and differentiation of the sexual method of reproduction, has however obviated the possibility of a plant famine, due to all the readily available material having been used up without a corresponding replacement. In the sexual method of reproduction, the leading idea is the mingling together of two distinct portions of protoplasm, which together form a cell. From this one cell, which constitutes the starting-point of a new individual, all tissues of whatever nature entering into its composition are derived. The two minute portions of protoplasm combining to form such a sexually-produced cell may be derived from different portions of the same plant, when the term *self-fertilized* is applied; on the other hand, *cross-fertilization* is brought about by the two portions of protoplasm being derived from different individuals of the same *species* or kind.

Sexual reproduction, as already mentioned, is shadowed in under the form of conjugation, where two apparently similar portions of protoplasm, either under the form of motile zoospores, or contained in cells as in *Spirogyra*, blend together to form a sexually-formed reproductive body or zygospore. In these examples the greater part of the protoplasm is used up in the formation of the reproductive bodies; but as differentiation in this direction proceeds, we observe that the relative bulk of the individual specialized for reproductive purposes becomes less and less, until we reach Phanerogams, where the parts concerned in the process, *stamens* and *ovules*, or young unfertilized seeds, usually bear a very small proportion to the whole; and yet in the fertilized seed we get a concentration of all that is required to evolve, under favourable conditions, into an individual like the parent form. This concentration of the energy of an individual into a small portion—a *seed*—for reproductive purposes, admits of the remainder, which usually constitutes the bulk of a fully-grown individual, being sooner or later returned in the form of dead organic matter, that eventually resolves itself during the process of decay into those same inorganic compounds that were utilized for the building up of its own structure, and retained, so long as life was the dominant force over the mass. After complete disintegration the same material is available for use over again by some other living plant; thus it is seen that the evolution of sex, and concentration of the reproductive portions into a small compass, has furnished an endless supply of material available for plant food, by utilizing the same material over and over again. The cycle of movement of inorganic matter suitable for plant food may be varied; for instance, a given plant that has built itself up, or in other words that has fashioned so much inorganic matter into a living tree, eventually dies, and sooner or later its wood, leaves, etc., become broken up into gases, water, and salts; that is, other forces now dominant over the dead tree are undoing what life while dominant did for the tree.

When the unravelling is completed, the water, gases, and salts resulting from the decomposition of the tree may almost at once pass through a similar cycle, by being again pressed into the temporary service of another tree of the same species as the one into whose composition it was previously incorporated; or the cycle may be slightly modified by being utilized by a different kind of tree. A yet wider cycle of change would befall our original inorganic matter if, after being fashioned by life into a plant, this plant should be eaten by some herbivorous animal, whence it would rapidly change from plant to animal substance, in turn to find itself once more, on the death of the animal, the same inorganic matter from which it started its cycle of varied chemical and physical combinations.

The evolution of sex, in addition to the advantage referred to of concentrating the hereditary peculiarities of species within the compass of a small portion of the plant substance —the seed, also gave directly an enormous impetus to the invigoration and consequent extension of plant life, by rendering possible cross-fertilization, which is amongst the most active of means for heightening variations, and also of mingling such in the most favourable proportions. For the purpose of securing cross-fertilization and at the same time preventing self-fertilization, numberless modifications and developments in phanerogams have been from time to time added; as a rule, colour, scent, and diversity of form met with in the flower have originated for the purpose of aiding this object; the various forms of inflorescence, or grouping of flowers in clusters, as also the division of labour met with in some forms of inflorescence, well illustrated in composite plants, as the ox-eye daisy (*Chrysanthemum leucanthemum*), where the peripheral or ray florets have the corolla large and showy for attractive purposes, while the central or disc florets have the corolla much smaller, the stamens and pistil perfect, and produce the seeds.

In all Cryptogams where the sexual organs of reproduction are differentiated, water is the agent that enables the antherozoid or fertilizing body, which in the great majority of cases is motile, or possessed of the power of spontaneous

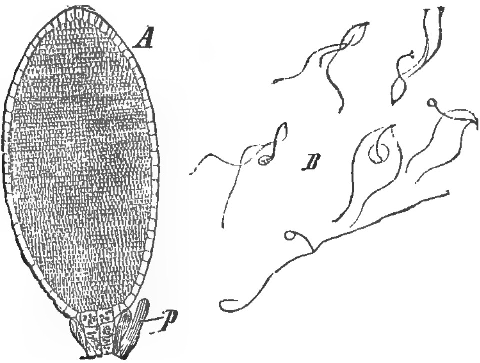

Fig. 12.—Liverwort (*Marchantia polymorpha*). *A*, an almost ripe antheridium ; *p*, paraphyses ; *B*, antherozoids (*A* × 90, *B* × 600). (From Strasburger.)

movement, to reach the oosphere or body to be fertilized. This statement is equally true of those groups of Cryptogams that are established on dry land, as the mosses and ferns, where the sexual phase is developed during the winter or rainy season. The rigid adherence to this method by Cryptogams may possibly have to do with their distribution, being as a body confined to damp forests and humid localities.

With the evolution of Phanerogams the utilization of water as a means for enabling the pollen or fertilizing body, which is never motile, to reach the oosphere, has except in rare instances been discarded, and in its stead, in addition to self-fertilization, where the pollen fertilizes the oospheres of the same flower, wind and members of the animal kingdom, more especially certain groups of insects, perform this function. Flowers that are fertilized by the agency of wind, as Conifers, hazel, etc., are said to be *anemophilous*, whereas those flowers that utilize insects for this purpose are said to be *entomophilous*. The last method is most general, as proved by the variety of colour, form, and scent developed by the majority of flowering plants, and has perhaps at the present day attained its maximum of development, as evidence is at hand to show that even this method, which has done so much towards enabling plant life to reach its present high state of differentiation, is in some quarters being superseded by a reversion to the older method of self-fertilization, illustrated by many of the members of the Violet family (*Violaceæ*) and others, where certain flowers are produced having the calyx or outer green covering permanently closed, thus effectually preventing cross-fertilization; the corolla or attractive coloured portion with its scent and honey-secreting structures being suppressed; the stamens are also fewer in number than in the older type of violet flower. The term *cleistogamous* is applied to such permanently closed flowers, obviously constructed for the purpose of securing self-fertilization. The proof that the last-mentioned mode of reproduction has superseded the entomophilous method, is shown by the fact that in most of our wild violets cleistogamous and entomophilous flowers are both still produced, the latter, in the irregular or *zygomorphic* corolla, furnished with a nectary and scent glands, pointing to a high state of differentiation in connection with insect fertilization; but the seeds produced by these flowers are for the most part sterile, and the entire structure may be looked upon as one that is practically useless to the plant, but which it has not yet been able to arrest, whereas the seeds produced by the cleistogamous flowers are all fertile, and produce vigorous plants. As to whether this reversion to the old method of self-fertilization carries along with it the disadvantages of this method in the older sense as compared with the advantages of cross-fertilization, or whether the new or cleistogamous mode of fertilization embodies some power of invigoration equal to that effected by cross-fertilization is not determined. If the last idea proves to be correct, then, however much we may regret the idea of the eventual disappearance of the brilliant colours of flowers, from the plant's point of view it will be a great saving of energy, if a modified form of the old method of self-fertilization confers equal benefits to those imparted by the entomophilous mode of cross-fertilization, by being enabled to dispense with the varied structures and secretions at present necessary to secure the visits of insects.

The relative advantages and disadvantages of plant life as compared with animal life in the struggle for existence can be best understood by following briefly the two principal lines of departure from what may be termed a common or primitive stock, the *Protozoa.* The lowest members of this group, as previously stated, owing to their scanty differentiation, lack those characteristics which are considered typical of plants and animals respectively; they are all aquatic in habit and require organic food. From the primitive condition animal characteristics are slowly evolved in such groups as the *Infusoria*, where a more or less rudimentary digestive cavity is present, which constitutes one of the important features of animal life; and as we ascend in the scale, the digestive cavity or stomach becomes more and more specialized for the purpose of receiving and digesting solid organic food. Now this requirement of organic food obviously limits the range of animal life to those places where such food exists. As a set-off against this apparent drawback to the extension of animal life, it must be borne in mind that organic is much more easily assimilated than inorganic matter, which forms the staple of plant food; inasmuch as the chemical energy required to convert inorganic into organic food is already accomplished, and consequently a surplus of energy is left to the animal, to be expended in the development of other functions than those required for preparing the indispensable food supply. As a result of the above conditions—and more especially as progressive differentiation necessitated special kinds of organic food—the power of locomotion, universal in the higher forms of animal life, became a necessity.

Returning to the *Protozoa*, which as a group are considered to belong to the animal side of life, numerous forms are met with differing so far as is known from typical *Protozoa* only in the presence of chlorophyll, which as already stated is one of the leading features of plant life; and although chlorophyll is not considered at this stage as absolutely stamping the plant nature of the body producing it, yet it enables the organism to feed on inorganic food, and as this tendency becomes more pronounced, so in proportion the power of feeding on organic food degenerates until eventually it is completely lost, and the organism is then considered as a plant belonging to the group *Schizophyceæ*, still aquatic in habit, and frequently possessed of spontaneous movement, due to the presence of cilia like the typical *Protozoa*, but differing from the latter in being able to add to its bulk, and derive its energy directly from inorganic matter. Along with this change is the development of cellulose used for protective purposes in the form of cell-walls. As already said, locomotion is still possessed by some of the simpler forms of plant life, but owing to the fact that the inorganic food required by the members of this new line of departure exists everywhere, the power of locomotion became lost, and we find the great majority of plants permanently fixed, and it is only when the group has become broken up into highly specialized branches that we meet with plants possessed of migratory habits, necessitated by the requirement of special kinds of food present in only small quantities at any one spot. The mode of migration is not however effected by the animal method, but by the constant extension of those portions of the plant that are destined to develop into the vegetative parts during successive seasons, away from the locality previously occupied. The common bracken illustrates this method of migration, the growing-point of the underground stem extending horizontally from year to year, and producing new roots and a frond in a new locality. Our common orchids and many other plants move from place to place in a similar manner, and even forest trees that appear to be permanently fixed in one place, follow the same idea by constantly extending their roots into new soil. As already pointed out, the inorganic food required by plants, on account of its general distribution allows of a wide range, limited only by the presence of water, which is necessary for the solution of the various salts derived from the soil or rock on which the plant is growing. Nevertheless this feature more than any other places plants under a disadvantage, when contrasted with members of the animal kingdom, for the following reason. In order to convert carbonic dioxide, water, and mineral substances into an organic body, first appearing under the form of starch, the action of chlorophyll working under the influence of light is necessary; consequently we find that throughout the vegetable kingdom there is a gradual evolution in accordance with this idea, the greater the area of chlorophyll-bearing surface exposed to light the better. Thus we get a very large proportion of the substance of the plant flattened out in the form of thin plates, as fronds, leaves, etc., for this purpose, which collectively may be looked upon as a condensing and chemical apparatus for manufacturing protoplasm or organic matter from the raw inorganic material. Subsequently the protoplasm by further chemical changes becomes resolved into starch, cellulose, etc., which corresponds to the starting-point of nutritive processes in the animal kingdom, in the sense of dealing from the first with organic matter. The general habit of plants is also that which favours this process, as shown by the gradual evolution of trunk and branches, which protect the leaves from the attacks of herbivorous animals, and at the same time place them under the most favourable conditions for performing their functions. Finally, we meet in the leaves with a gradual evolution tending towards the same idea, as illustrated by the gradual transition from the entire or undivided form, to the very much cut up or compound leaf, possessed of the power of closing up when unable to perform its functions, and thus more or less effectually protecting itself, as in the so-called "sensitive plant," and numerous others. Other modes of leaf protection are met with under the form of spines, bitter tastes, etc.

The division of the Vegetable Kingdom into two primary groups, *Cryptogams* and *Phanerogams*, originated with Linnæus; but, according to the artificial system of this author, the arrangement depended on the number and position of the only sexual organs known to him (*stamens and pistils*), and all plants possessing such constituted the division *Phanerogamia*, commonly known as Flowering plants; whereas the ferns, mosses, seaweeds, funguses, etc., not possessing these organs, constituted the division *Cryptogamia*, sometimes called Flowerless plants, and considered by Linnæus as a subordinate department of the Vegetable Kingdom.

The most generally accepted primary division of the Vegetable Kingdom at the present day is into the two divisions formed by Linnæus, and his names are still retained, but with a totally different signification; and the idea of flowering and flowerless plants is incorrect, because in a broad sense every specialized structure for the purpose of reproducing a plant sexually is equally a flower, and sexual reproduction is general amongst *Cryptogams;* in fact universal in all except the simplest forms. In Cryptogams the contact of the antherozoid or fertilizing element with the oosphere or female organ is always effected by the agency of water, consequently the sexual organs remain very minute, and unattended by such supernumerary parts as calyx and corolla, the latter, appearing with the evolution of the Phanerogamia on dry land, which consequently had to make arrangements for a new method of fertilization in those cases where structural peculiarities rendered self-fertilization impossible. In accordance with this requirement the essential parts of the flower also increased in size, either for the purpose of utilizing the wind or insects in this connection.

The most pronounced distinctions between the two divisions, as at present understood, are as follows—

(1) In Cryptogams the sexually produced reproductive body never enters into a resting-stage after undergoing cell-division and differentiation. In the lower forms, as illustrated by *Spirogyra*, the zygospore clothes itself with a firm cell-wall, and passes the winter in a passive condition as a unicellular body, germinating in the spring. In the higher groups the fertilized oosphere—the oospore—at once secretes a cell-wall of cellulose, and then divides into a number of undifferentiated cells. In this state it is known as the *embryo.* The earliest subsequent division of the embryo is into the rudiments of the first *root*, first leaf or *cotyledon*, growing-point or *stem*, and *foot* or organ which furnishes the plantlet with its first food, absorbed from the prothallus. The point to be remembered is, that when this stage of differentiation has been reached there is no resting-stage ; the structure must uninterruptedly continue its growth or perish. In Phanerogams the fertilized oosphere by cell-division becomes differentiated into a minute plantlet or embryo, presenting a root, stem, and one or two leaves or cotyledons. This development takes place while the embryo is yet surrounded by the coverings of the ovule, which become converted into an external protective covering, the whole constituting a *seed*, and at this period corresponding to the maturity of the seed, the entire structure enters the resting state. The advantage of a resting-stage, as affecting the dispersion of species, is obvious, and indeed becomes indispensable, inasmuch as the asexual mode of reproduction by spores, which facilitated dispersion in Cryptogams, is arrested in Phanerogams.

(2) *Alternation of generations* is very clearly marked in

some groups of Cryptogams, as mosses and ferns, being only vaguely indicated in the lower forms, while in the higher ones it is indistinct through arrest; whereas in the majority of Phanerogams alternation of generations is obsolete.

By alternation of generations is meant the alternation of two diversely formed structures producing respectively sexual and asexual reproductive bodies, the two conditions constituting an individual. In a fern, for example, the spore or asexual organ of reproduction, on germination gives origin to a small plate of cells lying flat on the ground and called a *prothallus;* certain of the cells of this prothallus become differentiated into the sexual organs, *antheridia* and *archegonia;* the whole structure constitutes the first or sexual generation or *oophore.* The fertilized oosphere—the oospore — produced by the sexual generation grows directly into the fern plant as popularly understood, which eventually produces reproductive bodies called spores, not the direct result of fertilization, and constitutes the second or asexual generation, the *sporophore.* The spores under favourable conditions germinate and give origin in turn to the sexual generation or oophore.

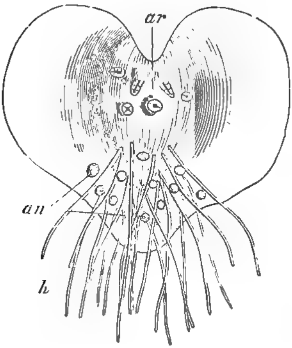

Fig. 13.—Prothallus of a fern, illustrating the first or sexual generation; under surface showing, *ar*, archegonia, *an*, antheridia; *h*, root-hairs (× 10). (From Prantl.)

(3) In Cryptogams the asexual reproductive bodies called spores are almost universal, whereas in Phanerogams spores are entirely absent, although in the last-named sub-

division asexual modes of reproduction by bulbs, tubers, etc., are by no means uncommon.

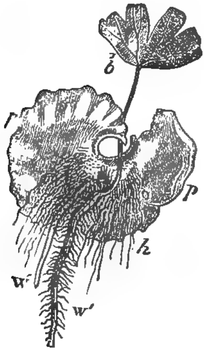

Fig. 14. — Maiden-hair fern (*Adiantum capillus-veneris*). The prothallus or sexual generation, *pp*, seen from the under side with the young fern plant *b*, or the second asexual generation, attached to it; *w'*, *w''*, first roots of the asexual stage; *h*, root-hairs of prothallus (× about 3). (From Prantl, after Sachs.)

(4) In the great majority of Cryptogams fertilization is direct, the antherozoid coming directly in contact with the oosphere or body to be fertilized; the *Florideæ*, or red seaweeds, are however exceptions to this rule. In Phanerogams fertilization is indirect, the pollen grain or fertilizing body being received on a specialized portion called the stigma, and from thence emits a tube which eventually comes in contact with the oosphere or ovule. An exception to this rule is met with in *Gymnosperms*, those Phanerogams most closely related to the higher Cryptogams, where fertilization is direct; that is, the pollen comes directly in contact with the oosphere, without the intervention of a stigma.

Other acknowledged divisions of the Vegetable Kingdom into two primary groups are as follows—

Thallogens or *Thallophytes;* those plants showing but little differentiation and division of labour in the vegetative portion, e. g. *Algæ* and *Fungi.*

Cormogens or *Cormophytes;* where the vegetative portion is differentiated into an axis or stem, bearing lateral appendages or leaves, *e.g.* the remainder of the Vegetable Kingdom not included in the *Thallogens.*

Or again, the division may be based on the fundamental parts, as follows—

Cellular plants include those not furnished with fibro-vascular bundles, e. g. *Algæ*, *Fungi*, and *Muscineæ*.

Vascular plants; furnished with fibro-vascular bundles in addition to cellular or fundamental tissue, *e. g.* all plants not included in the first subdivision.

The following arrangement will be followed in the present work—

SUBDIVISION I. **Mycetozoa.** Saprophytes. During the vegetative phase consisting of a motile plasmodium formed by the coalescence of numerous zoospores. During the reproductive stage the plasmodium becomes differentiated into spores contained within a sporangium, rarely borne on the surface of a sporophore and uncovered.

SUBDIVISION II. **Thallophyta.** Plants with or without chlorophyll, without any differentiation into stem and leaves, true roots and fibro-vascular bundles absent, alternation of generations not distinctly marked.

Class I. *Algæ.*
„ II. *Fungi.*

SUBDIVISION III. **Muscineæ.** True roots and fibro-vascular bundles absent. Alternation of generations becoming distinctly marked in the higher forms, the sexual generation with a distinct stem bearing leaves, the oophore giving origin to the asexual generation, which consists of a sporangium containing spores.

Class III. *Hepaticæ.*
„ IV. *Musci.*

SUBDIVISION IV. **Pteridophyta.** Alternation of generations distinct, disappearing in the higher forms. Fibro-vascular bundles, stem bearing leaves, and true roots present in the asexual or spore-bearing generation. Sexual generation a small prothallus.

Class V. *Filicinæ.*
„ VI. *Equisetaceæ.*
„ VII. *Lycopodinæ.*

SUBDIVISION V. **Phanerogamia.** The sexually-formed reproductive body a seed containing an embryo. True roots, leaf-bearing stem, and fibro-vascular bundles present. Alternation of generations obsolete.

(A) **Gymnospermæ.**
Class VIII. *Gymnospermæ.*

(B) **Angiospermæ.**
Class IX. *Monocotyledones.*
„ X. *Dicotyledones.*

CHAPTER II.

SUBDIVISION I.—MYCETOZOA.

Peculiarities presented during the Vegetative Phase—Characteristic Features of the Reproductive Phase—Affinities—Occurrence.

THE *Mycetozoa*, known also by the older names of *Myxogastres* and *Myxomycetes*, were until recently considered as belonging to the Fungi, some groups of which they superficially resemble in the mature condition; but a careful study of the life-history of several typical forms has shown that this idea is untenable, and some of the best authorities consider the group as entirely outside the Vegetable Kingdom. The species are saprophytes, and either aquatic or more generally met with on decaying wood or other vegetable matter during their vegetative condition. There are two principal groups, the *Myxomycetes* and the *Acrasieæ*.

CLASS I.—MYXOMYCETES.

The spores on germination give origin to motile cells, which are either furnished with cilia or move in an amœboid manner by the protrusion of pseudopodia. During the active period the spores multiply rapidly by division, eventually the cilia are withdrawn, and sluggish amœboid movements only take place previous to the formation of a *plasmodium*, which is accomplished as follows. Several of the cells come into contact and coalesce; this small mass possesses the power of attracting to itself other free cells,

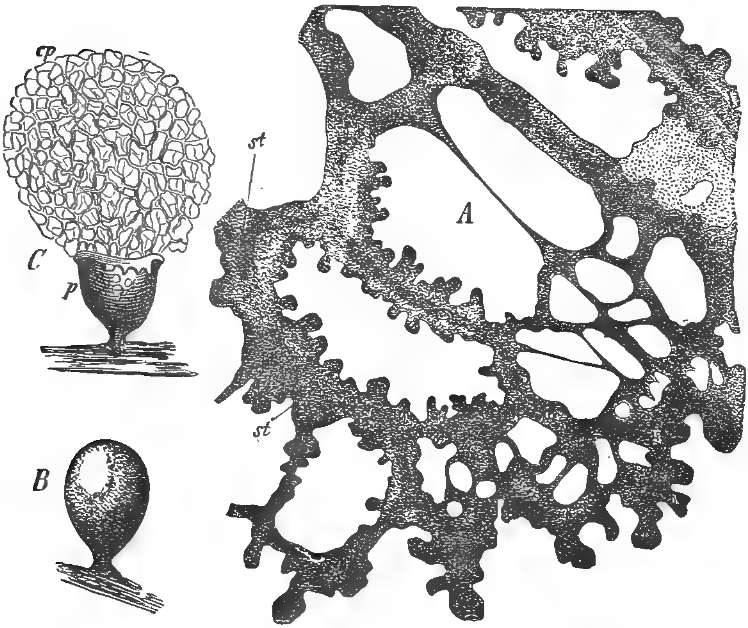

Fig. 15.—(× 300). *A*, part of the naked protoplasm of *Didymium leucopus*, a Myxogaster, in the motile condition, during the vegetative state; the strands of protoplasm are continually changing their form, and the whole mass also moves. *B*, a closed sporangium of another species of Myxogaster, *Arcyria incarnata*. *C*, the same after rupture of wall of sporangium, *p*; *cp*, the expanded capillitium (× 20). From Prantl.)

which also blend to form a large mass or plasmodium that in some species extends for several inches. The plasmodium is usually if not always enclosed in a thin, yielding pellicle, which gives a cellulose reaction, and still possesses the power of movement, creeping over the surface of decayed wood, etc. The most pronounced feature of the Myxomycetes is that the entire vegetative stage is passed in this condition, the motile plasmodium moving about and feeding on organic matter. During the winter the plasmodium retires into the crevices of decaying wood or amongst leaves, and under certain conditions secretes a thick wall and passes into a resting-stage. As a rule the plasmodium is bright coloured, sometimes pure white, and in the active condition is of a semi-liquid nature, so that it cannot be handled without becoming resolved into a shapeless mass resembling the white of an egg in consistency. At the end of the vegetative period the plasmodium comes to the surface of the substance amongst which it previously passed its existence, and not unfrequently creeps up the stems of grass or twigs for the purpose of forming its spores. The passage from the vegetative to the reproductive phase is abrupt: when the plasmodium has placed itself in a favourable position exposed to light, the protoplasm at once becomes converted into spore-containing bodies or *sporangia*, which vary considerably in form and size in different species. In the simpler forms the plasmodium becomes differentiated into a protective covering or sporangial-wall and spores only; whereas in the higher forms, in addition to the above, a portion of the protoplasm is formed into threads, often forming a network, mixed with the spores, and known as the *capillitium*, which in some instances is elastic and aids in the dispersion of the spores. The sporangia are often brilliantly coloured and present very beautiful shapes. When individually small, the sporangia are frequently produced in great numbers from the plasmodium, and form crowded masses which are very conspicuous on decayed wood, etc., as the chrome-yellow of various species of *Trichia*, or the vermilion forms of *Arcyria*. In one group the plasmodium contains a large quantity of *carbonate of lime*, which is deposited in the wall of the sporangium, and also in the capillitium, to such an extent as to render them quite rigid. The spores are as a rule spherical, and either clear yellow or brown with a violet tinge, passing in many species to a clear purple. The wall at first gives a cellulose reaction, and is often ornamented with characteristic markings. In many species the spores are capable of germinating at once, the contents again combining to form a plasmodium.

The genus *Ceratium*, containing twelve species, some of which resemble much branched trees in miniature, differs from all other known Myxomycetes in not having the spores produced in sporangia (*endosporous*), but free on the outside of the sporophore (*exosporous*).

Class II.—Acrasieæ.

The members of the present group differ from those of the Myxomycetes in never producing ciliated swarm-spores, the amœboid movement being the only one known; and further, the spores although becoming massed together previous to spore-formation, never coalesce to form a plasmodium as defined above.

As already stated, the Mycetozoa are considered by De Bary and his followers as lying outside the Vegetable Kingdom, and certainly the whole behaviour during the vegetative phase favours this view. Of course the spontaneous movements exhibited by the swarm-spores are not supposed to prove their animal nature, as similar motile cells occur in seaweeds, mosses, and ferns. During the reproductive phase the whole of the differentiation exhibited is in the direction of plant life, in a rudimentary form, as would be expected. The spores are at first enclosed in a cellulose cell-wall, and the various modes of spore-dispersion are those followed by the Gastromycetous fungi or puff-balls. This however may be the outcome of the Mycetozoa having adopted a terrestrial mode of life. The Mycetozoa are certainly not genetically allied to fungi, differing in the formation of a plasmodium and the absence of hyphæ.

The Mycetozoa are a terminal group, not connecting with any higher forms ; in other words, they have not given origin by differentiation to a higher group.

CHAPTER III.

SUBDIVISION II.—THALLOPHYTA.

CLASS I.—ALGÆ (*Seaweeds*).

Protophyta—Primordial Types of Plant Life—Transition from Unicellular through Cell Colonies to Multicellular Plants—Earliest Indications of Sexual Reproduction—Terminal Groups of Protophytes—Algæ Proper—Gradual Differentiation of Vegetative and Reproductive Parts—Evolution of new Groups—Distribution—Fossil Algæ.

(A) PROTOPHYTA.

THE *Protophyta*, as the name denotes, includes the primordial types of plant life, and are often considered as belonging to the Algæ, but are treated by Bennett as a distinct subdivision. This author states, however, that "whether the Protophyta should be reckoned as a distinct subdivision from the Algæ, or only as the lowest members of that great series, is a question rather of convenience than of principle." The great bulk of forms included in the present class are unicellular, without a distinct process of sexual reproduction, and are either destitute of chlorophyll, or this substance may be present in a pure form, or its characteristic green colour masked by the additional presence of blue or brown colouring matter. Although the above characters may be considered as characteristic of the Protophyta, we nevertheless meet with indications of the multicellular type of structure, and also of the simplest form of sexual reproduction by conjugation.

CLASS I.—SCHIZOMYCETES (*Bacteria*).

The exceedingly minute size of the cells constituting the members of the present group preclude an exact study of their nature. With very rare exceptions chlorophyll is absent; hence they are either saprophytes or parasites. In one species, *Beggiatoa roseo-persicina*, a red colouring matter tinges the protoplasm, and in many other examples, in certain stages of development, bright colours are produced; but owing to the minute size of the cells, it has not been clearly determined whether the colour occurs in the cell-contents or in the substratum. The individual Bacteria vary in shape from a sphere to an elongated cylindrical rod, the latter being either straight or curved, and some species show a transition from the spherical to the elongated form. Not unfrequently numerous individuals form large gelatinous masses.

The Bacteria are divided into two groups, based on the mode of reproduction. *Endosporous Bacteria* reproduce themselves by spores formed within the cells; *Arthrosporous Bacteria* do not form spores, but reproduce themselves by breaking up of the rods into short portions, each of which constitutes the starting-point of a new individual.

During recent years the Bacteria have been considered as the cause of various diseases, and in some instances this has been clearly demonstrated, as in the case of splenic fever, caused by *Bacillus Anthracis*.

The true position of the *Schizomycetes* is by no means definitely settled. Bennett says, "They are only fungi in the very limited sense of their being 'thallophytes which contain no chlorophyll,' and indeed it has been seen that certain Bacteria do contain chlorophyll. Looking at their morphological characters, as far as these are at present known, it cannot be doubted that the nearest allies of the Arthrosporous Bacteria are those Protophyta, Nostocaceæ, Oscillariceæ, Chroococcaceæ, etc., which contain chlorophyll. *Leuconostoc* (Van Teigh) has already been mentioned as an intermediate form. A gap certainly exists between Arthrosporous and Endosporous forms; but so far as can be seen the latter stand nearer to the former than to any other group, and the interval which separates them may become narrower with further knowledge. On the other side a connection appears to be indicated between Bacteria and Flagellata."

CLASS II.—SCHIZOPHYCEÆ.

The present group includes numerous presumably primordial forms of plant life, agreeing in some respects with the Schizomycetes, but distinguished by the universal presence of chlorophyll, and in most cases showing a higher degree of specialization. The Schizophyceæ are divided into three sections, the *Diatomaceæ*, *Cyanophyceæ*, and *Protococcoideæ.*

Diatomaceæ.

The chlorophyll is masked by a brown colouring matter, and the organic substance of the cell-wall is hardened with a deposit of silica or flint. The species, which are very numerous and very minute, are unicellular, and the cell-wall consists of two halves; the older half is slightly larger than the younger one, and fits on to the latter like the lid of a box. This siliceous wall is covered externally by a thin film of exuded protoplasm, and it is now generally considered that the spontaneous movements exhibited by many species is due to the contractility of this external protoplasm. In the majority if not all species the two portions or valves of the cell-wall are furnished with numerous rows of exceedingly minute perforations, which unless very highly magnified present the appearance of fine ridges.

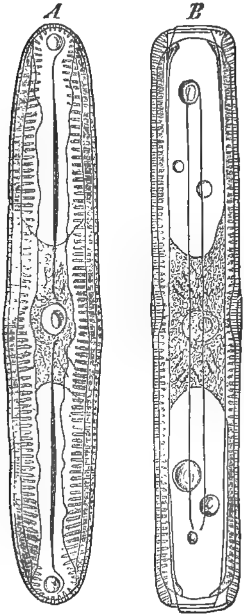

Fig. 16.—(×540). *Pinnularia viridis*, a diatom furnished with a siliceous cell-wall. *A*, side view; *B*, edge view. The central shaded portion is the protoplasm enclosing a nucleus. (From Strasburger.)

Three modes of reproduction are known. (1) By division. The first indication of this process is the division of the nucleus; the two valves separate and the protoplasm becomes resolved into two daughter-cells, each of which becomes enclosed in a cell-wall formed of two valves, the smaller of the two being formed last. As the valves of the daughter-cells are formed within the old valves of the mother-cell, it necessarily follows that each generation formed by this method becomes smaller than the preceding one. The original size is restored by a second form of reproduction, where what is termed an *auxospore* is formed by the escape of the contents of a small diatom escaping from the valve, increasing by growth and secreting a new wall. Sometimes two auxospores formed by the same mother-cell coalesce to form a new individual; in others the two auxospores produced by a single mother-cell form distinct individuals after growing to the normal size. The third method is by the conjugation of two distinct individuals, which become arranged side by side; the contents of the two escape by the opening of the valves and combine to form a *zygospore*. This latter method, although closely resembling the process of conjugation acknowledged as a sexual act in some of the higher algæ, as *Spirogyra*, etc., is not considered by some of the best authorities as a true process of sexual conjugation in the present instance. The above described modes of reproduction are connected by transitional methods.

Diatoms are aquatic forms met with in both fresh and salt water. Some species are solitary, either free or attached by one side to aquatic plants; others are attached in clusters by simple or branched gelatinous stalks; others again occur in immense numbers enclosed in a common gelatinous envelope. The Diatoms, like the Mycetozoa, form a terminal group.

Cyanophyceæ.

The leading feature of the present group is the presence of a blue-green colouring matter dissolved in the cell-sap, and consequently masking the green colour of the chlorophyll, which is always present. The most general mode of reproduction is by fission or cell-division; thick-walled resting-spores are formed in some cases, and in the higher filamentous forms short portions of the filament known as *hormogones* escape from the sheath enclosing the filament, and serve as the starting-point of new individuals. Motile reproductive cells or zoospores are, with a few doubtful exceptions, absent. The simplest forms, as *Glœocapsa* and

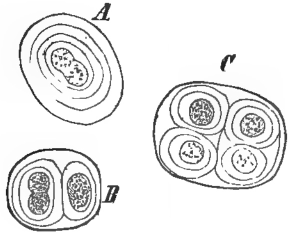

Fig. 17.—(× 540). *Glœocapsa polydermatica*, a minute fresh-water alga, showing stages in the formation of a colony or cell-family (*cœnobium*). In *A* the protoplasm (shaded portion) of an individual is becoming elliptical with a slight constriction in the centre, preparatory to dividing into two individuals, the thick mucilaginous cell-wall is lamellated. In *B* the division is complete, and the two daughter-cells or individuals have become elongated, preparatory to further division. In *C* the four individuals forming the colony are spherical and in the vegetative condition. (From Strasburger.)

Chroococcus, are unicellular, and usually form colonies enclosed in a gelatinous envelope formed by the gellification of the outer layers of the cell-wall; this envelope is frequently lamellated or composed of several layers. In the genus *Nostoc*, common on damp ground and in bog-pools under the form of bluish-green or dingy violet gelatinous masses of variable size, the chlorophyll-bearing portion forms a filament which at first sight resembles a chain of cells; the component portions however differ from true cells in the extremely thin cell-wall being inseparable from the protoplasm, which it also closely resembles in its chemical reactions. These primitive cells differ from those of *Glœocapsa* in being arranged in a moniliform or necklace-like chain. The protoplasm of all the cells composing the chain are in contact, being connected by strings of protoplasm passing through perforations in the transverse walls; in fact we have continuity of protoplasm exhibited contemporaneously with the most primordial attempt to form multicellular plants. During the vegetative phase all the cells are morphologically alike, and add to the length of the filament by repeated division. The two ends of a filament are alike, that is, there is no differentiation into base and apex. During the vegetative development of a filament certain of the ordinary cells increase in size, become incapable of cell-division, and their contents are replaced by colourless cell-sap. Such cells are termed *heterocysts*, and may be either terminal or intercalary; their function is unknown. The filaments increase considerably in length by cell-division, and become much contorted and more or less interwoven; the gelatinous sheath in which they are involved usually becomes confluent, and forms an outer gelatinous mass in which the filaments are imbedded. Reproduction is effected by hormogones, that is, portions of a filament composed of strings of four to eight cells break away, escape from the gelatinous envelope, and develop into new individuals; or certain of the cells of a filament are transformed into spores.

In the species of *Rivularia* and *Calothrix* the filaments do not consist of elliptical or sub-spherical cells or pseudocysts as in Nostoc, but are without constrictions, the thread being cut up into superposed cells by delicate transverse septa, thus approaching nearer to a filament composed of true cells. Such filaments also show an advance on Nostoc in having the two ends differentiated; the basal end terminating in a large, colourless, *basilar cell*, while the apex is attenuated into a long, tapering, colourless hair.

Many of the forms at present included in the present group may eventually be shown to be phases in the life-history of higher species of Algæ.

Protococcoideæ.

The organisms included in the present group are all minute, unicellular, never forming long septated filaments, and are characterized by the presence of bright green chlorophyll, which is not masked by colouring matter as in the *Diatomaceæ* and the *Cyanophyceæ.* The special interest attaching to the present group consists in the fact that from it all the higher forms of the Vegetable Kingdom have been derived. Some of the species are permanently motile, others always passive, while a considerable number exhibit the two conditions at different periods, as illustrated by *Protococcus*, a common form in fresh water, where it forms clear green masses of variable size, composed of numerous individuals which consist of a spherical cell furnished with a cell-wall. The green chlorophyll is often mixed with a varying amount of red colouring matter. In this condition the cells are motionless, and reproduce themselves by cell-division. The above quiescent condition is termed the *palmella* stage. The change to the free-swimming or *protococcus* stage is accomplished by the protoplasm escaping from the cell-wall furnished with two extremely slender cilia, which along with a pulsating vacuole, enable the organism to move rapidly in the water. The pulsation of the vacuole is said to be due to the action of the chlorophyll in extracting carbonic dioxide from the water, and liberating oxygen as a result of assimilation. The motile form may remain as a naked cell or become enclosed in a very thin cellulose wall, furnished with openings through which the cilia protrude. In some instances the protoplasm of the passive cell, instead of escaping as a single large zoospore, breaks up before escaping into several small zoospores. After existing for some time in an active state, the cilia contract into the mass of protoplasm, which secretes a thick cell-wall of cellulose, and returns to the palmella stage as a resting-spore, which possesses the power of retaining its vitality for years in the form of dry powder, and may be carried for a considerable distance by the wind and at once resume their vitality when placed in water. The power of assimilating carbonic dioxide and liberating oxygen under the influence of light, as also the secretion of a cell-wall composed of cellulose, prove the plant nature of Protococcus. In some genera, as *Chlorothecium*, swarm-spores are produced which conjugate by the gradual fusion of two such bodies into one, which may be considered as the earliest indication of sexual reproduction amongst the chlorophyll-producing forms of plant life.

As in the Cyanophyceæ, many forms at present included in the present group may ultimately be shown to be conditions of higher Algæ.

Commencing with the Algæ proper, we may be considered as clear of debatable ground, and dealing with organisms where those differentiations considered characteristic of plant life are distinctly evolved.

The following diagram illustrates the divergence of the groups already mentioned from the primitive *Flagellate Infusoria.*

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Alternation of generations is indicated in the Algæ, but does not become distinctly evolved, for although the majority of species, as already stated, possess sexual and asexual modes of reproduction, yet these do not regularly alternate; but there may be several successive generations of one method without the intervention of the other. In many species there is, throughout the summer or season of active growth, a succession of asexually produced generations; and in the autumn, when the vegetative structure is languishing, sexual organs are produced, the product of impregnation not unfrequently passing the winter in a resting-stage.

Cœnobieæ.

The members of the present order are mostly microscopic, and united in colonies to form a cœnobium, the individuals being usually imbedded in a mucilaginous matrix. Very little is known respecting the life-history of the lowest types; in the higher forms reproduction is effected asexually by cell-division, or by zoospores; sexually by the conjugation of similar or dissimilar motile zoogametes, or by differentiated antheridia and oogonia.

The following account of the life-history of typical forms will illustrate the stage of development attained in the group.

Pandorina morum is by no means rare during the summer months in still, clear water, appearing under the form of very minute green spheres involved in mucus. These spheres, when examined under the microscope, are seen to consist of sixteen cells or individuals containing bright green chlorophyll, each furnished with two long, very slender cilia, which protrude through the mucilaginous covering, and by their vibrations cause the entire cœnobium to move with great rapidity. The sixteen cells constituting the first colonies formed in the spring, originate from the repeated division of a single cell, that had passed the winter

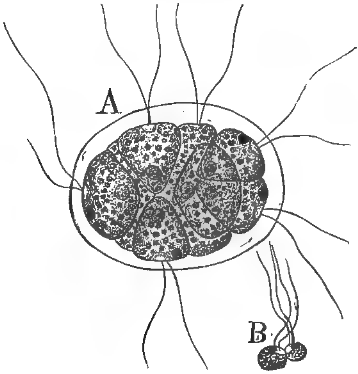

Fig. 18.—*Pandorina morum* (× 400). *A*, a motile colony (cœnobium). The individual cells have their cilia protruding through the gelatinous envelope of the colony. *B*, two zoogonidia, formed by the division of the cells of *A*, in process of conjugation. (From Prantl.)

as a resting-spore. But during the summer, the cœnobia, after remaining in a motile state for some time, become quiescent, owing to the retraction of the cilia; each of the sixteen cells then divides into sixteen smaller cells; the mucilaginous envelope of the cœnobium disappears at this stage and the 256 daughter-cells are liberated, each of which secretes a mucilaginous sheath, and forms the starting-point of a new cœnobium.

Sexual reproduction by conjugation of zoogametes takes place as follows. The sixteen cells of a cœnobium each divide into sixteen daughter-cells, which escape from the colony as motile pear-shaped zoogametes, having bright green chlorophyll at the broad end; the pointed end is destitute of chlorophyll, but contains a bright red pigment-spot, and is furnished with two cilia. The zoogametes vary in size, which however is not supposed to correspond to a difference of sex, and as they swim actively about conjugate in pairs, irrespective of relative size. The zygospore resulting from the conjugation of two zygogametes becomes surrounded by a firm cell-wall, changes to a red colour, and passes into the resting-stage. On germination the contents of the zygospore escapes in the form of from one to three motile zoospores, which after a short period of activity retract their cilia, secrete a mucilaginous covering, and form the starting-point of cœnobia. The present species is interesting, as being the first in which the conjugation of zoogametes was observed.

Volvox globator is a favourite object with microscopists, and consists of a minute hollow bright green sphere, which exhibits a rotatory movement in the water, and is in reality a cœnobium, quite visible to the naked eye, and often occurs in immense numbers in still, clear water. The wall of the colony consists of more or less pear-shaped motile cells, having the pointed end towards the periphery and furnished with two slender cilia, which protrude through the enveloping mucilage into the water. The great majority of these peripheral cells, which are individually enclosed in a gelatinous sheath, possess vegetative functions only so far as is known, and possess the peculiarity of being connected with each other by minute strands of protoplasm—a primitive form of protoplasmic continuity. Certain cells of the colony distinguished by their larger size are reproductive in function, and by the division of their contents give origin to asexually formed young colonies, which remain enclosed within the parent colony for some time, and eventually escape. These daughter-colonies may often be seen within the parent colony under the form of dark green balls. Towards the autumn the asexual mode of reproduction is replaced by a sexual method; certain cells recognized by their large size and dark green colour appear—these are oogonia; the large end projects into the interior of the sphere, and the contents become transformed into an oosphere. Other cells, the antheridia, produce antherozoids, which become free within the sphere and eventually blend with the oospheres, which after fertilization become covered with a thick cell-wall covered with prominences, and change to a brick-red colour. When the oospores are mature, the mother-colony breaks up, and they sink to the bottom of the water as resting-spores.

In the genus *Hydrodictyon*, popularly known as "water-net," the cœnobium presents the appearance of an inflated net, the wall being formed of slender cylindrical cells combined to form numerous irregular polygons. Asexual reproduction takes place by the protoplasm of one of the cells breaking up into numerous zoospores, each furnished with four cilia; after moving about in the mother-cell or zoosporangium for some time, the zoospores arrange themselves in such a way that by increasing in size they form a net which is liberated from the mother-cell, and by continued growth within the course of a few weeks reaches to the size of the parent net. In the above mode of reproduction the zoospores do not conjugate. Other cells of the net give origin to numerous minute zoogametes, furnished with only two cilia, which leave the parent-cell and conjugate, the resulting zygospore remaining for some time as a resting-spore. It has been clearly demonstrated, that by varying the nutrient solution in which the plant is kept, it can be made to reproduce itself by the sexual or asexual mode at pleasure.

Multinucleatæ.

The most pronounced character presented by the members of the present group, is the high phase of differentiation of the individual cell. The species are unicellular during the vegetative condition; but this one cell assumes in many species gigantic proportions, and in the species of *Caulerpa* is divided into portions which resemble in general appearance the root, stem, and leaves of an ordinary plant, all perfectly continuous and composed of a single cell, which is furnished inside with solid strands of cellulose stretching from wall to wall and forming an irregular network, the functions of which are to give strength, and also to convey assimilated food from one portion of the cell to another. In the genus *Acetabularia* the cell presents the appearance of a small mushroom with a long slender stem, bearing at its apex a spreading umbrella-like cap, the whole consisting of a single, much-branched cell. The name *Multinucleatæ* is derived from the fact that a very large number of nuclei are present in the cell.

Asexual reproduction by zoospores, and the highest forms are also reproduced sexually by the formation of highly-specialized antheridia and oogonia.

In the genus *Vaucheria*, several species of which are common in shallow, sluggish ditches, or in shady places on damp ground, where they form bright green felt-like expansions, the sexual mode of reproduction is most perfect. During the vegetative condition the plant is unicellular, the cell being usually very long and irregularly branched, and containing bright green chlorophyll and numerous nuclei. Asexual reproduction is effected in various ways. The tips of certain branches become swollen and separated by a transverse wall or septum from the remainder of the cell, the contents contracting and forming a new cell by the method of rejuvenescence: after escaping from the mother-cell the new cell either germinates at once, or spends some time as a resting-spore. This method of reproduction is said more especially to follow an injury to the plant. Zoospores are formed in the tips of branches which are separated from the cavity of the plant by a septum, the contents contract and form a single large zoospore completely surrounded by fine cilia; after a brief period of activity the cilia are contracted, a wall of cellulose formed, and germination commences at once. The sexual organs are produced laterally on the elongated wall, usually on the same, sometimes on distinct plants. When developed on the same plant, the antheridia and oogonia are usually near to each other. The antheridia are formed at the tips of slender, straight, or curved branches, and contain a quantity of biciliate zoospores, which eventually escape through the ruptured apex of the antheridium or mother-cell. The oogonia originate as stout blunt swellings, which eventually develop into elliptical or circular bodies, furnished at the free tip with a narrow nipple-like prominence. Their contents, like those of the antheridia, are separated from the cavity of the supporting cell by a septum; the contents then contract to form an oosphere, which is exposed by the deliquescence of the nipple-like apex of the oogonium. Through this opening the antherozoids find their way to the oosphere and coalesce with it; the fertilized oosphere secretes a cellulose cell-wall, assumes a red or brown colour, and becomes a resting-spore. On germination, several asexual generations are produced during the summer, the sexual condition developing towards the autumn and forming resting-spores, which enable the species to survive the winter or season unfavourable for active vegetation.

Confervoideæ Isogamæ.

In the present class we first meet with typical multicellular plants, consisting for the most part of simple or branched single rows of cells, placed end to end. Increase in length takes place by the repeated bipartition of the terminal or apical, and sometimes also by the division of intercalary cells. In some species the terminal cell is prolonged into a slender, tapering colourless hair. This character is well seen in the genus *Draparnaldia*, a very beautiful alga not uncommon under the form of bright green, gelatinous-feeling small masses attached to other plants, twigs, etc., in clear fresh water. Most of the species included in the present class inhabit fresh water, but a few occur in brackish water, or in the sea. As a rule the plants are bright green, but in the genus *Chroolepus* the green colour is masked by a bright orange or red colouring-matter. *Chroolepus aureum* is not uncommon on rocks and walls, forming bright orange, velvety patches, sometimes of considerable extent. Several nuclei are usually present in each cell, as in the *Multinucleatæ;* but the members of the present order differ from those of the last-mentioned in being distinctly multicellular.

The most general form of reproduction is asexual, by ciliated zoospores. A second form of asexual reproduction is by the formation of non-motile cells, which often form resting-spores. Such non-motile reproductive bodies when formed by rejuvenescence of the contents of a mother-cell are called *aplanospores;* when formed without rejuvenescence, *akinetes.* The only known method of sexual reproduction is by the conjugation of two motile zoogametes, which are not apparently differentiated into male and female elements. The term *isogamous* is applied to those cases of primitive sexual reproduction where the two elements are similar in size, and without marked differentiation into male and female bodies. In many species, included under the present order, the sexual mode of reproduction is unknown.

Conjugatæ.

The most pronounced characteristic of the present order, and the one from which the name is derived, is the sexual mode of reproduction, which is effected by the conjugation of two passive or stationary cells. According to some authorities we meet with the first morphological indication of male and female sexual organs in the present order; this idea will be explained when describing the morphology of *Zygnema.* Motile zoospores are unknown, asexual reproduction being carried on by the formation of akinetes or aplanospores, which form resting-spores. The individuals are either unicellular, as in most of the Desmids, or consist of a single row of cells attached end to end, and almost invariably unbranched. The arrangement of the chlorophyll in spiral bands, symmetrical stars, or discs, is a marked feature of the order. The external mucilaginous sheath is still present, but is not so pronounced as in some of the preceding orders.

Most species occur in fresh water, a few occur amongst damp mosses, or on moist ground.

The Diatoms, described under the Protophyta in the present work, in accordance with Bennett's idea of their affinities, are by some writers included in the present group, with which they agree in the sexual mode of reproduction.

The Desmids are all unicellular, and in most instances free, but some species are united by a gelatinous sheath into long filaments. In the majority of species the cell is divided by a deep constriction into two symmetrical halves, united by a narrow band called the "isthmus." Generic characters are founded to a great extent on the form of the cell, that is, of the individual, which varies in outline from circular through elliptical and crescent-shaped, to straight and linear. The cell-wall is usually transparent, but in many species contains a little silica, but never to the extent met with in the cell-wall of Diatoms. The surface may be perfectly even, warted, or furnished with prominent spines, usually symmetrically arranged. The chlorophyll is bright green, and often arranged in bands or stars, and even in those cases where the cell has no median constriction the chlorophyll is arranged in two halves of the cell.

Many of the free species exhibit spontaneous movements, considered to be due to a film of protoplasm outside the cell-wall, which protrudes from the interior through perforations in the wall.

Asexual or vegetative reproduction takes place by the division of the cell in the following manner. The isthmus or neck-like constriction increases in size and becomes divided by a septum or cross wall into two equal parts, one of which is continuous with each original half-cell; the half-cells of the isthmus receive a certain amount of endochrome from the original half-cells of the desmid, and rapidly grow and assume all the structural features of the original half-cells, which they slightly exceed in size; after which the two desmids separate along the septum formed across the isthmus. From the above account it will be noticed that in all desmids produced by fission, or division, the two halves of the cell are of different ages, the youngest half being slightly the larger of the two.

The sexual process takes place by the conjugation of two morphologically or structurally similar individuals in the following manner. In the free species two individuals, lying either parallel or across one another, become involved in a mucilaginous sheath. In each individual the inner layer of the cell-wall protrudes through an opening in the outer wall at the central constricted portion, the two protruded portions become swollen with protoplasm, meet, and after the disappearance of the cell-walls at the point of contact, the two portions of protoplasm combine to form a zygospore, which becomes clothed with a firm, coloured, smooth, or more frequently warted or spinulose cell-wall, and settles down as a resting-spore. The empty half-cells of the two conjugating desmids are pushed off during the early growth of the zygospore.

After a period of rest the zygospore germinates and produces at once a new individual, structurally resembling the fully developed form but smaller; however, by quickly repeated division, the typical size is attained by the method already described.

In the genus *Zygnema* and its allies, as *Spirogyra*, *Mougeotia*, etc., the individual consists of a single unbranched row of superposed cells, often of considerable size. In *Spirogyra* the chlorophyll is arranged in a spiral band, which encloses large starch-grains, that can be rendered very distinct by the application of a solution of iodine, which causes them to assume a blue colour; a very fine large nucleus is also present in each cell, suspended in the sap-cavity by strands of protoplasm, which spring from the parietal layer. If a few filaments are placed in water in a watch-glass, and a small amount of watery solution of eosin, to which a drop of acetic acid has been added, be mixed so as to give to the water a very pale rose colour, at the expiration of half an hour or less the nuclei will be found stained a brilliant red, the remaining portions being unstained.

In Zygnema the chlorophyll forms two stars in each cell.

The sexual method of reproduction is by conjugation, and generally occurs in the following manner. Two distinct individuals lying side by side send out lateral prolongations from their cells on the sides opposite to each other, these prolongations from the cells belonging to distinct plants meet, the whole structure now presenting the appearance of a ladder, the sides being formed by the two filaments, or plants, and the rungs by the transverse outgrowths from the opposed cells. On account of the ladder-like arrangement formed by the two plants, this method has been termed *scalariform* conjugation. During the development of the lateral outgrowths from the cells, the whole of their protoplasmic contents contract, and a passage being formed between the pair of conjugating cells, owing to the absorption of the wall at the point of contact of the two lateral outgrowths, and the contracted portions of protoplasm from all the cells of one plant pass through the tube formed by the outgrowths, and blend with the masses of protoplasm that have remained stationary in the cells of the other plant. When the union of the two portions of protoplasm is complete a cell-wall is formed, the resulting zygospore usually becoming liberated owing to the decay of the parent plant, and sinks into the mud as a resting-spore. In some instances the zygospore germinates almost at once, and while yet enclosed in the mother-cell.

The fact of all the contracted protoplasm masses passing from the cells of one of the conjugating plants and coalescing with the passive protoplasm contained in the cells of the second plant, certainly suggests an indication of sexual differentiation, the plant from which the protoplasm migrates being considered the male, and the one in which the protoplasm remains passive, the female. The masses of contracted protoplasm in the cells of the latter are also slightly larger than in the former, and other slight differences also exist; but a true differentiation of sex is not yet stereotyped, as the following modifications of the above process show. In some cases so-called *lateral* conjugation between two cells of the same filament takes place, processes from two contiguous cells grow outwards,

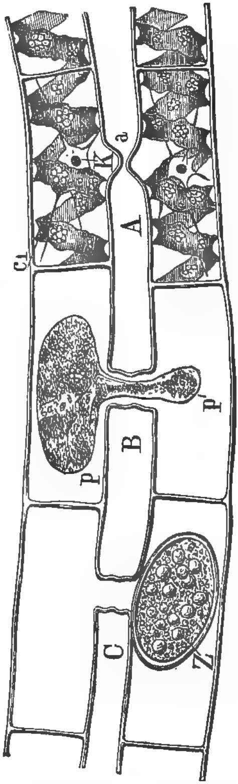

Fig. 19.—(× 400). Conjugation of the cells of two individuals of *Spirogyra*. *A*, two cells prepared for conjugation; at *a* the filaments have begun to swell towards each other; *cl*, spiral bands of protoplasm. *K*, nucleus. At *B* the protoplasm of the cell *p* is fusing with that of the cell *p'*. *Z* is a perfectly-formed zygospore which has secreted a cell-wall. (From Prantl.)

curve towards each other, and finally meet; absorption of the walls takes place at the point of contact, and the whole of the protoplasm from one cell passes along the tube formed by the outgrowths from the two cells, and coalesces with the stationary protoplasm of the second cell. To assume the differentiation of sex in the present example, it would be necessary to consider some of the cells of a single plant male, and others female. In other cases the zygospore is formed in the connecting tube between the two cells, the protoplasm from both cells moving to this point. Finally *parthenospores*—resembling ordinary zygospores, and capable of germination, but differing in being formed from the protoplasm of one cell only, without any act of conjugation—are sometimes formed.

In the genus *Mesocarpus* and its allies conjugation in a scalariform manner takes place, as in *Zygnema;* but the whole of the protoplasm does not contract, a small portion being left behind. The two masses of protoplasm meet and form the zygospore in the connecting tube, but not in the central part, being nearer to one cell than the other; and this may possibly represent the female cell; but the sexual differentiation is very slight and vague. Lateral conjugation, also the formation of parthenospores, also occur at times. The chlorophyll in *Mesocarpus* is arranged in the form of thin, flat plates. Asexual reproduction takes place by the formation of resting-spores from the vegetative cells of the plant.

The most pronounced difference between the *Zygnema* and *Mesocarpus* types consists in the behaviour of the zygospore in the latter, which does not germinate directly after a period of rest, as in *Zygnema;* but immediately after its formation it divides into several cells, the central one alone germinating after a period of rest, the others being sterile. This peculiarity must be considered as the shadowing in of Alternation of Generations, which becomes such a marked feature in the Mosses and Ferns.

In the present case, the first or sexual generation terminates with the formation of the zygospore, which is the direct and immediate product of fertilization. The zygospore however does not germinate directly, but at once produces two, three, or more cells by division, which constitute the second or asexual stage, the one cell that eventually germinates not being the immediate result of sexual fertilization, hence a spore; and the sterile cells must be considered as an incipient pericarp.

In the present group the sexual mode of reproduction by conjugation reaches its maximum of development, and does not recur higher in the scale of plant-development, the two sexes being in all the ascending groups morphologically differentiated.

Dictyotaceæ.

The species included in the present group are olive-brown in colour, of a membranaceous texture, usually growing erect, and often beautifully iridescent. Asexual reproduction takes place by the formation of *tetraspores*, that is, the contents of special cells called *tetrasporangia* break up into four spores, which on their escape enclose themselves in a cellulose cell-wall and germinate at once. Occasionally the contents of a tetrasporangium divides into two portions; or, rarely, the contents escape as a single large spore. Tetraspores are perfectly motionless, and ciliated motile zoospores are unknown in the group. The tetrasporangia are formed by outgrowths of the superficial cells of the thallus, and may be either marginal, or forming clusters on the surface called *sori.* The supposed sexual organs are produced in similar positions to the tetrasporangia, but on distinct plants, and never on those producing the asexual reproductive bodies. The oogonia consist of special cells, each containing a single large, motionless oosphere. The antheridia consist of a number of cells, which are divided into numerous small cells, each of which contains a single motionless pollinoid. The presence of a trichogyne has not been demonstrated, and whether fertilization of the oosphere takes place is not at present known.

The *Dictyotaceæ* resemble the *Florideæ* in having tetraspores, and also in the motionless pollinoids, and may perhaps be considered as the progenitors of the characteristic sexual and asexual modes of reproduction met with in the *Florideæ*, the sexual organs not being completely evolved in the present group.

Phæosporeæ.

The present order may be considered as temporary and purely artificial, owing to absence of information respecting the life-history of numerous included forms; the common points of agreement being the asexual mode of reproduction by motile zoospores, and the olive-brown colour. With very few exceptions the species are marine, and vary in size from microscopic forms to species that attain a length of hundreds of feet, as in *Macrocystis pyrifera*, which occurs on the coast of California and in the Antarctic Ocean. Some of the smaller forms are epiphytic, and others parasitic, on other algæ. The structure of the thallus also varies considerably in different genera, being crust-like and radiating in *Ralfsia;* composed of slender filaments consisting of a single row of superposed cells in some species of *Ectocarpus*; while in *Laminaria*, the largest of our brown seaweeds, popularly known as "devil's aprons," the thallus is differentiated into portions resembling in appearance, but not in function, root, stem, and leaf. In the stems of *Macrocystis* and *Nereocystis* there is a considerable amount of differentiation exhibited; elongated cells called *trumpet-hyphæ* occur, having the transverse septa and also lateral portions of the wall perforated and forming true *sieve-plates*, with a callus formation similar in structure to the *sieve-tubes* met with in the bast of some *Phanerogams*. In some species increase in size depends on the division of an apical cell; in others that form crust-like expansions, increase in size takes place by the simultaneous division of the tips of several contiguous filaments, which collectively constitute a peripheral generating zone. A third mode of growth, known as intercalary, is illustrated by the genus *Laminaria*, where the point of growth is situated at the junction of "stem" and "leaf"; the new "leaf" originates at the apex of the stem, and growing by addition to the base, gradually pushes off the old "leaf." In *Scytosiphon*, *Chorda*, and some other genera where the thallus is unbranched and the "stem" absent, the point of growth is near the base of the thallus.

Protoplasmic continuity is very clearly shown, especially in the larger species.

When young, the thallus of many species is covered with very slender hair-like outgrowths from the superficial cells, which usually disappear with age.

The olive-brown colour is due to the presence of a pigment called *phycophæin*.

In many of the larger species the thallus is enabled to float on or near the surface of the water by means of air-bladders, or specialized hollow portions of the frond containing air. In the genus *Nereocystis*, these floats are barrel-shaped, and often attain a length of two yards.

Asexual reproduction by means of motile zoospores is general throughout the group. The zoospores are more or less pyriform, furnished with two cilia of unequal length, a longer one pointed forwards, that is, in the direction of the pointed colourless end of the zoospore, and a shorter one pointing backwards. The cilia originate laterally and nearest the pointed end; whereas, in the groups previously described, they originate from the narrow end. The zoospores are produced in zoosporangia of two distinct types: the unilocular sporangium, containing a large number of zoospores in one cavity; the multilocular, consisting of numerous small cells, each containing a single zoospore.

Unilocular sporangia vary in form from subglobose, through elliptical to pyriform, and are comparatively large; whereas the multilocular form is usually elongated, hair-like, and transversely septate. The zoosporangia are either external, terminating short branches, or imbedded in the substance of the thallus, usually in considerable numbers, forming *sori* or definite groups; in the latter arrangement clavate cells termed *paraphyses* are usually mixed with the zoosporangia. In some species both kinds of zoosporangia are produced on the same plant at the same time, but more frequently the two kinds are produced at different seasons of the year; in others the two forms of zoosporangia are produced on different plants of the same species, whereas in others again only one or other of the two forms of zoosporangia are known to exist. For example, unilocular zoosporangia are alone met with in the genus *Laminaria* and its allies; both kinds in the genera *Ralfsia*, *Chordaria*, etc.

The zoospores produced in the two forms of zoosporangia present no observable differences in shape or size. Those formed in the unilocular zoosporangia germinate directly, so far as is known; while those from the multilocular zoosporangia sometimes conjugate, and must then be considered as zoogametes possessed of sexual functions.

The sexual modes of reproduction met with in the *Phæosporeæ* show an interesting sequence from the conjugation of precisely similar zoogametes, to the fertilization of a large passive oosphere by motile antherozoids.

In *Ectocarpus siliculosus* the zoospores produced in multilocular sporangia are alike in size and form, but some of these presumably female zoogametes lose their cilia and come to rest. In this condition they appear to exert an attractive influence over the male zoogametes, which remain active, and swarm round them until fertilization is effected by the coalescence of the two forms, and after which a cell-wall is formed and germination commences at once. In cases where the female zoogamete is not fertilized germination still takes place, as is also the case with those male gametes that do not conjugate; but the individuals resulting from the germination of the latter soon perish. The above example illustrates the gradual acquirement of sexual functions by originally asexual organs of reproduction.

The small group known as *Cutleriaceæ*, including the genera *Cutleria*, *Zanardinia* and *Agalozonia*, are included by Bennett in the *Phæosporeæ*, on account of agreeing with the latter in the asexual mode of reproduction by motile zoospores. The general habit is also the same, but the sexual mode of reproduction is marked by a decided differentiation of the male and female organs, which as explained above is indicated in *Ectocarpus*, carried one step

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further in the *Cutleriaceæ*, and completed in the next order to be considered—the *Fucaceæ*, where we find the oosphere a perfectly motionless body from its earliest differentiation.

In the *Cutleriaceæ*, besides the asexual mode of reproduction by motile zoospores, the only method known to exist in the genus *Agalozonia*, a true sexual mode of reproduction occurs in the genera *Cutleria* and *Zanardinia*, the female organ being an oosphere, the male a ciliated antherozoid. The oogonia divide into thirty-two or sixty-four cells, each of which produces a single oosphere. The oospheres escape as biciliated active *zoospheres*, closely resembling the zoospores of the *Phæosporeæ* proper, but are larger. After moving about for some the cilia are retracted and the oospheres become motionless, when they are approached by the active antherozoids. The coalescence of a single antherozoid with an oosphere is sufficient for effecting fertilization, a cell-wall is then formed, and the oospore germinates at once without entering into a resting-stage.

Fucaceæ.

The *Fucaceæ* resemble the *Phæosporeæ* in having the green chlorophyll masked by the presence of the olive-brown colouring-matter called phycophæin, but are characterized by the absence of any asexual mode of propagation and by the characteristic mode of sexual reproduction.

The species included in *Fucaceæ* are marine, and constitute the bulk of olive-brown seaweeds growing between tide-marks, the common "bladder-wrack," *Fucus vesiculosus*, being especially abundant on our coasts. The thallus is usually large, often several feet in length, and usually variously branched, the branches all lying in the same plane ;

but in *Himanthalia lorea* the vegetative portion of the thallus commences as small pear-shaped bodies, attached by a small disc. Eventually the upper portion becomes cup-shaped, and during the second year a long, narrow, dichotomously-branched receptacle springs from the depressed centre of the basal, cup-like portion. The branches of the receptacle are of nearly uniform width, varying from one-sixth to one-quarter of an inch, and sometimes reaching a length of fifteen feet or more. The "gulf-weed" of the "Sargasso Sea" is not attached, and floats in dense masses on the surface of the sea, being buoyed up by numerous air-bladders.

The tissue of the thallus shows a considerable amount of differentiation. The central portion consists of a so-called *medullary* system, composed of loosely compacted, elongated cells, and surrounded by a *cortical* layer of short cells, which is again surrounded by an *epidermis* of small cells that are closely compacted. Increase in length depends on the repeated division of a single pyramidal or four-sided apical cell; increase in thickness depends on the radial division of the outermost cortical cells. In some species the flattened or leaf-like portions of the thallus are of equal thickness throughout; in others, as the species of *Sargassum* and *Fucus*, there is a central thicker portion or "midrib."

Protoplasmic continuity is very clearly shown in most species.

Air-bladders or floats are present in most of the species. These may occur in the substance of the frond, as in *Fucus vesiculosus* and *Ascophyllum nodosum.* In the gulf-weed, *Sargassum bacciferum*, they are globose and stalked, while in *Halidrys siliquosa* they are long, pod-like, and constricted at intervals.

The sexual reproductive organs consist of antheridia and oogonia, which are produced in cavities called *conceptacles.* The conceptacles are situated near the circumference of the thallus, are circular in section, and communicate with the exterior by a narrow mouth or *ostiole*, and may be compared to circular flasks immersed in the substance of the thallus, and communicating with the surrounding water by a small mouth.

In some species, as *Himanthalia lorea*, the conceptacles are scattered over the entire surface of the receptacle; but they more frequently form crowded patches at the tips of the branches, as in the genus *Fucus;* in *Sargassum* they are produced on special branches of the thallus.

In some species the conceptacles are exclusively male or female, and in such cases the species are always *diœcious*, that is, the male and female conceptacles are borne by distinct plants, as in *Fucus vesiculosus;* in others, the same conceptacle contains both antheridia and oogonia, as in *Fucus furcatus.*

In the diœcious species the male plants can be recognized by the orange colour of their conceptacles, the female conceptacles being dull in colour.

The inner walls of the conceptacles bear numerous filamentous, jointed cells, some of which remain sterile, and in some species project through the mouth of the conceptacle into the water; such barren filaments are known as *paraphyses.* In the male conceptacles the filaments are usually branched, and the antheridia are formed from lateral ramifications of the branched filaments. Each antheridium consists of a thin-walled oval cell, the protoplasm of which breaks up into numerous—usually sixty-four—antherozoids. These are very minute, pear-shaped; contain a nucleus and an orange-red pigment spot, and are provided with two lateral cilia of unequal length. In the *hermaphrodite* conceptacles, or those containing both antheridia and oogonia, the former are situated at the upper part, nearest the mouth.

The filaments formed in the female conceptacles remain unbranched; the oogonium originates as a short filament, which is soon cut off from the parietal cell from which it springs by a transverse septum, and as it increases in length is again divided by a septum into two cells; the lower remains short and thin, and is called the *pedicel-cell*, the terminal cell increases considerably in size and forms the oogonium. During development the wall of the oogonium becomes differentiated into two distinct layers, the protoplasm becomes coloured with phycophæin, and contracts to form a single oosphere, as in the genus *Sargassum*, or divides into four oospheres in *Ascophyllum*, or into eight in *Fucus*.

Fertilization takes place after the oospheres have escaped from the conceptacle into the surrounding water. The outer layer of the wall of the oogonium is ruptured at the apex, and the inner layer, which yet remains intact and enclosing the oospheres, protrudes, but for a time remains attached to the torn outer layer by a point at the base, which corresponds to the point of protoplasmic continuity between the pedicel-cell and the oosphere. Eventually the inner layer of the oogonium with its contained oospheres breaks away and escapes into the water, where the enclosing membrane disappears, and the liberated oospheres, at first angular from mutual pressure, assume a spherical form and remain from the first perfectly motionless, not being furnished with cilia. The motile antherozoids that have in the meantime escaped into the water, swarm round the oospheres in considerable numbers, and by their movements impart to them a rotatory movement which lasts for some time. Eventually one or more of the antherozoids become blended with the substance of the oosphere and fertilize it; after which a cell-wall of cellulose is formed, and without a period of rest commences to germinate. It is stated that unfertilized oospheres show indications of germination, which however never proceed far before they perish.

In many species cavities exactly resembling in structure the conceptacles are present, but produce no sexual organs. These are sometimes termed *cryptostomata*, and may be considered as abortive conceptacles.

Confervoideæ Heterogamæ.

All the species included in the present order inhabit fresh water, are small in size, and have bright green unmasked chlorophyll. They form a connecting link between the Isogamous Confervoideæ and the simpler Florideæ, differing from the former in having well-differentiated male and female organs of reproduction, and from the latter in having the male sexual organs motile and furnished with cilia, and in having asexual motile ciliated zoospores. The thallus consists of a filament of superposed cells, either simple or branched, or of a flattened plate of cells radiating from a centre, consequently exhibiting far less differentiation than in the two preceding orders, and the reason for their occupying the present position in the scheme of classification rests on the sexual mode of reproduction present in the highest members of the order, which is in touch with that characteristic of the Florideæ, the highest order of Algæ.

The simplest type, illustrated by a somewhat rare alga, *Sphæroplea annulina*, consists of an unbranched filament of superposed cells, having very thick, perforated, transverse septa; the plant is *monœcious*, that is, having both sexes produced in different parts of the same individual. Asexual reproduction is unknown. Certain of the cells of a filament become oogonia, others antheridia; the contents of the former break up into several oospheres, each having a colourless "receptive spot," at which fertilization by the absorption of an antherozoid takes place. The contents of the antheridia change to a dull red colour, and break up into a large number of biciliated zoospores, which pass into the oogonia through the perforations in the transverse septa. The fertilized oospheres become clothed with a thick, warted cell-wall, and change to an orange-red colour. The mature oospheres remain within the parent filament during the resting-stage, and frequently float on the surface of the water for some time during the autumn, as a thick, orange-red felt.

In the spring the resting-spores on germination produce three or four zoospores, each of which changes into a fusiform or spindle-shaped cell, with thin hair-like ends: from this cell the plant grows by cell-division.

In the genus *Œdogonium*, the sexual mode of reproduction is more complex than in Sphæroplæa, and the mode of cell-formation is of a very peculiar type, not met with elsewhere in the Vegetable Kingdom.

Several species are common in fresh-water streams and ponds, and all agree in consisting of an unbranched single row of cells, containing clear green protoplasm, and by the presence of a considerable number of rings, or striæ, close to the basal end of certain of the cells. These concentric rings are the result of intercalary cell-division, and originate as follows. The young alga, whether originating from a sexually produced resting-spore or from an asexual zoospore, becomes attached at one end to some solid body, the free end elongating for some time, and eventually becoming divided into two cells by the formation of a transverse septum. Immediately above the septum, that is, near to the basal portion of the terminal cell, a narrow zone of the cell-wall becomes very much thickened by the deposit of cellulose, in the form of a ring projecting inwards into the cavity of the cell. When a sufficient supply of cellulose has accumulated, the outermost portion of the cell-wall splits in a circular manner over the ring-like thickening, and the ridge of cellulose elongates into a cell which is interposed between the two previously existing ones. The two margins of the outer cell-wall, caused by the splitting over the region of the accumulated internal ring of cellulose, are now separated from each other by the length of the new cell, resulting from the extension into a long, circular cell of the thickened ring, and one split circular margin points to the apex of the cell, and the other, that has been pushed upwards by the formation of the cell, points to the base of the plant. A transverse septum, formed immediately above the internal thickened ring, separates the cavity of the new cell from that of the terminal one. If the above account has been understood, it will be seen that the diameter of the new interposed cell is slightly less than that of the two original cells, less in fact by the thickness of the outermost portion of the outer cell-wall, that split to allow of the extension of the thick ring of cellulose to form the new cell-wall. After the new cell is fully grown a thick zone forms at its base, immediately above the first one, followed by a similar splitting of the outer layer of the wall all round the cell and immediately over the thickened portion, which in turn elongates and forms a new cell, pushing the two upper ones before it, so that the original apical cell continues to remain so throughout the entire life of the plant. We have now two frills, or free margins of cell-wall, at the base of the second cell, and as this process is often repeated from six to ten or more times by the same cell, the result is a corresponding number of free margins of the split cell-wall, that have received the name of *caps*. Any one of the daughter-cells resulting from this method of division may in turn become a generating cell, the number of caps or free margins indicating the number of cells produced by a given generating cell.

The asexual mode of reproduction is by motile zoospores formed by rejuvenescence in certain of the cells of a filament. The zoospores are very large, and the anterior colourless end is furnished with a *tuft* of cilia; a well-defined nucleus and an orange-red spot are also present.

The sexual mode of reproduction is effected by antherozoids and oospheres. The antherozoids originate in two different ways. In one method the antheridia are cells forming the filament, but recognized by being much shorter than the vegetative cells, and may be scattered and solitary, or following each other in considerable numbers. In most instances the cells destined to become antheridia divide into two mother-cells by the formation of a horizontal or transverse septum, the contents of each mother-cell becoming transformed into an antherozoid. The antherozoids are furnished with a tuft of cilia like the zoospores, but are much smaller.

A second and more complicated formation of antherozoids takes place as follows. Asexually-formed zoospores called *androspores*, closely resembling the antherozoids already described in form and size, are produced in special short cells of a filament. On their escape they attach themselves to the filament on or near an oogonium, and develop into very small male plants, called "dwarf males," consisting of two or three superposed cells, the terminal one becoming an antheridium, in which are formed two or three antherozoids, that escape by the separation of the upper portion of the wall of the mother-cell in a circumscissile manner.

The oogonia are produced on the same plants as the antheridia or on different ones, depending on whether the species is monœcious or diœcious. They are always developed in cap-cells, and may be solitary or in groups. The oogonia become swollen into an elliptical or spherical form, and the protoplasm contracts into an oosphere, having its chlorophyll grains massed together at one part, leaving a colourless "receptive spot," opposite to which the wall of the oogonium opens in a definite manner. Through the opening thus formed, a mucilaginous substance protrudes, to which the antherozoids become attached, and thus reach the receptive spot. After fertilization the oosphere becomes clothed with a thick cell-wall, changes to a brown colour, and becomes a resting-spore, still remaining within the oogonium, which breaks away from the filament.

On germination, the contents of the resting-spore breaks up into zoospores, each of which gives origin to several generations of asexual plants produced by zoospores, after which plants with sexual organs are produced.

The species of *Bulbochæte* are closely allied to *Œdogonium* in the sexual mode of reproduction, but are distinguished by being branched, and in having each branch terminated by a slender, tapering, colourless spine, with a swollen base.

In the genus *Coleochæte*, although the chlorophyll is bright green, and not masked by the presence of a colouring matter, there is a close approach to the mode of fertilization characteristic of the *Florideæ* or red seaweeds; but the members of the present genus differ in having motile antherozoids.

The vegetative part resembles a minute plate or cushion attached to aquatic plants, and consists of dichotomously branched filaments of cells radiating from a centre in one plane; consequently the plant grows peripherally, owing to the increase in length of its component filaments at the tips. In some species the spreading filaments produce branches that grow erect in a compact manner, forming a cushion-like tuft. Some of the cells of the thallus form a protuberance on the free upper surface, which elongates for some distance and then splits at the apex, and from out of the split apex a long, slender, colourless spine protrudes, as from a sheath.

Asexual reproduction takes place by means of biciliated zoospores, which escape from the mother-cell or antheridium through a round hole which appears in the wall.

Sexual reproduction is brought about by the fertilization of an oosphere by ciliated antherozoids, but not directly as in the preceding groups, but through the agency of a *trichogyne*, or outgrowth of the oogonium. The oogonium is formed from the terminal cell of a branch which increases in size, and at the same time elongates at its apex into a long slender tube or trichogyne, which opens at its point and exudes a drop of mucilage. The protoplasm of the swollen part of the oogonium which contains chlorophyll contracts and forms a single oosphere containing a nucleus. In monœcious species the antheridia are formed from cells near to the oogonia. Two or three flask-shaped protuberances spring from a cell and become cut off by septa, each protuberance being an antheridium, the entire contents of which form a single antherozoid furnished with two cilia. It is presumed that the oospheres are fertilized by the antherozoids passing down the tubular trichogyne, but this has not yet been actually observed. After fertilization the oosphere becomes clothed with a cell-wall, and forms an oospore. At the same time the oogonium becomes surrounded by a layer of cells, formed from branches that spring from the cell supporting the oogonium. This covering is called the *pericarp*, and the whole structure is known as a *sporocarp*, which assumes a dark brown colour, becomes liberated by the disappearance of the vegetative parts of the thallus, and enters the resting-stage. The trichogyne is not enclosed in the pericarp, and soon disappears.

During the resting-stage the oosphere remains unicellular, but in the following spring the cortical layer is ruptured, and the oosphere divides into several cells by repeated bipartition. Each cell produces a single zoospore, which gives origin to several asexual generations. Eventually a sexual generation arises, which may be monœcious or diœcious, according to the species.

Florideæ.

The most pronounced characteristics of the present order are, asexual reproduction by perfectly motionless spores not furnished with cilia; being usually produced in fours in a mother-cell or sporangium they are called *tetraspores*, or sometimes *tetragonidia*. The oosphere is fertilized by motionless male bodies called *pollinoids*, that become attached to a trichogyne: after fertilization the oogonium usually becomes enclosed in a pericarp.

With very few exceptions the species are marine, and grow in deep water below low-water mark, or in rock-pools that retain their water at low-tide. Their colour is always some shade of red or purple, when flourishing under normal conditions; but when growing in positions where they are much exposed to light they become green, as is also the case when stranded on the beach, and especially after a shower of rain. The red colour is due to a complex pigment called *rhodospermin*, that can be extracted by immersing the plant in fresh water.

The structure of the thallus presents a sequence in the various groups forming the Florideæ, from primitive filaments of superposed cells, to the most complex types of structure met with in the Algæ. In the simpler species of *Callithamnion* as *C. Rothii*, the thallus consists of minute, sparingly-branched filaments, consisting of a single row of cells, that form broadly-spreading velvety patches on rocks at half-tide level. In another group, represented in the British seas by the genus *Melobesia*, the thallus forms flattened or irregularly rugulose crust-like expansions, attached to the larger algæ or to rocks, and of a whitish colour, due to the cell-walls becoming encrusted with carbonate of lime. In the genus *Porphyra* the thallus consists of a large flat plate of cells. In the *polysiphonous* type of growth, illustrated by the species of *Polysiphonia*, there is a large central axis or filament, composed of a single row of superposed cells, surrounded by a varying number of smaller filaments known as *pericentral-cells*. This arrangement originates as follows: The species are filamentous; that is, consisting of numerous long slender branches, each of which grows by the repeated division of an apical cell, of a cylindrical form, with the *distal* or free end rounded. When the apical cell has reached a given size, a daughter-cell, in the form of a very thin disc, is cut off from its *proximal* or attached end by a transverse septum. Contemporaneous with the formation of this discoid daughter-cell, a varying number of pericentral cells, depending on the species, are cut off at equal distances round its margin by the development of septa, which curve inwards for some distance. At this stage a transverse section of the discoid cell presents the appearance of a cog-wheel, only the notches in the wheel are still filled in the section by the pericentral cells that are separated from the central cell by septa. When the above-described condition has been reached, the central cell, with its surrounding cells, increases rapidly in length, until the normal size is attained. By the constant repetition of this process, the branch increases in length, and consequently consists of a series of bundles of superposed axial and peripheral cells of equal length. All the peripheral or pericentral cells are united to the parent axial cell by strands of protoplasm, and also laterally with each other; the axial row of cells also shows very clearly protoplasmic continuity.

In many species constructed on the above plan, the central axis consists of more than one row of cells; the pericentral cells also by further division may form more than one row.

The genus *Batrachospermum*, a fresh-water type of the Florideæ, common in our streams, illustrates in a primitive manner a type of thallus development not uncommon in the Florideæ. In the species of *Batrachospermum* the branches are slender and elongated, and consist of a single row of elongated cylindrical cells. From the distal end of each cell numerous slender lateral branches are given off, which branch and form a dense whorl. Each lateral branch gives origin to a branchlet close to the point of origin from the parent axial cell, and these first branchlets, instead of spreading outwards to form the whorl, grow downwards and closely pressed to the axial cell, which by this means becomes corticated, or covered by closely adpressed branchlets, which continue to elongate downwards for a considerable distance, passing between the branches forming the whorls situated lower down the stem. By this method of cortication the original axial cells forming the lower portion of a long branch are completely covered and consequently strengthened by the descending branchlets, while towards the tip or apex the axial cells are still visible or only partly covered by the descending branches. This method is further developed in the marine genus *Ceramium*, where the long slender branches consist—as in Batrachospermum—of a single row of large, cylindrical, superposed cells. The lateral branches that spring from the distal end of each cell do not spread out, as in Batrachospermum, but remain closely adpressed to the axial cell, and differ from the corticating cells of the last-named genus in developing both upwards and downwards, consequently covering the distal end of the axial cell producing them, and the proximal end and the axial cell immediately above. In some species, as *Ceramium rubrum*, the cortical branches originating from distinct cells meet and completely cover the axial cells ; in others, as *C. ciliatum*, the cortication extends only for a short distance upwards and downwards from the point of origin, leaving the central portion of each axial cell naked.

The remaining type of structure which can be noticed at present may again be described as a modification of the Batrachospermum plan, which, it will be remembered, consists of a monosiphonous axis, producing distinct and scattered whorls of branches. If a vertical section of a branch of *Gloiosiphonia capillaris* be examined, it will be found to agree in all essential points with that of Batrachospermum, the only point of difference being that in Gloiosiphonia the secondary branchlets of the whorls branch repeatedly in a forked or dichotomous manner, and consequently become so widely extended that the branches of contiguous whorls meet, so that instead of the moniliform or beaded appearance presented by a branch of Batrachospermum, due to the scattered whorls, we get a continuous cylindrical branch in Gloiosiphonia, brought about by confluence of the whorls, and as the ultimate cells of the branches are very small and held together by mucilage, the periphery of the branch is the most compact part of the structure. So long as the branches are equally developed on every side, a circular or cylindrical thallus results. When the branches become more developed in one direction than in another, which usually takes place on opposite sides of the axial row, a flattened thallus is formed.

The presence of lime encrusting the species of *Melobesia* has already been noticed, and the same peculiarity is highly developed in the genus *Corallina* and its allies, which in addition closely resemble in habit some of the smaller corals, hence our common species of *Corallina* are popularly known as corals, and in like manner several members of the Animal Kingdom, as species of *Flustra* or "sea-mats," are popularly considered as seaweeds.

The asexual mode of reproduction by tetraspores is on the whole more general in the Florideæ than the sexual method; nevertheless it is absent in some genera, as *Lemanea* and *Nemalion*. Tetraspores are most frequently formed in fours in a mother-cell or tetrasporangium, and originate in different ways, the most usual being by simultaneous partition into four tetrahedra, which remain for some time in organic continuity by narrow necks of protoplasm; in other cases the tetraspores are formed by successive bipartitions in two planes at right angles to each other, thus forming four quadrants of a sphere; finally the four tetraspores are arranged in a single row, as in the genus *Corallina*. The tetrasporangia occupy different positions in the various genera, sometimes immersed in the substance of the thallus, and scattered or collected in *sori* or dense patches, or borne on modified branchlets called *stichidia*. In the genus *Corallina* and its allies the tetrasporangia are developed within highly-specialized conceptacles. On germination the stationary tetragonidia may give origin to either sexual or asexual plants, but sexual and asexual organs of reproduction are not produced by the same plant.

In the sexual mode of reproduction the female organ exhibits in the various genera a sequence from a simple type to one of considerable complexity, but in every instance fertilization is indirect, the naked, motionless antherozoids or pollinoids becoming attached to the upper portion of a trichogyne, where they develop a cell-wall. At the point of contact the cell-wall of both pollinoid and trichogyne is dissolved, and the contents of the former pass down the trichogyne, and effect fertilization, after which the latter disappears. The trichogyne is always closed at the apex.

In the present order the female organ is called a *carpogonium*, a structure homologous with the oogonium of preceding orders, but distinguished by its complexity, and by the fact that the fertilized oosphere—the oospore—never germinates directly, but undergoes further cell-division previous to the formation of bodies capable of germination known as *carpospores*. Thick-walled resting-spores, the immediate result of fertilization, are unknown in the present order.

In the simplest type, illustrated by the genus *Batrachospermum*, the carpogonium consists of a single cell, continued at the apex into a long, thin trichogyne. After fertilization the carpogonium divides into two cells, the uppermost one along with the trichogyne disappears, the lower one contains the fertilized oosphere, and soon becomes divided into several cells: these cells bulge outwards and form a dense cluster of short branches, the terminal cells producing the carpospores. The entire structure is enclosed in a gelatinous pellicle.

In the more complex condition the carpogonium consists of one or more fertile cells, in addition to one or more sterile cells forming the *trichophore*, terminated by the trichogyne, which in the present order always remains closed at the apex. In the genus *Crouania* and some others, each cystocarp has usually two trichogynes. After fertilization the carpogonium becomes differentiated into a central portion, the *placenta*, from which spring the carpospores, often produced in simple or branched chains. In the genus *Callithamnion*, the carpospores are only enclosed in a gelatinous covering, whereas in *Polysiphonia* and the majority of genera the carpogonium becomes surrounded by a pericarp consisting of closely-apposed branchlets: the entire structure is then known as a *cystocarp*. In the genus *Gracilaria* the pericarp is developed before fertilization.

A still greater amount of complexity occurs in the genus *Dudresnaya*, where the trichophore and carpogonium are formed at some distance from each other, and are not in organic continuity. The carpogonia originate as large cells, terminating in short septate branches. The trichogyne terminates a row of cells constituting the trichophore. These

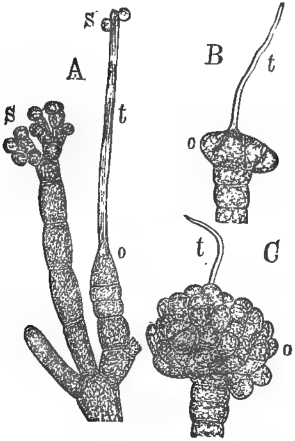

Fig. 20.—Sexual organs of a red seaweed (*Nemalion*). *A*, the end of a branch bearing a cluster of antheridia, *S*, on one branchlet, and on the other a female organ terminated by a trichogyne, *t*; *o*, the basal portion that becomes the cystocarp or fruit; two antherozoids, *s*, are seen attached to the trichogyne near its tip. *B* and *C*, stages in the development of the cystocarp (× 300). (From Prantl.)

cells very soon put out a number of short branches, and when this stage of development has been reached, the pollinoids become attached to the trichogyne, and their contents absorbed. The short branches springing from the cells of the trichophore increase in length and are called *fertilizing-tubes:* these grow between the cells of the thallus until they come in contact with the carpogonia, which become fertilized by this very indirect method. A single fertilizing-tube frequently fertilizes several carpogonia, by increasing in length and passing from one to another. Several other genera exhibit a similar arrangement to the above, and in many instances the process is yet more complex.

In some genera, as *Polysiphonia*, the carpogonia project from the thallus, and are sometimes furnished with a short stalk; but in the majority of cases they are immersed in the substance of the thallus, the trichogyne alone appearing above the surface.

In some species antheridia and carpogonia are produced on the same plant, but by far the greater number are diœcious, consequently in such cases a species includes three distinct individuals, the asexual form bearing tetraspores, as a rule the most abundant; and the two sexual plants bearing antheridia and carpogonia respectively. In many cases the three forms of an individual are sufficiently distinct in size and form as to be recognized at once, the asexual condition being very often the largest and brightest coloured of the three.

In the simple types of structure, as *Batrachospermum*, the antheridia consist of the terminal cells of slender septate branches, each antheridium containing a single pollinoid; in the higher forms the antheridia are usually produced in dense clusters on or near the tips of the ultimate branchlets. In *Dasya coccinea* they originate in the following manner. The main stem is polysiphonous and corticated, but the ultimate branchlets consist of a single row of large cells which corresponds to the axial row in the stem. On these ultimate branchlets the antheridia are formed. As in *Polysiphonia*, increase in length depends on the segmentation of an apical cell, and in a branchlet destined to produce antheridia from three to six cells at the base are developed, after the manner of those of the ordinary vegetative branchlets, becoming about as long as broad when full-grown, and not in any way divided. After the formation of these cells, which constitute the stalk of the antheridia-bearing branchlet, the remaining daughter-cells, to the number of ten or more, immediately after their segmentation from the apical cell, have four cells cut off by incurring septa from the circumference. Each of these four cells again divides into two by the formation of a radial septum, the result being a central axial cell, surrounded by eight pericentral cells. From the free surface of each pericentral cell two or more minute papillæ appear, which grow out for a short distance as exceedingly slender tubes, and soon become swollen at the apex; the swollen portion becomes cut off by a septum from the cavity of the slender tube or stalk, and its contents transformed into a single pollinoid. The entire development is acropetal. At the base we find perfectly formed antheridia; higher up, the eight pericentral cells with rudimentary papillæ; still higher, only four pericentral cells, and at the apex the apical cell. At maturity the antheridial branch resembles a miniature bulrush in shape, the antheridia-producing portion being involved in mucilage. In the genus *Corallina* and its allies, the antheridia are produced in conceptacles closely resembling those containing the carpogonia, and possess the further peculiarity of having the pollinoids furnished with one or two minute appendages; whereas in the other groups the pollinoids are spherical and without appendages.

Allusion has already been made to the occurrence of fossil remains supposed to be algæ in the older geological formations; but apart from these doubtful examples it is certain that algal remains occur as far back as the Upper Silurian period, and in the older Carboniferous strata the siliceous valves of diatoms have occurred, two species agreeing in the minutest details of structure with *Epithemia gibba* and *E. granulata*, two species existing at the present day. In the Cretaceous and later formations, various fossils or impressions presenting affinities with the simpler green algæ and the Fucaceæ are met with.

The amount of development and differentiation exhibited by the Algæ may be briefly summarized as follows:—

(1) *Vegetative Phase.*—From the unicellular individual a sequence of development through the colony-forming species leads to multicellular forms, showing in many cases a tendency towards the formation of special organs, as root, stem and leaves; but these structures are not of the same morphological value, as in the higher members of the Vegetable Kingdom. For example, the "root" of a seaweed performs only the function of attaching the plant to a solid body by a disc or branched rhizoids, and is not specialized for the purpose of taking in food. Contemporaneous with the gradual development of the thallus we find phases of differentiation of its component cells, in the form of trumpet-hyphæ concerned with the transport of food, and the shadowing in of tissue-systems.

(2) *Reproductive Phase.*—The most primitive method of reproduction is purely vegetative, and consists in the division of a unicellular individual into two daughter-cells, both equally capable of growing into an individual resembling the parent in form and size. This method, which entailed the loss of the parent as an individual, was superseded by the differentiation of a small portion of the

parent into bodies capable of germination, such portions being in most instances capable of performing spontaneous movements by means of cilia. Advancing one step further, we find the sexual mode of reproduction indicated by the conjugation or blending together of two such ciliated bodies—zoogametes—to form a body capable of developing into a new individual. A modification of the above mode of conjugation between two motile cells is presented by *Spirogyra*, where the naked masses of protoplasm do not leave the parent cell before conjugating, and the amount of movement for effecting this object, although less evident than in the preceding examples, is still necessary. It will be noticed that amongst the most primitive groups of plants produced sexually, the two elements are as a rule formed by distinct individuals; in other words, cross-fertilization is in many instances secured. By degrees the distinction between the male and female elements of reproduction become sharply defined, and the female body or oosphere becomes immotile, and remains so throughout the Vegetable Kingdom. Notwithstanding the amount of progress made by the sexual mode of reproduction in the Algæ, on the whole the asexual mode is most frequent throughout the entire class.

True alternation of generations does not occur in the Algæ. What has been considered as such by some authorities, is thus stated by Bennett and Murray.[1] "A very singular genetic connection exists between the genera Chantransia and Batrachospermum, it being possible to transform the former into the latter by changing its conditions of life. The germinating carpospores of Batrachospermum put out a kind of protoneme, which is the

[1] *Crypt. Botany*, p. 214.

Chantransia of Fries, the non-sexual generation of Batrachospermum : this can propagate itself by simple budding from generation to generation, producing, as a rule, as its organs of propagation, only non-sexual tetraspores. Chantransia grows especially in dark situations under water, and, when transferred to the light, undergoes a metamorphosis. There springs up from the Chantransia protoneme a branch which is in every respect a Batrachospermum, and which bears sexual organs only, and no tetraspores. On one species only of Chantransia, *C. corymbifera* (Thur.), are sexual organs known. Although this phenomenon is sometimes spoken of as an example of 'alternation of generations,' it is not identical with the process known under that name in the higher Cryptogams, being rather a difference in the mode of development, dependent on a change in the vital conditions."

The following abstract illustrates Mr. A. W. Bennett's new arrangement of the Algæ, including the chlorophyllous Protophyta, in accordance with their affinities.[1]

"Too little importance has," he considers, "at present been attached to degeneration or retrogression, which may be exhibited in the partial or complete suppression of either the reproductive or the vegetative parts."

He traces all the various forms of vegetable life to three lines of descent, represented by three distinct kinds of cell-contents—colourless, blue-green, and pure green. The first appears to originate in the Bacteria or Schizomycetes, from which are derived the whole group of Fungi. The second primordial type consists of unicellular organisms, in which the cell-contents are composed of a pale, watery, blue-green

[1] *Journal of the Linnæan Society, London:* "Botany," xxiv. (1887), pp. 49—61.

endochrome, diffused through the protoplasm, without distinct chlorophyll-grains, starch-grains, or nucleus—the Chroococcaceæ, the simplest form of the Phycochromaceæ, or Cyanophyceæ, which attain their highest development in the Nostochineæ, including the Oscillariaceæ, Rivulariaceæ, Scytonemaceæ, and Nostocaceæ. To them are probably related the Diatomaceæ, which the author regards as a simple form of life, probably not nearly connected with the Conjugatæ.

The third series, or Chlorophyllophyceæ, is the only one which has developed into the higher forms of vegetable life. It is characterized from the outset by the cells possessing a nucleus, starch-grains, pure chlorophyll, and, in certain states, a true cell-wall of cellulose. The lowest family—the Protococcaceæ—exhibit further development in two directions: the perfection and differentiation of the individual cells, and the association of the cells into colonies, or cœnobes. The latter tendency leads to the Sorastreæ, Pandorineæ, and finally to the Volvocineæ. The further differentiation of the individual cell has advanced one stage in the Eremobiæ or Characiaceæ, from which are derived the Multinucleatæ, comprising the Siphonocladaceæ and Siphoneæ. The striving after a high development by the elaboration of a single cell culminates in *Vaucheria*, or in such forms as *Acetabularia*.

Cell-division is already well displayed in the Confervoideæ isogamæ, including the Chroolepideæ, Ulotrichaceæ, Confervaceæ, and Pithophoraceæ. From them evolution appears to have taken place in three different lines: (1) the Conjugatæ, including the Zygnemaceæ, Mesocarpeæ, and Desmideæ, which evidently came to an abrupt conclusion; (2) the Phæosporeæ, which led through the Cutleriaceæ and

Dictyoteæ to the Fucaceæ, the highest type of "oogamous" reproduction, consisting in the impregnation of a comparatively large oosphere by a number of minute antherozoids; the Syngeneticæ being regarded as a retrogressive offshoot from the Phæosporeæ; and (3) the Confervoideæ heterogamæ; including the Sphæropleaceæ, Œdogoniaceæ, and Coleochætaceæ, from which latter family the Pediastreæ are probably derived by retrogression. The Coleochætaceæ lead up directly to the highest type of structure attained by the Thallophytes—the Florideæ, from the highest form of which we have probably several retrogressive branches, viz. the Nemalieæ, the Lemaneaceæ, and the Bangiaceæ. The author suggests that the Ulvaceæ may possibly be derived from the Bangiaceæ by further retrogression.[1]

Class II.—**FUNGI.**

The present class includes above thirty thousand so-called species, varying in size from microscopic individuals up to the comparatively gigantic "puff-balls," which in some instances exceed a foot in diameter. The variety in consistency is equally marked, a sequence being present between the short-lived, ephemeral "moulds" that disappear on the slightest touch, to the large, perennial species of *Polyporus*, where the tissue is often as hard and compact as that of the hardest wood.

In such an enormous assemblage there is, as would be expected, a very varied range of differentiation and division of labour, both in the vegetative and reproductive portions; but more especially the latter, as in common with other groups that have degenerated to a state of parasitism, the

[1] *Journal of the Royal Microscopical Society*, 1887, p. 786.

reproductive portion is far more highly developed than the vegetative; in fact, what is popularly considered to be the entire fungus, as illustrated by a "toadstool" or "puff-ball," is only the reproductive portion or *sporophore*, the vegetative portion or mycelium, popularly known as "spawn," being buried in the substance from which the fungus obtains its food.

The most important and constant feature of the fungi is the absence of chlorophyll, hence fungi may be defined as cellular plants devoid of chlorophyll, the other cellular cryptogams not possessing chlorophyll—*Schizomycetes* and *Mycetozoa*—being separated by the absence of true cells forming hypha or mycelium.

The Fungi are considered as having descended by degeneration from the Algæ, and for this reason are placed immediately after the last-mentioned class, although in reality they must be considered as a side and terminal group, not connecting with any higher type of plant development. The reasons for the above statement respecting their origin will be explained in detail at a later stage.

Owing to the absence of chlorophyll, fungi require organic matter as food, and may from this standpoint be divided into two sections: (*a*) *saprophytes*, those fungi that obtain their food from dead organic matter—this section includes all those growing on—and consequently deriving their food from—rotten wood or decaying vegetable matter, as manure, leaf-soil, etc. The common edible mushroom (*Agaricus campestris*) and numerous other species that grow on the ground, might be supposed to obtain the same food as the grass and other chlorophyllose plants accompanying them; but this is not so. The fungi absorb, by means of their mycelium, the soluble portion of vegetable humus furnished by decaying vegetation and manure; (*b*) *Parasites* are those fungi that grow upon and obtain their food from a living body, which may be either plant or animal, most frequently the former. The diseases of plants and animals, as the potato disease, and the numerous pests popularly included under the terms "rust," "smut," "mildew," "mould," etc., also the silkworm disease known as "muscardine," are due to parasitic fungi, which are, as a rule, minute or even microscopic in size, although some timber diseases are caused by large perennial fungi, as the well-known dry-rot, due to the attacks of a fungus called *Merulius lacrymans.*

Between the above conditions there are intermediate forms. Some species, that under ordinary conditions live as saprophytes, can exist as parasites for a time, or altogether; such are termed *facultative parasites.* On the other hand, those fungi that ordinarily live as parasites, but under certain conditions can live for the whole or part of their life as saprophytes, are called *facultative saprophytes.*

Parasites attack their *host*, that is, the plant on which they are parasitic, in different ways. Access to the interior of the host is usually accomplished by the germ-tube from a germinating spore, either piercing the epidermis, or passing in through a stoma. Most species are *endophytes*, the whole of the vegetative portion of the fungus developing in the tissues of the host, where the sexually-produced reproductive bodies are also formed, as in the species of *Pythium.* When asexual reproductive bodies are present, they are usually formed outside the host, the sporangiophores not unfrequently emerging through the stomata, as in some species of *Peronospora*, or form dense clusters called *sori* just below the epidermis, which is eventually ruptured, exposing the spores, as in the genera *Ustilago*, *Uredo*, etc. A smaller number of parasites are *epiphytes*, where the vegetative portion is developed on the surface of the epidermis, and only specialized branches, called *haustoria*, penetrate the tissues of the host. The genera *Asterina* and *Erysiphe* are examples of the latter class.

The tissues of fungi, even when very dense and wood-like in consistency, consist of elongated cells or *hyphæ*. These hyphæ are either continuous or transversely septate, when the hypha consists of a row of superposed cells. Again the hyphæ may be simple or variously-branched; in the latter case the branches from the same or distinct hyphæ not unfrequently coalesce at the points where they come in contact, and by the absorption of the walls at the point of contact, establish a communication between previously isolated portions of the mycelium. Not unfrequently, in the case of germinating spores, the mycelium forms a very complex and irregular network, brought about in the manner described above. The coalescence does not only take place where two branches of mycelium come in contact in the ordinary course of growth, but it has been clearly demonstrated that branches are drawn out of their original course through an angle of nearly ninety degrees, to form a union with another branch. The cause and object of this anastomosing are equally obscure; it has been suggested that it possibly serves to nourish every part more equably, or may effect the equal distribution of certain substances that are produced locally.

A modification of the above, known as *clamp-connections*, takes place as follows. In a transversely septate hypha a branch originates laterally immediately below a septum, grows outwards for a short distance, then bends until its apex comes in contact with the hypha just above the septum below which it originated, the walls of branch and hypha disappear at the point of contact, the result being that the loop formed by the branch has opened a communication between two cells of the hypha. It is rather significant that clamp-connections are very characteristic if not entirely confined to the large group of fungi known as the *Basidiomycetes*, where every trace of the sexual mode of reproduction has disappeared.

The hyphæ or mycelium forming the vegetative portion of the fungus usually remain distinct; but in many species, when conditions are unfavourable for active growth, or for the development of the *sporophore* or reproductive portion of the fungus, the vegetative hyphæ becomes concentrated into a solid mass called a *sclerotium*. These sclerotia are met with in widely separated orders of fungi, and, depending on the species, vary in size from a mere point to spherical or irregular masses six inches or more in diameter. When dry, sclerotia become dry and woody in texture, and a certain amount of differentiation is observable, the cells becoming thick-walled and dark-coloured, forming a protective rind. These bodies may be looked upon as concentrations of reserve material, and often possess the power of remaining dormant for a long period. Eventually, under favourable conditions of temperature and moisture, they produce sporophores, which as a rule are of a higher order than the sporophores formed by the mycelium, previous to the formation of sclerotia. Structurally sclerotia consist of a mass of intricately interwoven, continuous or septate hyphæ, that become cemented together into a horny mass when dry, due to the partial gellification of the outermost portion of the cell-walls.

A greater amount of differentiation is observable in the sporophore, which in its simplest form, as seen in the genus *Mucor*, consists of a single aseptate, erect hypha, bearing at its apex the sporangium ; in the genus *Stilbum* we have an erect bundle of similar hyphæ, more or less agglutinated at the lower stem-like portion, the tips being free and spreading, each producing a spore; in the *Agaricus* or mushroom type the stem in like manner consists of a bundle of more or less parallel hyphæ, that radiate at the apex and form the "flesh" of the *pileus* or cap, the latter being covered in many species by a pellicle that can be separated when moist. This external pellicle is formed from the superficial hyphæ, the walls of which become gelatinous and consequently cemented together into a continuous film which corresponds functionally to the epidermis of higher plants. In a few of the *mesopod* or central-stemmed species of *Polyporus*, a thin zone of hyphæ, lying just within the peripheral portion of the stem, becomes highly differentiated as a mechanical sheath for giving rigidity to the stem ; the hyphæ forming this zone are branched and interwoven, the walls become very thick, so that the *lumen* or cavity is nearly filled up, and by their partial gellification firmly cemented together; at the apex of the stem this sheath becomes broken up into spreading, frequently anastomosing rays that pass into the pileus as a supporting framework. The whole of this hard lignified framework often remains intact when all the other portions of the fungus have decayed or been destroyed by minute beetles. The above examples of sporophore structure are characteristic of the group of fungi called *Basidiomycetes ;* a second type, equally characteristic of the *Ascomycetes*, consists of *isodiametric* cells that form a pseudo-parenchyma ; in the genus *Peziza*, typical of the *Discomycetes*, the tissue remains soft and colourless ; while

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the instant it is cut or broken and exposed to the air, it assumes a deep indigo-blue colour. Schönbein's explanation of this change is summarized as follows by De Bary—

"Schönbein has carefully examined this phenomenon, and finds that it is a substance capable of being extracted from the fungus by alcohol, and probably of a resinous character which turns blue in the air. The blue colour appears in the alcoholic solution under the same conditions as it does in a solution of guaiac-resin, and since it has been proved that the colour is produced in the latter by combination with ozonized oxygen, Schönbein assumes a similar cause of the blue colour in the fungus. The alcoholic extract from the *Boletus* does not by itself become blue when exposed to the air; there must therefore be another substance contained in the fungus, which ozonizes the oxygen of the atmosphere, and then effects a combination with the resin, giving off the oxygen to it in the state of ozone. Phenomena of a similar kind, observed in other cases, confirm this conjecture. Thus both the tincture of guaiac and the alcoholic extract of *Boletus* turn blue at once, if they are allowed to fall in drops on the fresh tissue of some of the Agarici which do not themselves turn blue, especially *Agaricus sanguineus.* The watery juice of *Agaricus sanguineus* squeezed out from the plant and filtered, produces the blue colour at once in both tinctures. From these facts it may be concluded that a number of fleshy fungi contain a substance soluble in water, which absorbs oxygen and gives it up to other bodies in the state of ozone. The Boleti which turn blue contain this substance, with another resinous substance, which, like the guaiac-resin, is turned blue by ozone." [1]

[1] *Fungi Mycetozoa and Bacteria,* Engl. ed., p. 15.

The various modes of reproduction met with in the fungi may be conveniently studied under two sections—asexual and sexual—at the same time bearing in mind that the two modes, sufficiently marked in extreme examples, pass almost uninterruptedly into each other. It is equally important to remember that, taking the class as a whole, there is a gradual sequence from the distinctly sexual to the asexual mode of reproduction.

(1) *Asexual Mode.*—In the *Saccharomycetes* or yeast-fungi, an individual consists of a single spherical or elliptical cell, and reproduction takes place by what is termed *sprouting.* A small papilla appears on the wall of a cell, which continues to increase in size for some time, the connection with the parent-cell becoming constricted to a thin neck, and is eventually separated by a septum at this point, the daughter-cell becoming free. When growing in a favourable liquid the sprouting takes place rapidly, one cell often producing two or three daughter-cells, each in turn going through the same process, the result being a more or less branched hypha, formed of bead-like cells joined by narrow necks; eventually the cells separate, and in turn form new chains.

In a second and much larger group, including all those fungi belonging to the puff-ball (*Lycoperdon*) and toadstool (*Agaricus*) types, the asexual reproductive bodies are called *basidiospores*, and originate as follows. Certain large terminal cells called *basidia* produce at the free apex two, or more frequently four, very slender spine-like outgrowths called *sterigmata;* the apex of each sterigma becomes swollen, the protoplasm passes from the basidium into the swollen apices of the sterigmata, which are then cut off by a septum and fall away as mature basidiospores.

In a third type the spores are formed within a mother-cell or sporangium, and may be either motile, that is, zoospores, as in the genera *Saprolegnia* and *Cystopus;* or non-motile, as in *Mucor*, and in the large group known as *Ascomycetes*, where the sporangia contain a definite number of spores, usually eight, and are called *asci.*

(2) *Sexual Mode.*—The sexual fungi are those most nearly allied to the algæ, from which they are derived, in fact in many instances the only observable difference between certain algæ and fungi turns on the complete absence of chlorophyll in the latter; hence, as would be expected, the sexual modes of reproduction run parallel in the two groups, and will be described in detail under the respective orders. At present it will be sufficient to enumerate the most prominent modifications of sexual reproduction, with examples of each. (1) *Zygospores* resulting from the conjugation of two morphologically similar branches of the mycelium, as in the species of *Mucor*, *Rhizopus*, etc. (2) The formation of an oosphere which is fertilized by motile, ciliated antherozoids, *Monoblepharis.* (3) The oogonium contains one or several oospheres that are fertilized by passive antheridia, consisting of the inflated tips of slender branches formed on the same branches as the oogonia, or on distinct branches. The antheridium comes in contact with the wall of the oogonium, pierces its wall by means of one or more fertilizing-tubes, through these tubes the protoplasm passes from the antheridia and mingles with the oospheres.

It is well known that certain species, belonging to widely separated natural orders of Phanerogams, have degenerated so far from the typical condition as to have lost the power of forming chlorophyll, and consequently, like the fungi, have become parasites or saprophytes: the species of broom-rape (*Orobanche*), tooth-wort (*Lathræa squamaria*), and bird's-nest orchis (*Neottia nidus-avis*), are British examples of such. In the above and numerous other examples of degenerate species the general structure is retained, consequently there is no difficulty in referring such to their proper orders. This, however, is not always the case. The species belonging to the orders *Rafflesiaceæ* and *Balanophoreæ* have become so far modified that the vegetative system is reduced to very small proportions and completely buried in the host, where it performs the mechanical function of absorbing assimilated food, the flower or reproductive portion alone appearing above the surface, thus approaching in this respect the habit of true fungi; and in the last-named order there is the further coincidence—if nothing more—that the inflorescence of minute flowers in many instances mimics in form and colour well-known fungi. The characteristic odours of the *Phalloidei* are exhaled by many species, some of which spring up with marvellous rapidity after rain, and from the general resemblance are popularly mistaken for fungi; for example, *Cynomorium coccineum*, a species belonging to the *Balanophoreæ*, is the *Fungus melitensis* of the Crusaders. Finally the embryo produced in the seed of the above species remains undivided—that is, not formed by cell-division into a plantlet—during the resting-stage, agreeing in this respect with the sexually produced resting-spore in Cryptogams. This last peculiarity again appears to be the result of retrogression, since the orders most closely allied to the degenerate ones have the typical phanerogamic embryo. If this degeneration of Phanerogams continues it may probably result, as I have stated elsewhere, in a group of phanerogamic fungi possessing morphological and physiological characteristics of its own, and bearing the same relation to chlorophyll-producing Phanerogams that fungi do to chlorophyll-producing algæ.

The evidence in support of the idea that the fungi are derived from the algæ by retrogression, is the close morphological agreement of both vegetative and reproductive parts presented by certain sections of the two groups; for example, in the sub-division of fungi called *Phycomycetes*, the vegetative portion frequently consists of a long, aseptate, variously branched cell or hypha, similar to the vegetative portion of such algal genera as *Vaucheria;* in the reproductive portion, asexually formed ciliated zoospores occur in *Pythium*, *Saprolegnia*, *Cystopus*, etc., while oogonia containing one or more oospheres fertilized by motile antherozoids occur in *Monoblepharis*. In a second group, the *Mucorini*, the sexual mode of reproduction is effected by the conjugation of two similar branches, as in the *Conjugatæ*, the resulting zygospore becoming invested by a thick cell-wall, and forming a resting-spore. Many species belonging to the *Phycomycetes* are aquatic, being parasitic in the tissues of aquatic plants or animals.

In numerous species two or more modes of reproduction are known: in the *Phycomycetes*, or algal-like fungi, one form is usually sexual, the remaining one or more asexual. In some instances both forms of reproductive bodies are produced by the fungus at the same time, but as a rule the asexual form appears first, the sexual or at all events more highly evolved form being developed later, and either on the same mycelium as the asexual form, or on a distinct individual springing from the asexually produced reproductive bodies.

True alternation of generations as understood in the higher Cryptogams is absent from the fungi where either the sexual or asexual condition can under certain conditions repeat itself for an indefinite period.

Until recently every detached fungoid development, provided with any kind of spore-formation, was considered as a distinct species, consequently the asexual forms of numerous species were considered not only as distinct species, but distinct genera, that were usually located in a different order to the one in which the second stage of the same individual was placed. As an illustration of the above, numerous forms of minute fungi, producing naked spores at the tips of erect branches, and closely agreeing in structure, constituted a genus called *Botrytis*. This genus was considered autonomous until it was clearly demonstrated that one of the species, *Botrytis cinerea*, produced a sclerotium which, after a period of rest, gave origin to one or more complex sporophores of a higher development than the Botrytis form, and agreeing in every point with the genus *Peziza*, where the spores are produced in asci—ascospores—and consequently belonging to the *Ascomycetes*. Such genera as *Botrytis*, that include forms now known to be conditions of other species, are called *form-genera*, and the components are termed *form-species*.

Various schemes of classification of the fungi have been propounded from time to time; the one adopted in the present work is by Brefeld, which is based as far as possible on a knowledge of the life-history of typical forms, and in this respect differs from earlier ones, which in most instances depend on morphological points of agreement presented by mature forms.

According to this author, fungi are divided into two primary groups, the *Phycomycetes*, or algal-like fungi, characterized by sexual as well as asexual modes of reproduction, and the *Mycomycetes*, where the sexual phase is completely arrested, and consequently propagated exclusively by asexually-formed spores. Each primary group is further divided into two sections; in the *Phycomycetes* we have the *Zygomycetes*, producing zygospores by conjugation, and the *Oomycetes*, producing oospheres that are fertilized by motile antherozoids, or by transfusion of the contents of passive antheridia. In the *Mycomycetes* the *Ascomycetes* have spores produced in asci—ascospores—the *Basidiomycetes* form naked spores on basidia—basidiospores.

The *Ustilagineæ* or smut-fungi are considered as forming a transition from the *Phycomycetes* to the *Mycomycetes*. The above arrangement may be represented as follows—

PHYCOMYCETES.

Zygomycetes. **Oomycetes.**

MYCOMYCETES.

Ustilagineæ.

Ascomycetes. **Basidiomycetes.**

The two modes of reproduction are not produced by every species. In the *Phycomycetes* the asexual method is more constant throughout the group than the sexual, although in some species the latter method is the only one known.

In the *Mycomycetes* the most complex sporophores produce spores in asci or on basidia; but in numerous species other and simpler reproductive bodies are also formed, and various attempts have been made to individualize these different bodies—spores in the old sense ; but as the homologies and functions of the various forms are not yet known, the old term *spore* has been retained in the present work, either alone, or in the form of compounds sufficiently expressive of the nature of the organ producing them, as ascospore, basidiospore, oospore, etc. The reproductive bodies formed by the simpler secondary methods have been termed conidia. De Bary has suggested the name *gonidium* for all specialized spore-like bodies not sexually produced, and this idea appears very feasible as read in a book ; but when we come to read several books on the subject by men of equal merit, it is found that no two agree as to the point where sexual organs cease to be of functional value.

The following arrangement is from Brefeld's latest work on the fungi. The term conidium is used for all reproductive bodies produced asexually according to the author's view, whether borne in sporangia or naked on basidia, etc.

PHYCOMYCETES.

Mycelium generally without transverse septa in the vegetative portion, parasitic on plants or animals, or saprophytes, aquatic or aerial; sexual reproduction by zygospores formed by the conjugation of morphologically similar branches, or by oogonia and antheridia; asexual reproduction by ciliated, motile zoospores, or by non-motile spores.

The species are all minute, and in many instances microscopic, although in many of the species popularly known as "moulds" the mycelium forms a broadly-expanded, felt-like mass.