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THE MYCETOZOA.

THE MYCETOZOA

AND

SOME QUESTIONS WHICH THEY SUGGEST

BY

THE RIGHT HONOURABLE
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AND
AGNES FRY.

"Rerum natura tota est nusquam magis quam in minimis."
Plin. Nat. His.

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CONTENTS.

WORDS EXPLAINED.

GENERA AND OTHER GROUPS REFERRED TO.

ERRATUM.

PAGE 21.—*For* "The granules stream in one direction; then pause, from sixty to ninety seconds (in the case of healthy plasmodia)"; *read*, "The granules stream in one direction from sixty to ninety seconds (in the case of healthy plasmodia), then pause."

NOTE.

The quotation on the Title Page we have attributed to Pliny in his "Natural History," on the authority of Wordsworth in his heading to the Vernal Ode. We have not succeeded in finding it in Pliny himself, but our search has not been exhaustive.

THE MYCETOZOA,

And some Questions which they Suggest.

WE are desirous to make known some small friends of ours to those who are hitherto unacquainted with them; but we are embarrassed as to how to introduce them—by what name to present them. It is true that they bear several names derived from the Greek language, Mycetozoa, Myxomycetes, Myxogastres, Myxothallophyta, but these are not familiar words. In German these organisms bear a name which has been translated into English, but it is so repulsive that we would willingly suppress it if we could, just as one would not like to introduce a charming girl to strangers by some name of a distinctly disagreeable suggestion :—

> "A name? if the party had a voice,
> What mortal would be a Bugg by choice?
> As a Hogg, a Grubb, or a Chubb rejoice?"

And so what beautiful little thing would, if it had a voice, be introduced as a "slime fungus"? and yet this is the only English name of the organisms in question. Some intimates of these ill-named beings try to get over the difficulty by inventing pet names, and call them "myxos," or "myxies," and, on the whole, we incline to adopt the latter word. It is short, and it rhymes with pixies.

But what are these myxies? someone will be impatient to say. Are they fungi? No. Are they mosses? No. Are they ferns? No. Are they lichens? No. At any rate, plants? That is doubtful. Then surely they are animals? We do not know. They are living things—and beyond that we will not go for the present.

There is another difficulty in the way of presenting these organisms to the novice: that their forms and structure are so far unlike those of plants or animals with which every one is familiar that we cannot use very well-known terms in describing them, and we shall have to ask permission to employ some special terms, when common ones fail. But we shall endeavour to be as clear as we can, and to readers who will give us their attention we believe that we shall overcome these obstacles, and we believe, too, that a little difficulty in following the exposition will be more than repaid by the interest of the subject. It appears to us that many most interesting biological problems are presented in very simple form by this class of organisms, and we shall not hesitate to refer to these from time to time in the following pages.

If our reader will turn over the pages and look at the illustrations which follow, he will by his eye get a general notion of the kind of thing about which we are going to talk.

Life-history.—We propose in the first place to sketch the life-history of one of these organisms as an example of

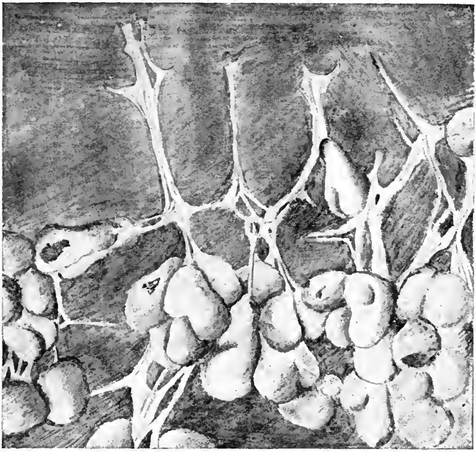


Fig. 1.—*Badhamia utricularis*, showing Sporangia.

all, and then to retrace our steps and dwell a little more in detail on points of interest which emerge in the consideration of the several stages of its existence.

If our reader will look at Fig. 1, he will see depicted an organism consisting of a number of bodies somewhat like grapes in shape; he will see that each little berry is attached by a tender stalk to a substance which is a piece of dead wood, and he will notice that these berries are so grouped together as to suggest the notion of a common origin. This little organism is known as *Badhamia utricularis*, the generic name being derived from a Dr. Badham, a labourer in the field of cryptogamic botany, and the specific name describing the bladder-like form of the principal part of the structure. This species is not uncommon, and is to be found on stumps and logs of decaying wood.

The bladder-shaped vessels which we have spoken of are the spore cases of the organism, *i.e.*, they are cases in which the spores are stored, much as seeds are stored in a seed vessel. They are known as *sporangia.* We have chosen to begin with the organism in this form because it is the most conspicuous, and therefore the most easy for a beginner to get hold of.

If now a specimen of this Badhamia be placed under the microscope, it will be seen that the coat of the sporangium is a delicate shell containing minute granules of lime, and that the dark appearance of the body is due to the brown spores which lie beneath the transparent shell. Next if a sporangium be broken and the contents examined under the microscope (as shown in Fig. 2), it will be found that the delicate white shell contains a network of threads, also white from the lime with which they are charged, and that they occupy the interior of the sporangium, and pass from wall to wall much like the cancelli in a long bone.

In addition to these threads there are the small round spores. In these threads we have come upon a very characteristic structure in these little organisms; it is found in the sporangia of most of them but in very varying forms, and very diversely arranged, of which we shall say more hereafter. This system of hairs in the sporangia is known as the *capillitium*.

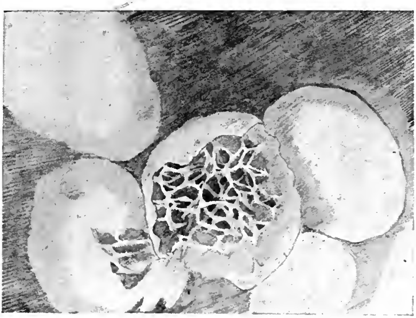


FIG. 2.—*Badhamia utricularis*, broken Sporangia showing Capillitium.

As the sporangia contain spores it will be at once understood that we stand on the threshold of a new generation, and we must now follow the history of the spores. These, when carefully looked at, are seen to be covered with minute spines, and thus present a somewhat rough appearance.

If now the spores be placed under favourable circumstances, *i.e.*, with sufficient moisture and warmth, small translucent bits of naked protoplasm will be seen to emerge from them, leaving a mere shell behind them; these bits of protoplasm have a movement of their own in the water, and can be seen both to shake themselves, and to move forwards; they push out a part of their protoplasm as a whip or *flagellum* at one end of the body, swimming with this in front of them, the whip having a sort of lashing movement. Fig. 3 exhibits some of these bits of protoplasm. Their motions are particularly amusing to watch; they swim, they wriggle, they revolve, they shake themselves, they are full of life and motion; they seem at once wilful and purposeless; they gambol with one another, and their frolics remind one of young lambs in spring. They are capable not only of motion but of digestion, and of the capture of food in a manner to be hereafter described. These little pieces of protoplasm bear several names, and as the variety of phraseology is apt to puzzle students, we pause to say that they are called sometimes swarm spores, or swarm cells, sometimes zoospores, and as individual pieces of protoplasm they are sometimes called protoplasts. The spore of a moss, or of a fern, is a small structure, endowed with no power of motion; these swarm spores, as we have seen, have a power of motion; the spore of the moss, or the fern, is capable by itself of reproducing the plant from which it has come, but these swarm spores are only reproductive after fusion with others, as we shall hereafter see. The name swarm cell is likely to mislead, because the

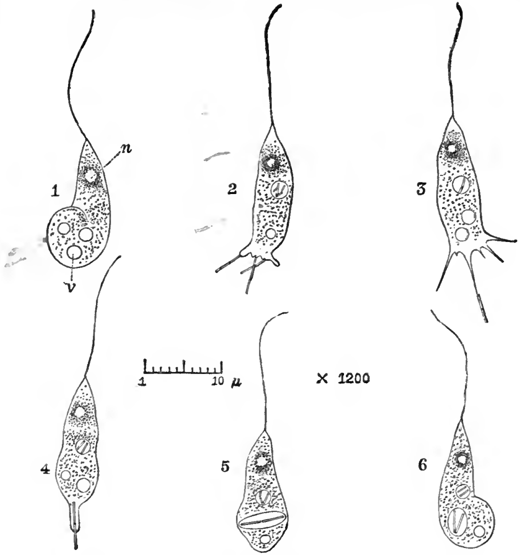


FIG. 3.

1.—Swarm Spore of *Stemonitis fusca* of the usual form when swimming. *n.* Nucleus; *v.* Vacuoles.

2.—Swarm Spore with three Bacilli adhering to expanded posterior extremity.

3.—A Swarm Spore with delicate pseudopodia, to one of which a Bacillus is attached.

4.—The same Swarm Spore. The Bacillus in the act of being drawn in and partly invested with a tube-like extension of the body surface.

5.—The same Bacillus contained in a long vacuole, and bulging out the sides of the Swarm Spore.

6.—The same Bacillus bent double after violent jerking movement of the Swarm Spore.

(From *Journ. Linn. Society, Botany*, Vol. 25, p. 440, by permission of the Linnean Society and Mr. Lister.)

thing so called is protoplasm without any containing wall, and therefore does not answer to the notion of a cell as it exists in a beehive or in a police station. We shall therefore speak of them as *swarm spores*, though even that name seems to us to be far from felicitous.

The next step in the life of these swarm spores is that

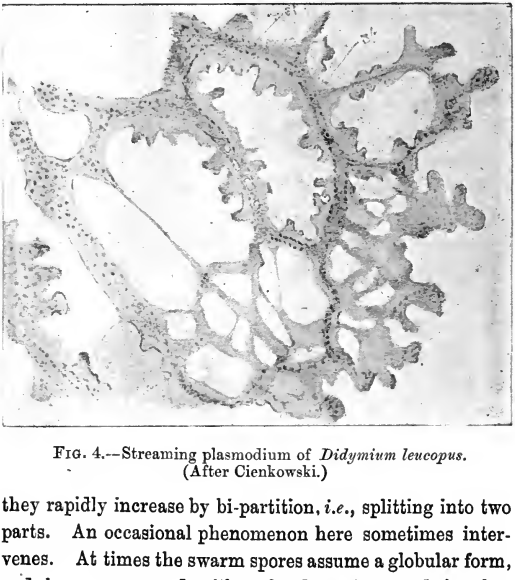


FIG. 4.—Streaming plasmodium of *Didymium leucopus*. (After Cienkowski.)

they rapidly increase by bi-partition, *i.e.*, splitting into two parts. An occasional phenomenon here sometimes intervenes. At times the swarm spores assume a globular form, and become covered with a hard coating, and in that condition are known as *Microcysts.* But from the wall of this cyst the contents afterwards escape, and renew their movements.

The swarm spores (whether after encystment or not) now enter upon a new stage. They gather together and fuse into masses of naked protoplasm, the swarm spores losing their individuality in a common mass. This mass is called a *plasmodium.* This plasmodium grows in bulk by the digestion of food, such as bits of fungus or dead wood, and attracts to, and unites with itself, other smaller plasmodia of the same species. In the *Badhamia utricularis* this plasmodium is yellow; it is white in many species; green or orange, or red or grey in other kinds. This plasmodium moves, sometimes through the substances of dead wood, in other cases on the surface, expanding in an irregular fan shape, and marked irregularly by streaks or veins, as may be seen in Fig. 4. It appears to move in search of its requisite food. The Badhamia is much devoted to fungi, and will extend itself over the surface of a fungus till it has devoured all its more delicate parts.

In the substance of this plasmodium there arises a strong alternate movement of the more fluid protoplasm, a rush of circulation through the channels of the plasmodium. The granules move for a short time in the one direction, then pause, and then move in the opposite way. The strongest currents are indicated in Fig. 4 by the letters *st.*

The plasmodia of different species differ much as regards size. In some genera they are very visible, and were known to some of the older botanists as Mesenteriæ, and were believed to be a species of fungus. In some cases they can only be discovered by the microscope; and, haunting the interstices of dead wood, they are rarely visible. Such are the plasmodia of Lycogala, Arcyria, and of some species of Trichia.

Here, again, a phenomenon of encystment sometimes occurs. During drought the plasmodium may become quite dry and hard without losing vitality. In this stage the hard plasmodium bears the name of *sclerotium*. That of the Badhamia is quite horny, and orange-red in colour. On being wetted it will resume its old plasmodium form, and move as before.

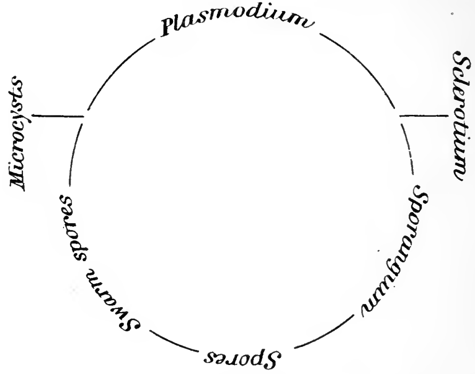
This conversion from an active into a passive condition of the plasmodium seems to be brought about by two conditions—the want of moisture and the want of food. This last fact is illustrated by a case in which a plasmodium placed on wet cotton wool, but without food, was found to turn into a sclerotium. The capacity for rest and awakening is thus a protective one, and enables the organism to tide over a time of famine or drought. It is certainly a better plan even than the Lydian practice of playing games to forget hunger.

From the plasmodium stage, whether broken into by a sclerotium condition or not, the organism, after a time, prepares for its next effort. It seeks some spot, on the surface of dead wood or leaves, sometimes a rather exposed and elevated position, at other times a sheltered one, and there forms sporangia, so that what before was a mass of more or less amorphous protoplasm has differentiated itself into several parts, into delicate pedicels, the coating membrane of the sporangia, the hairs of the capillitium, and the spores—which in due time are to begin again the circuit of the life-history of the Badhamia, which is in all essential features that of the whole group of myxies. The sporangia in the course of their development sometimes undergo a great change in colour; for instance, the young sporangia of Comatricha are an ivory white, and they gradually change into a glossy black; and the groups of little tree-like growths with their developing forms and varying colours, all gathered together within a few square inches, is a sight of great beauty. In the maturity of this sporangium stage of the organism it has lost all its powers of locomotion, it has lost its powers for digestion, and in its stationary condition devotes its energies to the reproduction of the species. The motion of the granules of the protoplasm continues to some extent until the formation of the spores.

Now, pausing here for a moment, and taking merely the outline of the facts as we have drawn it, we have surely abundance of matter for thought and surprise. Some seventy years ago, Fries, one of the first naturalists who grasped the series of changes through which these organisms pass, compared these changes to the metamorphoses of insects. We get, too, an inkling of the difficulty which naturalists have felt in assigning the myxies either to the animal or the vegetable kingdom: their locomotion and rapacious youth seem to shut them out from the plants; their stationary condition and their production of sporangia from the animal world.

The life-history of our organism may be briefly summarized in the following diagram, in which the circle shows the essential stages of life, and the outliers show occasional and non-essential stages.

We wish to dwell a little more on some of the points of



interest which arise from the brief narrative we have given, and from other facts which may be brought in relation to it, and in doing so, we shall find it best to consider the life-history of the organism in a different order from that previously used. We started with the sporangium, as the most easily grasped and the best known stage of life; but we shall now ask you to consider the life-history by passing from the simpler to the more complex stages.

Swarm Spores.—And first let us revert to the swarm spores, those little bits of mere translucent protoplasm which escape from the spores of the myxie (Fig. 3), leaving the shells of the spores, from which they have emerged, behind, as in like manner the spores leave behind them the membrane of the sporangium. We have seen that in some cases the myxies form a membrane or coat—as in the sporangium, the spores, the microcysts, and the sclerotium; and it is probable that this membrane is in some, though comparatively few, cases of the same or a similar nature to the material of cell walls in the higher plants, *i.e.*, is formed of cellulose. But what is to be noted is this, that these membranes are used only as protections; they are allowed no part or lot in the vital actions of the organism, and, so soon as their protection is no longer wanted, they are cast off and allowed to perish. It is evident that the contained protoplast and not the containing membrane is the dominant partner in the concern.

A swarm spore has been defined as "a mobile, ciliated, asexual, reproductive cell, destitute of all membrane," or, in other words, it is a piece of protoplasm without any covering membrane, which is produced without any sexual action, and which of itself possesses the powers of motion, of putting out cilia or hairs, and of joining in the reproduction of the species to which it belongs. That all this should be true of a little bit of jelly is marvellous enough, and presents some of the mysteries of life in a very simple and condensed form.

Swarm spores, in the sense of the preceding definition, are common in both the great kingdoms of organized life. There is a whole group of protoplasts which, under the name of Monads, are reckoned to belong to the animal kingdom; there is the group of somewhat larger organisms known as "Amœbœ"—a group of which a suspicion has sometimes been entertained that they are an immature form of other organisms; there are the white particles of the blood which are almost, if not quite undistinguishable from Amœbœ; there are the swarm spores, whether belonging to the Algæ, the Fungi, or the Myxomycetes; in all these cases the protoplasts are of the same kind, endowed with nuclei and vacuoles, capable of putting out cilia, and endowed with the power of motion and assimilation. To all appearances there is no essential difference between them, and yet, in point of fact, they are organisms as distinct as possible from one another in their nature and their future careers.

One thing marks off the swarm spores of the myxies from all other swarm spores which reproduce the organism; they are reproductive only in conjunction. The swarm spore of an alga is capable by itself of reproducing an alga; in the myxies, on the other hand, the swarm spores only reproduce when they have merged with their fellows and formed a plasmodium. This phenomenon of the union of a large number of individual swarm spores into a new and larger individual which carries forward the course of life is unique in the myxies, and distinguishes them broadly from all other known organisms.

In all cases in which reproduction depends on swarm spores it seems essential that there should be water enough for the swarm spores to live and move about in; and, in the case of myxies, to enable them also by their movements to join together into a plasmodium. Nothing is known of their reproduction except in water.

It would at first sight appear that this condition of their reproductive activity cannot be otherwise than inconvenient and restrictive, especially in the case of such myxies as, *e.g.*, the Comatrichæ, which often produce their sporangia on the upper sides of wood, or on the tops or sides of wooden posts. But it is probable that a very little moisture is enough, and that in a shower of rain, or in a morning's dew, they find sufficient water for the swarm spores to live and unite. But we confess that the point seems to us to require further attention.

Water being the medium in which most of the lowest organisms exist, it is generally thought that the doctrine of evolution involves this—that the earth has been peopled by migrations from the water: and the migrations of amphibious animals from the one element to the other, have been dwelt on as assisting us to understand such migration. In this connection the cases of the myxies and of the mosses, and no doubt of other mainly terrestrial organisms which need water as a necessary condition to fertilization, are worthy of note. One of the most important functions of life still depends on the presence of the original medium of their lives.

Cell Theory.—The swarm spore is, as we have said, a bit of naked protoplasm; so is the plasmodium. Let us consider briefly what is meant by the expression naked protoplasm.

When in the seventeenth century the microscope was applied to vegetable tissues, especially by our countrymen Hooke and Grew, and by the Italian Malphigi, they were struck with the presence of small walled cavities in the fleshy parts of plants. These Hooke called cells, and Grew and Malphigi utricles or bladders. Hooke's name has stuck to them, and plays a great part in botanical writings from his day to the present. We are accustomed to regard the cell division as the determining factor in growth, the mode of division providing, as it were, the form which the plant is to assume: and especially since the days of Schleiden and Schwann—when the cell came to be regarded as the structural unit in the growth of plants—the tracing of cell development, and the structure of the parts of the cell (especially the cell walls), and the behaviour of the cell, have been studied with the utmost care. Presently it came to be seen that the cell walls were inert and by no means the most important part of the structure, but that the slimy contents of the little box, which had been treated with scant attention in the earlier stages of study, were, after all, the most remarkable part of the cell, and were to all appearance the basis of both animal and vegetable life. When attention was first called definitely to it in the vegetable kingdom it was termed protoplasm, by Mohl; when first accurately observed in animals it was named sarcode by Dujardin; and by-and-by it was found that protoplasm and sarcode were one and the same thing. Then instances were found in which small masses of protoplasm lived and moved without any cell walls at all, but so firmly was the notion of the cell rooted in the minds of many physiologists, that these naked pieces of protoplasm have often been called naked cells, a most confusing term as it seems to us, for it is like calling a man with nothing on "a naked great coat." Another name, and a much more convenient one, is protoplast.

The accepted cell theory received something like a shock when the life-history of the myxies came to be carefully studied. "All the phenomena," said Cienkowski, in the year 1863, "which are observed in plasmodia are calculated to force the observer from the accustomed path of safety to those of doubt. The fundamental conception of morphological investigation of the cell leaves us wholly in the lurch in the case of plasmodia. Neither cell membrane, nor nucleus, nor other histological elements can be established in this case by the most benevolent interpretation of the facts, and, twist the cell theory as we may, it certainly cannot be fitted to the naked flowing protoplasm of the Myxomycetes." Nuclei, however, have since been found in plasmodia.

The cell walls of ordinary plants are composed of a peculiar substance known as cellulose, and within these the protoplasm of the cell is contained, with all that may be contained in the protoplasm—the nuclei, the chlorophyll, the colouring, and the oily matter, &c. The cell is thus a highly organized unit, and it is, moreover, capable of carrying on most marvellous operations, physical and chemical.

An organism which commences life in the simple form of a piece of protoplasm, in many cases produces cell walls and rests in these, and thus builds a home for itself in which it lives and labours. But in the case of the Myxomycetes this does not occur, or occurs only very exceptionally, and all the actions which these organisms perform, and all the beautiful forms which they assume, are reached without ever forming a cell wall or constituting a true cell, except in the spore itself. In these actions and in these forms we see the capacities of simple and naked protoplasm. The extreme simplicity of the mechanism seems to bring to the mind more powerfully the inherent powers of the worker.

Nuclei.—In the history of the theory of cells it was early discovered that there is in each cell a smaller structure called the nucleus, which was originally supposed to be a vesicle in the cell, but has been now ascertained to be a portion of a special substance distinct from protoplasm. The nucleus has been found to exercise something like a dominant influence on the destiny of the cell—"all the formative and nutritive processes seem to be dependent upon it," and, moreover, it plays an important part in each process of cell division—*i.e.*, in some or all cases of the division of the cell the nucleus undergoes a like division. This division occurs in three ways, of which two only need now be noticed. One of these modes of division is very simple. The nucleus gets constricted in the middle, the connecting link grows slighter and slighter, and breaks, and we have two nuclei where before we had one.

The other method by which nuclei divide is a highly complicated and remarkable process, known often by the long name of Karyokinesis—*i.e.*, the movement of the kernel. In this process certain polar bodies appear, round which the constituents of the cell gather, and the nucleus assumes a curious spindle-like shape before the division actually occurs.

Now, in the myxies, we have, as we know, no true cells with cell walls, except, perhaps, in the spores themselves, but we have protoplasts, in the form of swarm spores, provided with nuclei, as shown in Fig. 3. In the plasmodium, too, we have nuclei, and it has been supposed that the original number of nuclei in the plasmodium corresponded with the number of the constituent protoplasts, but it has been shown that the nuclei increase vastly in number, and that this division and multiplication of nuclei takes place in all the stages of the swarm cells, of the plasmodium and of the sporangium. The question whether this multiplication of nuclei in the myxies at the various stages takes place by simple division or by the complicated process of Karyokinesis is one which has been carefully investigated, although the results can hardly as yet be considered as conclusive. They appear to be, first, that Karyokinesis is the method pursued in the swarm spores when they divide, and again at a later stage in the sporangium shortly before the formation of spores; and, secondly, that the multiplication of nuclei in the plasmodium is sometimes accomplished by Karyokinesis, but probably, also, by direct division.

Powers of Protoplasm.—What are the powers with which the simple naked protoplasm of the Myxomycetes is found to be endowed? It is endowed with—

(*a*) The power of motion;

(*b*) The power of seizing and digesting food;

(*c*) A capacity for excreting what is not suited for retention by the organism;

(*d*) A capacity to perform chemical work;

(*e*) A capacity to assume and change colour;

(*f*) The power of attracting and being attracted by and uniting with other protoplasm of the same species;

(*g*) A converse power of avoiding the protoplasm of other species;

(*h*) A power to assume a definite external shape, and to divide into spores and non-spores;

(*i*) A capacity to enter into a state of suspended vitality.

"Life never can arise out of or depend on organization," wrote John Hunter; and unless naked protoplasm be regarded as organized, his remark seems to be verified and proved past dispute.

Let us consider some of these faculties more in detail.

Motion.—The motions exhibited by the protoplasm of myxies are of the most varied kind. We have already mentioned the jumping motion of the swarm spores and the crawling action of the plasmodium: now we will ask our readers to turn again to Fig. 4, and to allow us to describe what is seen in a crawling plasmodium under a microscope.

The plasmodium is differentiated into two parts: the larger and interior part contains minute oil granules, or *microsomata*; the external layer is free from granules, and is perfectly transparent like glass or water. The darker and granular interior protoplasm is known as the *endoplasm;* the hyaline superficial layer is known as the *ectoplasm.* Fig. 4 is on too small a scale to exhibit this difference distinctly.

There are two motions here to be observed, though they are not disconnected with one another: first, the pulsating motion of currents of protoplasm; and, secondly, the advance of the entire mass of protoplasm.

Under a microscope currents are seen to be established in the endoplasm, generally up or down the lines of advance of the plasmodium; the letters *st* in Fig. 4 indicate some of these currents. The granules stream in one direction; then pause, from sixty to ninety seconds (in the case of healthy plasmodia); then the current turns and streams in the opposite direction. These streams sometimes unite and sometimes divide. It is familiar that protoplasm when enclosed in cells often exhibits movements, as in the well-known case of the *Chara*, but then the movements are naturally constrained by the cell walls; in the free protoplasm of the myxies no such restraint exists.

If the peripheral edge of an advancing plasmodium be examined, there will be found in advance of the granular endoplasm a strip of the colourless and perfectly transparent ectoplasm, of which we have already spoken; it runs like the foreshore along the coast of the body. Into this from time to time a granule will be seen to advance, and then another granule, and so on till the line of the land has been pushed out into the foreshore, and the foreshore itself is moved forward into the sea. In this way the front line of the whole plasmodium advances, and as the rear of the plasmodium is drawn back in the line of advance as the front line is pushed forward, the whole body of the plasmodium gradually changes its place and moves forward.

It is a very striking thing to watch these forward movements of the granules. You seem to see in a minute and most intimate form the locomotion of living things; and, moreover, you perceive an internal movement of part, resulting in a movement in space of the whole organism. Mr. Spencer has said that "we have as yet no clue to the mode in which molecular movement is transformed into the movement of masses in animals." Does not the motion which we have described offer, if not a clue, yet a visible example of such transformation? Be this as it may, the mystery of motion remains just the same; there is the same antinomy between sense and reason—the one says that there is motion, the other that it is impossible.

"Io dirò cosa incredibile e vera."

It must not be supposed that it is only on the surface of dead wood or leaves that the plasmodia of myxies move. Sometimes, and especially under the influence of cold, they retreat downwards, and the *Fuligo*, a species which lives on tan and is known as the flowers of tan, will, under this influence, disappear from the surface of a heap and retire to the bottom of it. Cold or other unsuitable conditions seem to cause them sometimes to retreat into the wood to appear again under more favourable circumstances. Some plasmodia inhabit the interior of dead wood, and only appear on the surface for the purpose of fruiting: in the search for a suitable home for reproduction it has been thought that they move away from damper to drier spots, and they certainly often produce their sporangia in the dry air and in high positions. It has been thought also that light has a tendency to make the plasmodia ascend and darkness to descend. Sometimes a plasmodium will ascend a tree or a post for a foot or more, and a species known as *Lycogala epidendron* is said always to affect the highest point of the substance on which it rests. It is by no means infrequent for plasmodia to leave the dead wood on which they have been living and to ascend the stalks of flowering plants, or to spread over mosses, and often we have been surprised at the distances travelled by plasmodia in a few hours. The appearance, we may remark in passing, presented by the sporangia of delicate myxies on the leaves of mosses or blades of grass is sometimes very beautiful.

Plasmodia, as we have said, sometimes move in an upward, sometimes in a downward direction; in a seed, as we know, these two tendencies are separated, and the radicle tends to grow in the direction of gravity, and the plumule against it; in the myxies it would seem as if the same protoplasm at one time had the one tendency, and at another time the other. Perhaps, in passing, we may observe that the fact that plants and trees for the most part grow upward—*i.e.*, against the force of gravity—is one worth a good deal of thinking about, and when we look at the mass of fluid and solid matter raised every year, especially in the springtime, against the constant operation of the force of gravity, we get a notion of the magnitude of a force exerted by plants, to which we can assign no other origin than life, and give no other name than that of a living force.

It has been found with regard to the plasmodium of the flowers of tan that it has a curious tendency to move against the flow of water; thus, if one end of a piece of filter paper be placed in a vessel filled with water and the other on the table, so that the water flows downward, the *Fuligo* will move up the paper, and if the paper be so arranged that the water shall move up the paper, the *Fuligo* will move down.

Some observers believe that the myxie takes only such food as comes in its way; Mr. Lister believes that it uses its vibrating cilia to detect food; whilst others think they have observed that food exercises an attraction on plasmodia and influences their movements; thus, to return to the flowers of tan, a piece of tan or of wood steeped in tan has been seen, according to some observations, to induce the plasmodium to draw itself towards it, and that without reference to its position as regards the force of gravity. There seems no reason to doubt the accuracy of these observations. Here, then, we see in the primitive form of naked protoplasm that search after food which exercises so enormous an influence on the whole animal and vegetable world as well as in the social affairs of man. How, one cannot help asking, is the plasmodium made aware of the proximity of its appropriate food? Has it some rudimentary perception—some common sense, of which sight, and smell, and taste are only more specialized forms? What the plasmodium does in the equally near presence of two equally attractive morsels we do not know; but we do not believe that it would starve.

Sunshine is, again, a condition which seems to exert an influence on the movements of plasmodia. If a glass, on which the network of a plasmodium is spread, be partly exposed to the sunlight, it has been observed to withdraw to the shaded parts, and yet when the time comes for the sporangia to be produced it would seem in some species as if there was a movement towards surfaces exposed to light. But, according to the observations of Mr. Lister, light apart from direct sunshine does not affect the movements of plasmodia.

The plasmodium has been found to be sensitive not only to sunlight, to dampness and dryness, to heat and cold, but to the influence of chemical substances: the weak solutions of some chemicals having been observed to render it more fluid, whilst stronger solutions of the same substances have made it contract or perish in parts. This sensitiveness on the part of the plasmodia to so many influences must, it would appear, render very delicate the conditions under which alone myxies can succeed in the struggle for existence. Furthermore, it would appear that in the selection of places for the production of the sporangia they have to select situations affording enough atmospheric exposure to ripen the spores, and enough moisture to enable the swarm spores to swim and move about, and it is no doubt due to the width of the dispersal of the spores that they find these situations, which are, one would suppose, comparatively few. It is probably from this delicacy of the requisite conditions for success that plasmodia are not unfrequently seen to fail in the struggle of life. They will sometimes reach the surface, and commence the formation of the sporangium walls and spores, and then fog off and decay, without ever reaching maturity or producing sound spores.

The observations with regard to the influence of heat, drought, light, and darkness, on plasmodia may be correct, but it does not follow from them that the needs of the organism dependent on the stage it has reached, or on other circumstances unknown to us, may not also operate on their motions. We know that the sporangia are produced on the surface, but we hardly know whether the organism seeks the surface when it is time to develop sporangia, or develops sporangia when it reaches the surface.

Negative Geotropism.—It is not only in the motion of the plasmodium as a whole, but in the motion of its parts when it develops sporangia, that we observe an upward movement. Sometimes, no doubt, the sporangia are developed on the under surface or the side of the wood on which they grow. We are inclined to think that different species prefer different situations for the production of their sporangia, and that no one law is applicable to them all; but in all cases the sporangia appear to stand vertically to the plane on which they grow.

If we examine the trunk of an oak, we find an elaborate structure of hard parts which maintains the tree in its upward growth, and by the force of cohesion resists and overcomes the force of gravity drawing it downwards. If we examine the stalk of even a delicate flowering plant, we find that it is constituted of cells, and that the cell walls, as well as the fibres, afford to the stem a certain amount of support; but in the naked protoplasm of the myxie we have no woody tissue, no cell wall, and yet this, too, lifts itself away from the earth and towards the sun and the air. We then see that the upward motion of plants does not depend on cell walls, but is an inherent, an original capacity of some protoplasm.

We can easily appreciate the advantage which this upward tendency gains for the organism, for it lifts it into the air and exposes it to the influence of light. We know the great results on the surface of the earth of this so-called negative geotropism. If all plants had crawled along the ground like the thallus of Marchantia or the hyphœ of some fungi, we should have had a keener competition for surface space even than now exists, and we should have lost the beauty with which the earth's surface is clothed. In the myxie lifting up its sporangia, we can see in the small and in its simplest and most primitive form, the existence of the same power which enables the sequoia or the eucalyptus to lift themselves to such enormous heights above the ground. But of this power, this impulse, this faculty, this gift of resisting the force of gravity, and the attraction of the earth—what shall we say? what account can we give? We can only keep silence.

Capturing Food.—The habits of swarm spores in the pursuit or capture of their food have been very successfully observed by Mr. Lister. In the case of *Perichæna corticalis* he observed a swarm spore with four vacuoles, each stuffed with from six to eight bacilli; and in the course of twelve minutes he saw four bacilli drawn in by the projecting parts, or *pseudopodia* of the swarm spore. In the case of *Didymium* (or *Chondrioderma*) *difforme*, he observed that the capture of a bacillus is sometimes effected by pseudopodia. More often, a funnel-shaped aperture was formed in the posterior part of the swarm spore, and when a bacillus was unwary enough to enter, it was enclosed by a folding over of the lips of the funnel. The bacilli thus captured were seen to dissolve in the vacuoles, but no refuse matter was observed to be rejected; probably the whole bacillus was of absolutely digestible matter. On another occasion, Mr. Lister observed a swarm spore come upon a group of motionless bacilli. It spread itself out so as to cover four of them, and in about two minutes resumed its former shape, and crept away, carrying two bacilli in its vacuole. In the case of *Stemonitis fusca*, he observed the capture by pseudopodia of a bacillus so large that when drawn up into the body of the swarm spore it forced the swarm spore to bulge out on either side. On this followed a violent jerking motion of the swarm spore, which frequently occurs after the ingestion of food, and in a few minutes the bacillus was bent double, and the vacuole decreased in size. These observations of Mr. Lister seem to prove that the view of De Bary that the swarm spores take in nutriment only in a fluid state cannot be upheld. These processes are depicted in Fig. 3, which is reproduced by the permission of the Council of the Linnean Society and of Mr. Lister.

It is a curious fact that where a plasmodium on its march meets with a microcyst of its own kind, it has been observed to commit an act of cannibalism—to treat it as if a foreign body, and to enclose it in a vacuole, and then absorb it. Probably the presence of the membrane prevented fusion until it was removed by an act of digestion.

Rejection of Matter.—Mr. Lister has been equally successful in observing the method pursued by the plasmodium in the rejection of undigested matter. He fed, and I am afraid overfed, the plasmodia of *Badhamia utricularis* on thin slices of fungus, and when a plasmodium had become loaded with food material, many of the large vacuoles became charged with undigested matter, which assumed the appearance of a dark ball, and he "repeatedly saw these vacuoles push out as bubbles to the surface of the plasmodium and burst, discharging a cloud of refuse, consisting of fragments of starch and broken fungus hyphœ, into the water." But when the plasmodium creeps over glass, he observed the rejected matter, with a certain amount of plasmodium substance, to be left "on each side of the retreating veins, leaving a mass of the network after the plasmodium has withdrawn."

In other cases rejected matter, particles of starch or spores of algæ, or other things which have been taken up by the plasmodium, are found thrown aside in the hollow cavity of the foot of the sporangium, or even amongst the contents of the sporangium itself.

Species.—That true species exist in the myxies is doubted by no one who has studied them, and the constancy of many forms from distant places strongly supports this view. But it may be permitted to doubt whether the range of variation possible to one and the same species is yet sufficiently known to enable us to rely with security upon the whole of the present classification. In the progeny of a common parent when under cultivation, great diversities have been observed in the character of the calcareous walls of the sporangium, in the thickness of the capillitium, and even in its presence or absence, in the colour of the sporangium walls, the capillitium, and even of the plasmodium. Until, therefore, more species have been subjected to observations under culture, or more life-histories have been exactly traced, we must be prepared to regard the specific distinctions as open to revision. Mr. Massie considers that he has found cases of hybridism in myxies; but this, perhaps, requires confirmation.

Whatever be the limits of variation within a species, the great fact of specific distinction seems to admit of no doubt, and one of the most interesting faculties of these pieces of naked protoplasm is the power of knowing other pieces of protoplasm of their own species from the apparently similar protoplasm of other species. According to the concurrent testimony of three of the chief observers of these organisms, Cienkowski, De Bary, and Lister, "union never takes place between plasmodia of different species." "Branches of different plasmodia," says Cienkowski, "crawl near one another, and mutually embrace one another, without showing the least trace of any fusion."

The merging of two protoplasms has been seen under the microscope. "There appeared to be no mutual attraction until the two plasmodia were only separated by a distance of 40 μ. When a lobe from one was pushed out towards its companion, the intervening swarm cells were thrust aside, and they came into contact; the hyaloplasm (ectoplasm) of each blended at a single point, and then a stream of granular matter was seen to pass, then with a return flow of the streaming in the layer of the two, the channel was widened, and a gush of its contents poured into the smaller one, when union was complete and the system of circulation became common to both."

It may be permissible to adduce another instance of organisms of a very simple character to illustrate at once the attractive force of members of one species on their fellows, and of the capacity for selection which makes them reject the members of other, though very similar species. The case we are about to mention relates to two species of the genus *Cutleria*, algæ of a low type.

To the receptive ova of *Cutleria adspersa*, Falkenburg added actively mobile spermatozoids of the nearly allied species *Cutleria multifida* ; so like the other species *adspersa* that they can only be distinguished by small external differences. "In this case the spermatozoids, as seen by the microscope, wandered aimlessly about, and finally died without having fertilized the ova of the allied species of algæ. . . . A very different result was obtained as soon as a single fertilizable ovum of the same species was introduced into the vessel containing the spermatozoids. After a few moments, all the spermatozoids from all sides gathered around this ovum, even when the latter was several centimetres distant from the place at which the latter were chiefly collected."

These instances impress the mind with the fundamental character of the fact of species; whether it has arisen from variation and selection or not, it is a fact that goes down to the very foundations and rudiments of organic life, and even there influences the life and habits of the organism. As we see it in the myxies, it precedes the origination of the sexual distinction, it precedes any differentiation of parts or organs, it precedes the development of the cellular tissue. It may, perhaps, be said to precede the division into the animal and vegetable kingdoms. The distinction can exist in small naked bits of protoplasm, and each of these, indistinguishable in structure as the protoplasts of some of the species are to any organs or instruments which we possess, has the power of distinguishing between these indistinguishable masses, of attracting and being attracted by those of its own kind, and of remaining indifferent and neutral towards those of other kinds.

That the pollen of an oak should not act on a daisy seems to us natural; that the naked protoplasm of these minute organisms should be endowed with this selective capacity does seem very remarkable, and may well make one pause and think. Is it possible, one inclines to ask, to feel sure that all the various species of myxies have been produced from one original form by the force of a natural selection? How can the doctrine of the fittest be applied as between two naked protoplasts, and if applied only to the later stages of growth, how has it reacted on the earlier stages?

Classification.—We now propose to deal with the classification of these organisms, and this will afford us an opportunity of describing more in detail some parts of their structure.

The value of characters for the purposes of generic and specific distinctions is a subject well worth consideration, for it often reveals unexpected facts in the correlation of parts, startling one by dividing organisms which, at first sight, seem nearly akin. Colour is for the most part of little value as a distinction in flowering plants, for we know how widely colour will vary in the same species. "Color," says Linnæus, "in eadem specie mire ludit: hinc in differentia nil valet;" and yet in the pimpernel, the blue and red forms differing in scarcely any other character are true and not interchangeable species; in the algæ the presence of colours other than green is found a fundamental character in their classification, and in like manner we shall find in the myxies that the colour of the spores has been found a character of real value.

What is the meaning, some one may ask, of the value of a character for classificatory purposes? It means that the presence of that character affords a safe line of cleavage;

FIG. 5.—*Cribraria aurantiaca* × about sixty diameters.

that those plants or animals which are on one side of the line will be found to agree in other characters—will have a likeness in many points of that kind which creates what we call in human beings a family likeness; whilst those organisms which stand on the other side of the line will be found dissimilar from the first family group. For instance, if we gather the common white dead nettle and observe its stalk, we shall find that it is four-sided, so that a section across it is a square. Now this characteristic might easily be supposed to be one of little consequence, and yet, in fact, it will be found to be a true and valuable one, and that all plants with a square stalk and lipped flowers will be found to have a four-lobed ovary and four nuts on the bottom of the calyx, and these belong to the family of the Labiatæ. If now, on the other hand, we count the number of the stamens in plants, and use this character as the foundation of our classes, we shall break up this natural family with its square stems, and shall relegate some genera, such as Salvia, to one class, while the great mass of the family go to another, and, what is perhaps worse, these exiled genera find themselves put into a class together with plants with which they have no real connection or sympathy—with the Enchanter's Nightshade and the Duck-weed. This form of the stem then has a high value as co-existent with a general likeness of structure; the number of the stamens may vary in plants closely akin, and agree in plants widely different, and therefore has a low systematic value.

The variations of form of our domesticated dogs are generally held to be of no value even as specific distinctions; but the difference of the markings in the spores of myxies is held by those who have most studied their classification to be often a safe difference as between two species. It is only by experience that we can tell the systematic value of a difference—*i.e.*, by observing how far it is correlated with other differences of structure or life-history, and whether the difference does, or does not, lose itself in a series of easy gradations between the two extreme forms. And yet there are some minds whose thoughts so run along the lines of creative thought that, as if by a happy intuition, they are able to seize these crucial points which are of real value, and to reject those that are useless. Such is the mind of the true naturalist.

Some slight difference exists amongst naturalists as to the extent to which the group of the Myxomycetes is to be carried—viz., whether they shall include or exclude a small group of organisms about to be mentioned, and as to the way in which the two terms Mycetozoa and Myxomycetes shall be used in classification. The following table may be useful as indicating the primary and secondary divisions of the group, which we shall accept in its widest signification :—

			Example.
(*a*) Mycetozoa	With an aggregate plasmodium, *Acrasieæ*		*Dictyostelium.*
	With a fused plasmodium, *Myxomycetes*	Exosporeæ, spores borne externally.	*Ceratomyxa.*
		Endosporeæ spores borne internally.	*Arcyria.*

(*a*) NOTE.—To avoid confusion, it may be well to state that in the foregoing table we have followed the classification of De Bary—that Van Tieghem would write "Myxomycetes" as the name of the whole class where we have written "Mycetozoa," and would write "Myxomycetes proprement dits" where we simply write "Myxomycetes"; and that Mr. Lister uses "Mycetozoa" for what we have called "Myxomycetes," and so excludes the *Acrasieæ* from the Mycetozoa.

Of these classes, it may at once be observed that the endosporous Myxomycetes are by far the largest, and that the species at present known of the other groups are very few in number, and, accordingly, in the sketch which we have given of the life-history of a myxie we have dealt only with the changes in an endosporous myxie.

It now becomes needful to call attention to the points in which the smaller classes differ from the dominant one.

In the ordinary myxie, as we have seen, the swarm spores effect a true fusion and build up one mass of protoplasm. In the Acrasieæ, on the contrary, the swarm spores do not fuse or coalesce together, but only aggregate together, retaining a power of separating from and moving on one another. This is the first and broadest division of the group of organisms.

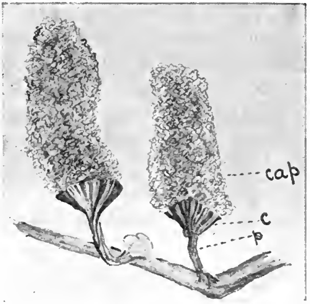


FIG. 6.—*Arcyria punicea* (*cap* = *capillitium*; *c* = *cup*; *p* = *pedicel*) × about ten diameters.

The next characteristic which has been used for the classification of the group is the position of the spores in the organism. Hitherto we have only mentioned spores as contained within the sporangium; but there are one or perhaps two species very different in many ways from the rest of the group, in which the spores are carried on the outside of the organism. From this character the whole myxomycetes have been divided into two classes: the Exosporeæ, in which the spores are developed on the outside of the *sporophore—i.e.*, the part of the organism which bears the spores; and the Endosporeæ, in which the spores are generated within the sporangium.

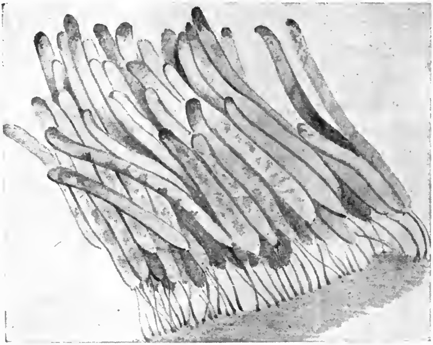


FIG. 7.—*Stemonitis ferruginea.* Group of Sporangia. × about eight diameters.

We propose hereafter to consider somewhat more in detail the peculiarities of these two sets of aberrant forms; but they will be better appreciated after we have dealt with the larger group. We therefore now turn to the myxies which carry their spores within the sporangium, and we shall indicate some of the points of structure of which use has been made for the purposes of classification.

Fructification.—Perhaps the point of distinction which first arrests the eye of the student is the variety of form in which these organisms fructify and bear their spores.

These forms, to which different designations have been given, may be considered :—

a. The sporangium, a term which is sometimes applied to the spore-bearing organ in general, has been often applied in a narrower sense when that organ is well defined

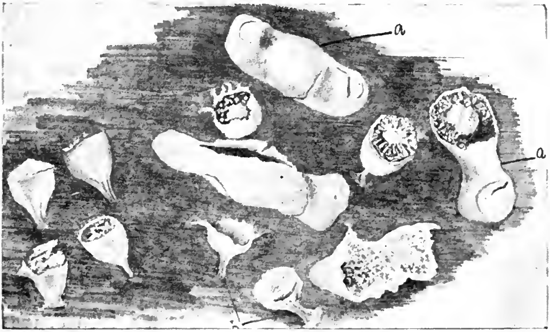


Fig. 8.—*Craterium pedunculatum.* Group of Sporangia and Plasmodiocarps. × about 10 diameters.

and symmetrical, such as the grape-like structures of *Badhamia* (Fig. 1), the baskets of *Cribraria* (Fig. 5), or the elongated forms of *Arcyria* or *Stemonitis* (Figs. 6 and 7).

β. Plasmodiocarp is a term applied to the spore-bearing part when it is sessile and irregular in form, sometimes like a cushion, sometimes like a creeping snake or a long tube. It may be said to represent the aggregated plasmodium which has stayed its onward course, gathered itself together, covered itself with a coat, and then produced spores. This form is shown at *a*, in Fig. 8.

γ. Æthalium is the name given to that form of fructification in which a number of separate spore cases exist; but where they are so densely packed together, so intricately coiled, and so freely anastomosing that their individuality seems to disappear. The *Fuligo septica*, the myxie to which we have already often alluded as living on tan, and which is known as the flowers of tan (the only instance, we believe, in which any one of these organisms has the slightest claim to an English name), is an instance of this form of fructification. Fig. 9 exhibits a section of the mature æthalium of Fuligo.

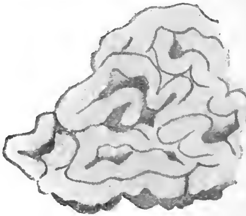


FIG. 9.—*Fuligo septica.* Section of mature æthalium. Somewhat enlarged.

Though it is both possible and convenient thus to classify the forms assumed by the fructification, it must not be supposed that the lines between them are hard and fast; on the contrary, there are abundant instances in which the plasmodiocarp and sporangium forms merge into one another; frequently the two forms will co-exist as the products of one and the same plasmodium.

Thus the beautiful little cups of *Craterium* will sometimes fail of complete separation, and part of the plasmodium is content to take the cruder form of a plasmodiocarp, as shown in Fig. 8. Again, sporangia, which are sometimes stalked, are at other times sessile, and thus differ but little from a plasmodiocarp. In the *Dictyostelium* (one of the Acrasieæ to be hereafter mentioned), a similar phenomenon has been observed; although in the normal form the production of spores occurs at the top of the pedicel, or column, in some cases the plasmodium turns into spores without ever developing the column at all.

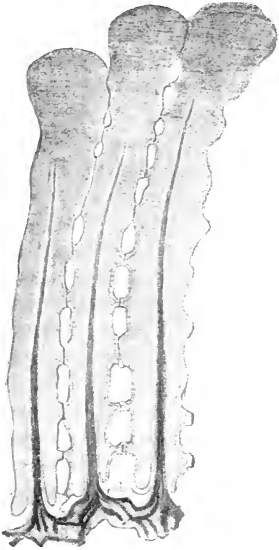


Fig. 10.—*Stemonitis fusca.* Plasmodium turning into Sporangia. (After De Bary.) Enlarged.

There appears to be a considerable difference in the way in which the plasmodium turns into sporangia. In some cases the plasmodium first separates, and then each separate part forms a sporangium. In other cases the plasmodium begins its transformation as a whole, and breaks up into sporangia as the process advances.

Comatricha and *Craterium* appear to be cases of the former mode of procedure; *Stemonitis* of the second. Thus in *Comatricha* the plasmodium emerges in separate centres, like small conical hillocks on the wood. These grow upward, and as they approach maturity the upper part of the protoplasm draws all the lower part after it, except so much as goes to form the pedicel and *hypothallus*, or foot.

In *Stemonitis*, on the contrary, the plasmodium gathers itself together in a lump or mass, and first shows signs of dividing up by the appearance of papillæ on the surface; then at points corresponding with the papillæ, dark-coloured stems grow upwards in the gelatinous mass. Around these stems, portions of the adjoining protoplasm gather, and separate vertically from their neighbouring parts; and again, before maturity, the lower portion of the protoplasm around each column moves upwards, leaving only the delicate stalk which supports the arborescent sporangium. Fig. 10 will explain these steps in development.

It would seem as if the sporangium forms were the most highly developed, and the plasmodiocarp form the more rudimentary. We suppose that in the matter of advantage to the organism there must be something to be said for and against each form, for the plasmodiocarp must expend less material on perishable walls and stalks, and, on the other hand, be less open to the atmospheric influences; whereas the opposite in each respect must apply to sporangia. If one of these forms be better than the other, why does it not universally prevail? and why do some individuals of some species halt between the two opinions? We certainly do not know. This is one of the many cases in which it is at least very difficult to see any advantage gained by the variations of development of an organism.

Sporangium Walls.—The walls of the sporangium vary very greatly; sometimes they consist of a single membrane; sometimes of two or even three membranes; sometimes they continue till by rupture they let loose the spores; in other cases, the whole, or the upper part only, early falls away and discloses the system of hairs and the spores within; sometimes, as we shall see, they are furnished with lime, at other times they are without it.

In *Cribraria* (Fig. 5) we have a very beautiful form of sporangium, the wall of the lower half persists and forms a cup, whilst the upper half in its mature state consists of a network only of slender threads more or less thickened at the points where they cross one another.

In *Dictydium* we have again another very beautiful form of sporangium—it consists of rays of longitude gathered together at the pedicel and at the top as their two poles, with much slighter transverse lines of latitude. The intervening membrane falls away in whole or in part, and leaves for the sporangium a basket of most delicate network (*see* Fig. 11).

In some cases the exterior of the sporangium has a most delicate surface, shining with iridescent colours. The *Lamproderma* is a genus with several species distinguished by this beautiful peculiarity. Our English species are very attractive, but they are excelled in brilliance by some tropical kinds. Of other genera, the *Physarum psittacinum* is another species with iridescent sporangia, and derives its name from its supposed resemblance to the colours of a parrot.

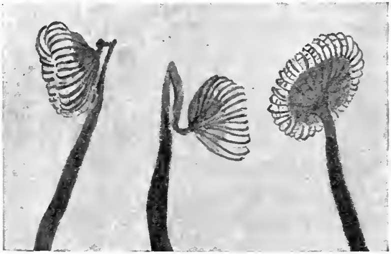


FIG. 11.—*Dictydium umbilicatum.* Empty Sporangia. × about 40 diameters.

CAPILLITIUM.—It is impossible to consider the form of the sporangium without reference to the *capillitium*, *i.e.*, the system of hairs contained within it, and sometimes entering into union with it as part of its structure. This capillitium is often of great beauty. It is formed before the spores in the course of development, and it is probable that it performs a part in the dispersal of the spores. Sometimes, as in *Trichia* (Fig. 12), the hairs lie free amongst the spores. In this genus the hairs are furnished with spiral thickenings, which give them very much the appearance of a twisted cord, and they are hygroscopic, *i.e.*, under the influence of moisture they twist and twirl and thus separate and disperse the spores. In *Trichia* the sporangium opens by the bursting of the upper part of the case, and then the hairs, covered with the spores, pour out over the remaining part of the sporangium, so that it appears as if covered by a piece of delicate fur.

In some cases the hairs have not only a spiral thickening, but are furnished with projections, bristles or cogs of

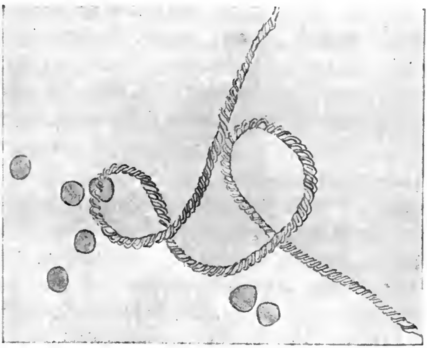


FIG. 12.—Elaters and spores of *Trichia varia.*

varying shapes. In one species, *Hemitrichia rubiformis*, the hair is so thickly beset with bristles that under the microscope it looks like the prickly stem of the bramble, and hence it derives its specific name. In some genera the hairs, as well as the spores, are remarkable for their bright golden yellow colour.

A connected system is presented by the capillitium of the beautiful genus *Arcyria* (Fig. 6). The immature sporangium is a long egg-shaped case standing on a pedicel; as it ripens the upper half or two-thirds of the membrane burst and fall off, leaving the lower part to form a cup (*c*), from which is seen to arise a thick web of fibres, almost like a pillow made of delicate horsehair (cap). These fibres are elastic, and so soon as the wall of the upper part of the sporangium gives way they expand to a height and breadth greatly in excess of the capsule in which they were contained. There can be little doubt but that these elastic fibres when mature must exert a great upward and outward pressure on the walls of the sporangium, and no doubt they hasten the disappearance of the upper parts of the wall.

In some species the system of hairs remains attached to the cup, which is the abiding part of the sporangium wall; in other species it is attached to the interior of the stalk only by a few branches, and then it is apt to fall away from its cup.

The likeness between the hairs of the sporangia of the genera *Trichia* and *Hemitrichia*, and of the *Jungermanniæ* is very close, and the same variety of arrangement is found in both cases. Both families exhibit elaters marked by spiral thickenings (*see* Fig. 12); but in the myxies these thickenings appear to be external, whilst in the Jungermanniæ they are generally, or always, internal. Both groups show differences in the number of these spiral thickenings; they are sometimes single (as in *Hemitrichia Wigandii*), or double, and sometimes reach to as many as six (in *Hemitrichia clavata*). In both groups the hairs are sometimes free and lie loose amongst the spores, and, in other cases, are joined together into a system—a regular capillitium, attached to the base of the sporangium. The *Jungermannia epiphylla* is a good illustration of such a regular system of hairs. In both groups the hairs or elaters appear to perform the same duties, of assisting by a pressure from within in forcing the sporangia open and of dispersing the spores by means of their hygroscopic activities.

In some sporangia, the most marked feature is a *columella—i.e.*, a prolongation of the pedicel, usually forming a column or a central line through the sporangium, but sometimes hemispherical and globose. In some genera it extends to only part of the height of the sporangium; sometimes to its entire height. A portion of such columella is seen in Fig. 13. To the columella the system of hairs is attached in many divers forms and ways. In *Lamproderma* the column reaches part of the way up the sporangium, and from near its summit it gives off a great mass of hairs spreading in every direction, so as to form a globe of anastomosing hairs. In *Enerthenema* the column is carried to the top of the sporangium, and spreads into a sort of capital, the top of which is part of the surface of the sporangium, and here the globe of slightly branching hairs is attached to the top, and falls down and fills the sporangium.

More complicated and more beautiful forms arise when the hairs branch out from all along the columella, and anastomose with one another so as to form a perfect network. In these cases the whole of the walls of the sporangium is supported by the ends of the hairs, and is usually very fugacious, and soon falls off, leaving a tree-like structure of delicate branches. The genus *Comatricha* shows round or ovoid heads, not unlike the system of branches of an oak (see Fig. 14). The genus *Stemonitis* has taller tree-like growths, which often remind one forcibly

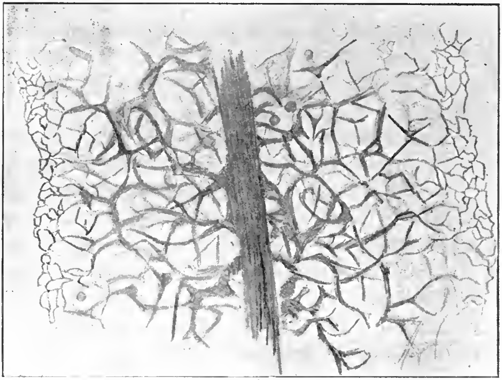


FIG. 13.—Capillitium of *Stemonitis fusca.*

of a Lombardy poplar. Fig. 7 shows a group of sporangia. Fig. 13 shows a portion of the capillitium when the spores have been shaken out.

It is curious thus to see these similar forms assumed by the mighty trees and by their poor little and very distant relatives the myxies; and yet, perhaps, this similarity is not a mere accident, but the same physiological necessity has in each case produced the same result. In order that the leaves and flowers and fruit may be exposed to the greatest amount of sun and air, and that the fruit may be

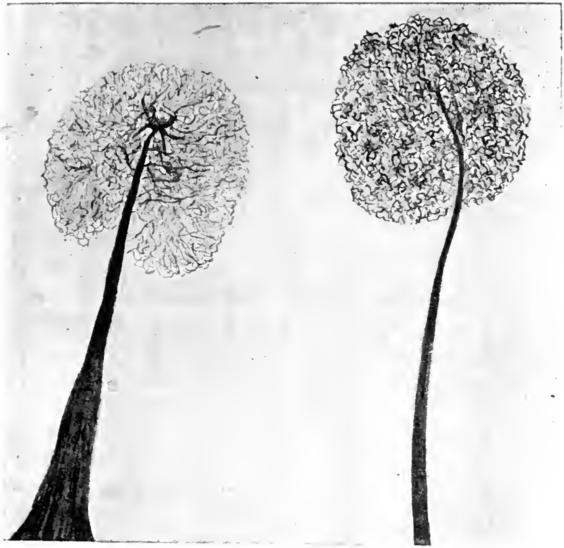


Fig. 14.—Pedicels and Capillitia of *Comatricha obtusata.*

spread far and wide, it must be supposed that the tree-like form has been assumed. A globe suggests itself as the most natural form in which a solid mass can obtain an extensive exposure to the action of the sun and of the atmosphere if they operated equally all round. We say the most natural, as it would result from an equal and universal outward growth, but for the purpose of exposing its surface, the globe must be mounted on a stand; but as the lower part will be of less value than the top and sides, because less exposed to the action of the sun, it will be convenient that the globe form shall be modified: and this has been sometimes attained by horizontal, sometimes by vertical expansion. Some such physical necessities seem to have influenced the shape of trees; and similar ends are, we suppose, subserved by the dendroid forms of the capillitium in *Comatricha* and *Stemonitis*. How has the chasm between the need and the supply been filled up in these minute organisms or in the stately oak?

Another fact which creates further varieties in the form the sporangia is the presence of lime in the capillitium and in the coats of the sporangium. In this presence of the carbonate of calcium in the sporangium, a character has been found for one of the subdivisions of the myxies, the so-called *Calcarineæ*. In some cases the lime is found in small grains in the substance of the covering membrane, in other cases it is found in star-shaped crystals lying on the outside of the membrane. These are very beautiful objects, and may both be seen in the family *Physaraceæ*.

In some cases the walls of the sporangium alone have the lime and the capillitium is without it; in many other cases the lime is found also in the capillitium, and that in different forms. We have already in our sketch of the life-history of *Badhamia utricularis* described the delicate lime structure of its sporangium.

Amongst all the delicate forms of the myxies there is none perhaps more beautiful than that of the genus *Craterium*. The sporangium, as the name of the genus is meant to tell, is goblet-shaped, and the top of the cup is usually covered with a distinct lid, which rests on the sides of the cup. In *C. pedunculatum* the colours sometimes suggest the notion of a golden cup with a silver lid, and in this dainty cup is found a capillitium of large white lime knots, connected by delicate hyaline or yellow threads, as shown in some of the broken sporangia of Fig. 8.

It has been suggested that the lime is to be regarded merely as an excretion, a thing of which the organism desires to be rid in its actively living parts. Be it so or not, it is evident that the organism sometimes continues to make this substance subserve the useful purpose of support.

It is worth while to note the several ways in which the capillitium appears to be used to attain the same end—the maturing and disposal of the spores. Sometimes it is the untwisting of the hygrometric spiral hairs which disperses them (as in *Trichia*, Fig. 12); sometimes it is the uprising of the elastic pillow contained in the sporangium (as in *Arcyria*, Fig. 6); sometimes it is by the spreading branches of the capillitium that the spores are scattered over a wide surface, as in *Enerthenema;* sometimes they are inelastic and charged with lime, and are then used as beams to prevent the walls of the sporangium from falling in and so injuring the young spores (as in *Badhamia,* Fig. 2). This wealth of plan, this variety of scheme for effecting the same end, and with the same or nearly the same materials, is not unfrequently found in the works of Nature. One might suppose, if Nature were striving to do the one thing needful with the utmost economy, and in the very best way, that there would be one, and only one way which was the cheapest and best, and that this would, on the principle of the survival of the fittest, be found everywhere to prevail. But this is by no means always the case. Look at the vast variety of schemes, by which, in orchids, insects are made to solve the problem of getting the pollen-masses out of the boxes into which they have been stowed away, and then of pollinating with them the stigmatic surface. Or look again at the vast variety of the forms of the peristomes in mosses (all varieties of the same elements and of the same fundamental idea), and the various ways in which they operate under the action of moisture. Or take again the insectivorous plants. Here the problem which Nature seems to have set herself is this—given a leaf, how to catch insects? And this problem has been solved by the use of different constituent parts of a leaf in almost as many ways as there are genera of insectivorous plants. Or, once more, take the case of birds fitted for subaqueous locomotion. Here the problem seems to have been—given wings and legs, how to drive the body through the water? and this has been solved, as we know, sometimes by using the wings, sometimes the feet, as paddles, and with a wealth of variation that is very remarkable. In all these cases Nature seems not to ask herself what is the single best way of using the instruments at command, but, given certain organs, how to attain the end in view with the greatest amount of variation!

THE OPENING OF THE SPORANGIA.—In some cases, as already mentioned, the sporangium opens by an indeterminate rupture, in other cases Nature differentiates it into two parts, the upper forming sometimes a lid, as in *Craterium*, sometimes falling away early, as in *Arcyria*. Just the same kind of difference prevails, it will be remembered, in the mosses, the sporangia of the clay mosses (*Phascum*) opening by a decay of their sides, the sporangia of most of the mosses on the other hand having a regular dehiscence.

It is a beautiful sight to see through a microscope the opening of a sporangium of a myxie under the warmth of the sun. We have watched it in the *Trichia fallax;* sometimes there appears a small hole in the membrane towards the top, which enlarges into a chasm; sometimes the whole upper part seems lifted or pushed up. Then the closely-packed spores begin to start out—one after the other—falling at varying distances; then the whole surface of the mass of spores and elaters begins gently to heave and move, and the elaters sway about like the arms of a polype. These actions are, we presume, due partly to the elasticity of the hairs seeking to expand in every direction, and partly to the unequal thickness of the parts of the elaters and the consequently unequal action of the heat on the elaters themselves. They curl and twist because they are unequally expanded.

Spores.—The spore is another part of the structure which varies much. Spores vary in size; they vary in colour, sometimes violet or brown, or red or yellow; they vary in their surface, sometimes smooth, sometimes spinulous or covered with warts; sometimes covered with a kind of network or furnished with a border or band. All these variations are used as points of distinction in the classification of the myxies, and the presence of a dark violet colour in the species is found, as already mentioned, to be of high classificatory value.

Another curious point about spores is the tendency in some of them to gather into groups of a more or less definite number, whilst others exhibit no such tendency, but remain single or aggregated without law. The spores of *Badhamia utricularis* have a tendency to gather into groups of from seven to ten, whilst the spores of its nearest congener, *Badhamia hyalina*, often congregate in numbers as high as twenty, and in other closely allied forms the spores are free. But this character, though generally true, is not absolutely constant. The spores of *B. hyalina* are sometimes almost free, and the same tendency to variation has been observed in other species.

Aberrant Forms.—Having thus given some description of the various parts of the Endosporous Myxies, we shall now revert to the aberrant forms which have hitherto been left out of consideration—viz., the Exosporous Myxies and the Acrasieæ, the position of which in the classification may be learned by again referring to the table given in an earlier paragraph.

EXOSPOREÆ.—The Exosporeæ, or Myxies which carry their spores on the surface and not in the inside of the sporangium, consist of one genus—*Ceratomyxa*—and of two species, or, according to other authorities, of one species only with one variety. Of this small organism a drawing will be found in Fig. 15. Its first describer, Micheli, called it *Puccinia ramosa* (in 1729). In 1805 it was called *Ceratium hydnoides* by Albertini and Schweinitz. It was described as *Ceratomyxa mucida* by Schrater in 1889, and, as that name is adopted by Mr. Lister, whose works are the most convenient for the English reader, we have thought it best to follow him. But we have given the synonyms to prevent our readers from being misled by the puzzling and lamentable variety of names.

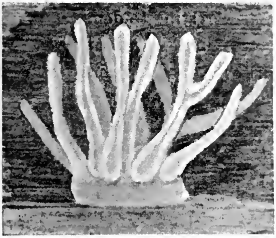


FIG. 15.—*Ceratomyxa mucida.* Magnified. (After Famintzin and Woronin.)

The *Ceratomyxa mucida* is by no means uncommon on rotten wood, and might at first sight be mistaken for a white or pale-coloured fungus. It consists of an aggregation of finger-like projections from a common base, and presents somewhat the appearance of a minute piece of white coral. When the surface of these projections is examined, it is found to be marked off by delicate lines into polygonal spaces, from the centre of each of which rises a delicate white stalk, and on the summit of this an equally delicate and white egg-shaped spore.

The development of this little organism has been elaborately studied by two Russian botanists, and it is sufficiently interesting to demand a few minutes' attention. Its plasmodium emerges from the wood in points about the size of a pin's head, and is found to be differentiated into two elements —(1) a transparent motile jelly, and (2) an irregular network of opaque plasma embedded in the transparent jelly. These two parts are shown in Fig. 16. Gradually little prominences are developed on the surface of the plasmodium, and as these grow into the finger-shaped projections, the network of opaque plasma appears just below their surface, the translucent

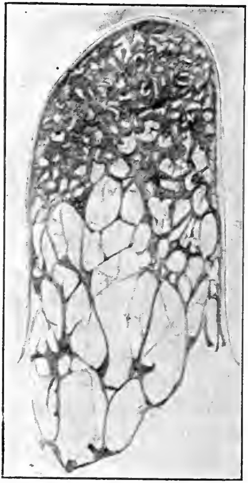


FIG. 16.—*Ceratomyxa mucida.* Plasmodium showing superficial transparent jelly, and opaque strands. (After Famintzin and Woronin.)

jelly of the interior passing through the strands of the network and forming a very thin external coat. The next step is taken when the strands of this network thicken so as to occupy nearly the whole surface of the projection and then break up into polygonal plates, each furnished with a nucleus; from each of these plates there grows a pedicel supporting a ball which is the future spore; into this the opaque plasma of the plate passes. This state of things is shown in Fig. 17. When the spores have fallen off, the rest of the plant withers and disappears.

Each swarm spore, according to these authors, often shows amœboid movements; divides into two equal parts, which assume a cross-like posture in their greatest length, the one lying on the other; then each of the two parts divides into two other parts and again each of the four divides into two parts, so that the original swarm spore is now represented by eight protoplasts all lying together; these then separate, develop cilia, and act as free swarm spores. Fig. 18 represents the eight protoplasts lying crosswise together, before their final separation. We are bound to add that this peculiar process has not been noticed by Mr. and Miss Lister in their numerous observations on *Ceratomyxa*, nor by our-

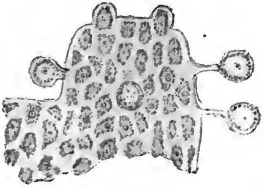


FIG. 17.—*Ceratomyxa mucida.* Development of Spores × 160. (After Famintzin and Woronin.)

selves in our more limited ones, and the matter appears therefore to require further enquiry.

ACRASIEÆ.—We have already indicated the existence of a small group of organisms differing from the ordinary myxies in the fact that the swarm-spores, though they gather together and act together, never fuse into a single mass or constitute a true plasmodium.

Three species have been studied and described with some care, and their history is so curious that we hope our readers will not weary if we dwell upon it a little.

FIG. 18.—*Ceratomyxa mucida.* Eight Protoplasts before their final separation. (After Famintzin and Woronin.)

The swarm spores are like those of true myxies, and have the same amœboid movements, but without the dancing movement with flagellæ. These swarm-spores meet and, as if by common consent, set up a centre of attraction, towards which they tend, the long arms or straggling parts of the original gathering coming more and more to the central point.

The course of growth in *Acrasis granulata* (one of the organisms in question) has been described by Van Tieghem. When the swarm cells have gathered together, they touch one another, and form a cellular mass. This mass grows upwards in a conical shape. The cells of the axis, somewhat longer than they are broad, assume a cellular membrane, and constitute a foot, buttressed up by other cells. The exterior cells move upwards on this foot, clothe themselves with a cellular membrane, heap themselves together at the summit of the structure, and thus form a chaplet of spores.

In *Dictyostelium mucoroides* a very similar course of growth has been observed. The mass which collects at the central point differentiates itself into a column, a membraneous veil to the column, and a residual mass surrounding the column. As the column grows upward this residual mass does the same, and thus withdrawing its lower part from the ground it wanders up the stalk and forms a cap or crown which turns into spores without a trace of capillitium. Fig. 19 shows in section the nearly adult form of this organism.

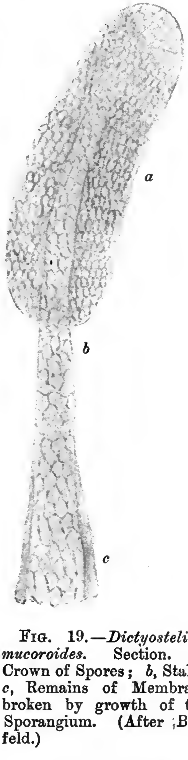


FIG. 19.—*Dictyostelium mucoroides.* Section. *a*, Crown of Spores; *b*, Stalk; *c*, Remains of Membrane broken by growth of the Sporangium. (After Brefeld.)

A still more singular history is presented by a third species, the *Polysphondylium violaceum.* Here the early stages correspond with those already described, the plasmodium, or more accurately the pseudo-plasmodium, gathers itself towards a central mass as shown in Fig. 20; the central mass again differentiates itself into a column and a surrounding mass of protoplasm which clings round the attenuated central column, as shown

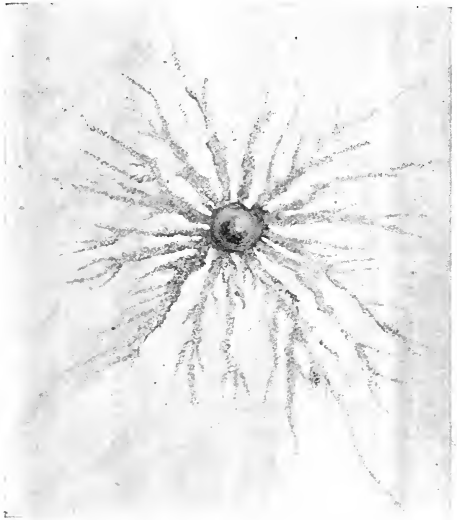
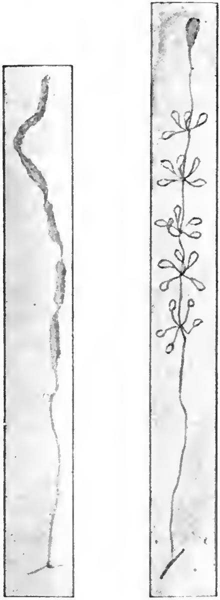


FIG. 20.—Pseudo-plasmodium of *Polysphondylium violaceum*. (After Brefeld.) × about 25.

in Fig. 21; it then begins to narrow in at intervals along this column, and breaks up into discontinuous lengths with intervening nodes, as shown in Fig. 22 (*a*).

From these discontinuous pieces of protoplasm there are subsequently developed in the top of the column a terminal head, and on the successive lower stages of

FIG. 21.—Immature Sporangium of *Polysphondylium violaceum*. (After Brefeld.)



a *b*

FIG. 22. — *Polysphondylium violaceum*. *a* and *b* successive stages in ripening of Sporangium. (After Brefeld.)

the column, successive whorls of stalks, each carrying a lateral and smaller head, as shown in Fig. 22 (*b*); each of these heads finally ripens and breaks up into spores.

The life-history of all these *Acrasieæ* presents many very curious points; it seems to bring before us the fact that separate protoplasts, without ever uniting into a plasmodium or ever becoming part of a single organism, may nevertheless acquire as it were the social instinct and live for the good not of themselves but of the whole organism, and for that purpose may submit to a division of labour; for whilst some of the protoplasts assume the function of only supporting their fellows, the others avail themselves of the support, raise themselves from the level of their original surface, and devote themselves to the function of reproduction. And, moreover, certain aberrant and sessile forms of the *Dictyostelium* seem to show that this elevation of a portion of the protoplasm is not necessary to reproduction, though it may well be that the greater exposure to the ripening influences of the atmosphere and the sun may render it beneficial to the organism, and so more than compensate for the withdrawing from the function of reproduction of a certain part of the protoplasm, and applying it to the purposes of support alone.

Unicellular Organisms.—Leaving now the subject of classification, and of the aberrant forms of myxies, we return to the principal group. We have already dwelt upon the fact that the myxies show all their vital powers and all their capacity for development without the formation of a true cell-wall, or undergoing division by septa formed in cells. It seems scarcely possible for organisms living in the air to attain any considerable size or complexity of form without the support of cell-walls, and without the formation of vessels which assist the transfer of nourishment from one part to the other.

But with plants inhabiting the water—a medium of nearly the same specific gravity as the plant—and drawing their nourishment directly from this medium, the case is different, and the possibility of such organisms attaining considerable proportions and complexity of outward form is shown by a considerable group of *Algæ*, for which there has recently been formed a class called *Multinucleatæ*, which includes four orders with considerable differences amongst themselves, but which all agree in possessing no cell-walls, and, under ordinary conditions, no septum dividing one part from the other. Each organism is thus a single protoplast. These unicellular organisms, as they are often called, show a capacity for developing a vast diversity of forms, many of them very beautiful, and many of them strangely mimetic of the forms of higher plants—of the mosses, the lycopods, the conifers, the cactus tribe, and the hymenomycetous fungi. Some of these organisms reproduce sexually, others asexually; some attain very considerable size—as in the genus *Caulerpa*, a beautiful form of marine alga. "Nature," says Mr. Geo. Murray, speaking of *Caulerpa*, "appears to have executed in the form of this genus a *tour de force* in exhibiting the possibilities of the siphoneous thallus—in showing that it is possible for a unicellular organism to display the varied beauties of outward form characteristic of highly organised types, to attain by means of a lattice-work of cross beams within the cell body that mechanical support effected by transverse septa and separate differentiated cellular structures for other algæ and for the higher plants."

A consideration of these structures impresses the mind very forcibly with the vast inherent capacities of protoplasm. Nature had two courses open to her, if we may so speak, as to the mode of dealing with protoplasm—endowed as it is with its varied capacities—each of which she has pursued to a certain extent. In the one course of development the single protoplast has remained a unit, and has in this undivided condition performed all the needful work of the plant. In the other course, the protoplasm has been broken up into detached parts by the cell-walls, and thus a division of labour has been brought about or promoted which has led to the highest results, and left the unicellular organisms far in the rear. The former course of development is seen in the myxies, and, as we have shown, reached a great development both as regards size, form, and function, in such algæ as *Caulerpa*. The other course of development is seen of course in nearly all the other members of the vegetable kingdom, and reaches its highest results in such vast and complex organisms as our forest trees.

One other observation naturally arises from the consideration of these unicellular forms. We are wont to trace the origin of the differentiation of parts—of the branches and leaves and so forth—to the divisions of the cell of the growing points in plants. We now see a differentiation of parts arising without any such cell to divide, and without any septa to mark off the future organ. The protoplasm is the master: the cell-walls are its humble servants, and we have another illustration of how the contents are apt to rule the containing structure, and the soft to rule and mould the hard. The divisions of the cell-walls are a secondary and subordinate phenomenon.

ISOMORPHISM.—We crave our readers' leave to return to the fact already mentioned, that unicellular organisms have a tendency to imitate the forms of cellular organisms, and that whereas we have in the series and chain of cellular plants such marked outward forms as those of the moss, the lycopod, the conifer, the cactus, &c., we have in the chain of unicellular plants very similar outward forms, so that we seem to have two chains branching off from one another, with links here and there which closely correspond with one another. This phenomenon is one found frequently to present itself to the attention of the philosophical systematist, and like all the phenomena of Nature is well worth pondering. It has been stated very forcibly by Mr. Brady, in respect to the *Foraminifera*, a group of organisms deeply studied by him:—"A purely artificial classification is ill-adapted to the conditions presented by a class of organisms like the *Foraminifera*, largely made up of groups of which the modifications run in parallel lines. This 'isomorphism' . . . . . exists not merely between a single series in one of the larger divisions, and a single series in another, but often amongst several series, even of the same family. It not unfrequently happens that a member of one group presents a greater similarity to its isomorph in another group with which it has no relationship than it does to any other member of its own group. Take a familiar illustration: suppose the fingers of the two hands to represent the modifications (species) of two such parallel types of *Foraminifera:* the thumb of one hand resembles more closely the thumb of the other hand than it does any other of the fingers of its own."

A comparison of the marsupial quadrupeds of Australia and South America with the placental mammals of the rest of the world presents another series of these isomorphs. There are certain Marsupials which seem set over against the Carnivora, others against the Rodents, and so forth. Mr. Murray, in his "Geographical Distribution of Mammals," has figured on the same page two animals, one a small placental mouse, and the other a small marsupial mouse, and their outward forms are almost indistinguishable; and yet the common parent of the two forms must be sought, according to our present notions of phylogeny, before the separation of the two great groups of Quadrupeds.

Another instance of isomorphs occurs in the two parallel groups of the *Irideæ* and the *Liliaceæ*. Every one knows how closely similar in outward appearance are the purple crocus of the spring and the purple colchicum of the autumn; and yet the crocus is more nearly related to the yellow iris than to the colchicum; and the colchicum is more akin to the garlic or the Butchers' broom than to the crocus.

It seems as if when two lines of development started from a common point, they sometimes carried *in gremio* the necessity of development along the same lines, and the production of like form at corresponding points in the divergent courses.

THE INDIVIDUAL AND THE GENERATION.—But it is time to return from the long digression into which we have been led by the unicellular plants. If we consider ourselves or any other higher organism, whether animal or vegetable, and ask what is the individual and what is the generation, we feel at first quite able to reply. We know that the answers to these questions, when we seek to pursue the enquiry to the bottom, involve other profound questions, perhaps, insoluble difficulties, but on the surface the answers are easy.

If now we turn to the myxies and ask what is the individual, the answer seems attended with no small difficulty. In the swarm spore stage each separate protoplast is the individual; each is capable of separate motion, of digestion, and of multiplication. If we turn to the plasmodium stage, the individual appears to be the entire plasmodium, built up as it has been by the union of a great number of protoplasts, and not always the descendants of the same parents; if we take the sporangium stage, and consider especially those cases in which each sporangium stands on its own hypothallus, separated from the hypothallus of its neighbours, the sporangium seems to represent the individual. The life-circle of the myxie thus exhibits a curious alternation of individualism and collectivism—an harmonious solution of the problem raised by the claims of the two principles which are found in conflict in other organisms and states of society.

Death and Reproduction.—We know that of late years, many interesting theories and questions have been propounded in relation to the great fact of Death, and that the entrance of Death into the great chain of organic life has been watched and studied.

One view, to which Professor Weismann has given great prominence, is that unicellular organisms possess an unending duration, or, in other words, that though susceptible of death by external force—as, *e.g.*, by fire—there is no natural death, but on the contrary a potential immortality. He considers death, therefore, to have come in with the multicellular organisms, and to take place, as he says, " because a worn-out tissue cannot for ever renew itself, and because a capacity for increase by means of cell division is not everlasting but finite."

Another view put forward (not by Weismann but by Götte) holds that death is always connected with reproduction, and is a consequence of the latter in the lower animals.

Lastly may be noticed another view, also propounded by Götte, that the first form of death is to be found in the phenomenon known as encystment, which occurs when an organism which has been alive and exhibiting the phenomena of motion becomes stationary, develops a cyst or coat around it, and after a period of rest and suspended animation again revives when the favouring circumstances occur.

We thus state some of the views with regard to death because we think that it will be found that the life-history of the myxies throws some light upon them.

Let us, however, first make these remarks: that in the higher organisms we know of death in two forms, the death of a part cast-off, as when we shed a hair or lose a tooth, or as when a tree casts off its dead leaves; and, secondly, the death which affects the whole organism; and further that reproduction is in a great majority of the higher organisms accompanied by the casting off of some parts of the organism which have been devoted to the nutrition and protection of the young offspring. In plants we know how the floral envelopes drop off, and how the seed vessels are allowed to fall and decay when their duty is done; and corresponding phenomena exist in the animal world.

When the plasmodium of the myxie has differentiated itself into the hypothallus and the sporangia, and these have sent forth the spores, how are we to regard the events which have happened? Is the true view that a parent organism has died; that the empty sporangium and the stalk, and the capillitium and the hypothallus which are left behind to decay are the dead body of the parent, and that the spores represent the new generation?

If this be the true view, and there seems much probability in it, then we have clearly before us an unicellular organism of the simplest kind, which exhibits the phenomenon of death, and we cannot say with Weismann that it is with the multicellular organisms that death for the first time occurs.

On this assumption it further follows that we have in the myxies an instance of the close association of death with reproduction; and we are reminded of the analogous cases of the mayfly and the butterfly, which die after laying their eggs, and of the death of the male bee after pairing.

The other view of the facts to which we have referred is that the throwing off of the sporangium and the capillitium, and the shells of the spores, is not the death of the whole parent organism, but the partial death only which occurs when the parts which have become useless are cast off and allowed to die, and in this view there is in the cycle of the myxie's life neither death nor generation, but an everlasting life; the same protoplasm would be thought of as going on in an eternal round of life, subject only to accretions and to losses. True it would be that the shell of the spore, the coats and foot of the sporangium, and the capillitium which it contains, have been thrown aside and perish; but the residue of the protoplasm seems to pass from swarm spores into plasmodium, from plasmodium to swarm spores, and so on in a perpetual round. The swarm spores thus appear not as emanations from the parent but as the parent itself, and the new generation and the old are but one person (if personality may here be spoken of). If we think of death we search without success for the moment of its occurrence, and we look in vain for the dead body.

Whether of these two views be the more reasonable it may be hard to decide. However that may be, it is certain that there are unicellular bodies, such as the Diatoms, in respect of which Weismann has so forcibly shown that death cannot be thought of as a normal event. Thus out of the depths and first rudiments of organic life there crops up a suggestion of that immortality which is the hope and aspiration of its very highest members.

Then with regard to encystment. We have seen that this occurs in two forms in the life-history of the myxies. We have found that the single swarm spore may be encysted and is then known as a microcyst, and that from this condition it may be awakened and recalled to its activity as a swarm spore, and we have found also that, in the form of sclerotium, the whole plasmodium may become quite dry and hard as an aggregation of cysts, and thus be reduced to a condition of suspended vitality, but from this also it may be aroused to its former powers of movement and life as a plasmodium. In neither of these cases do we find encystment to be associated with death, nor with reproduction. "The essential characteristic of encystment," says Weismann, "is a simple process of rejuvenescence without multiplication."

The length of time during which animation can be suspended in the case of plasmodia is very remarkable. De Bary found a plasmodium of *Didymium serpula* to move after seven months' desiccation; and a case is cited by him of a plasmodium which after twenty-five years' residence in an herbarium began, after four or five days' immersion in water, to develop as a beautiful network.

Relations of the Group.—The proper position of the myxies in the world of organized beings is a subject on which there has been and still is a great difference of opinion. So profound is the difficulty of the question whether they are animals or vegetables that one of the most careful students of their nature has declared that its solution "depends rather on the general philosophic position of the observer than on facts."

Those authors who place the myxies in the animal kingdom have generally attached most importance to the swarm spore and plasmodium stages of their existence, and have insisted on their likeness to the protozoa; the advocates of their vegetable character have mainly dwelt on their method of reproduction—on their sporangia and their spores.

But even assuming them to be vegetables, there remains the question where they are to take their place in that realm of Nature. They were placed among the fungi by Fries, but with a lively consciousness of how entirely they differed from all the other members of the class. "Vegetatio maxime singularis et a reliquorum fungorum prorsus diversa," he says of this group. The fungi seem as a natural group to be well characterized by a prothallus constituted of hyphæ—generally multicellular—whereas the myxies are represented in that stage by the strange plasmodium of which we have said so much.

Attempts have been made to show that different sections of the myxies correspond with different sections of fungi: the common myxies being treated as of the Gasteromycetic type; the *Dictyostelium* as of the Mucorine type; and, according to some writers, the *Ceratomyxa mucida* as of the Hydnum type and the *Ceratomyxa porioides* of the Polyporus type; and from this supposed correspondence of type it has been suggested as probable that other types of fungi will be found to be represented amongst myxies, and that so we shall have two parallel series of fungi; the difference in each case being that the one is characterized by a mycelium of hyphæ, and the other by a plasmodium. This view appears to us to be fanciful, and to slur the really broad line of distinction between fungi and myxies. More rational would seem to be the view put forward by one of the latest writers on classification, who has formed of these little organisms one of the four primary divisions of the vegetable kingdom, and made for them a place of equal rank with the whole of the phanerogamous plants; so distinct a position scarcely seems excessive to mark the singularity of their structure and life-history. In fact, one of the many interesting points about this group of organisms is the extent to which they stand alone; the difficulty of finding any other creatures to which they stand in the relation either of descendants or ancestors. "The mycetozoa," says De Bary, "show only a slight agreement, either in the general course of their development, or in the characteristic features of its separate stages, with organisms which are of undoubted vegetable origin, whether they be fungi or plants other than fungi; the agreement, with the exception of the few cases in which cellulose makes its appearance, is common to phenomena which are common to all organised bodies."

We are much impressed with the notion that the position of the myxie will be found to vary according as the one or the other stage of their existence is held to have the highest classificatory value. We therefore propose to consider what relations they exhibit in these various stages of their life-history.

Their Relations in the Swarm Spore Stage.—Reproduction by *swarm spores* is by no means confined to the myxies. It plays a conspicuous part in the cycle of life in many of the Algæ and Fungi: or rather we should say conspicuous parts, for the functions of these simple pieces of motile protoplasm are most various. Sometimes the swarm spore is asexual and is of itself capable of reproducing a new organism—as in some of the Algæ and in the *Peronosporeæ*, for instance, amongst the Fungi. In some of the Algæ (*Florideæ* and *Phæosporeæ*) the swarm cells are sexual, and a conjugation between two of these moving bodies occurs before the production of a new organism. Sometimes the same organism (as in *Ulva*) produces two kinds of swarm cells—the megaspores with four cilia which germinate asexually, and the microspores with two cilia which germinate only upon conjugation. But more remarkable still is perhaps the case of the well known and beautiful Volvox—which appears to emit no less than four distinct kinds of swarm spores, (1) sterile swarm spores;

(2) asexual spores, or as they are called *parthenospores*; (3) male spores; and (4) female spores. So marvellously complicated are the modes in which Nature is capable of differentiating and using to attain the same end by different roads that which seems the simplest thing in life—a minute piece of naked protoplasm.

In the swarm-spore state the myxies may thus seem to claim relationship with the Algæ and Fungi, but it is doubtful whether much stress can be laid on this suggestion, for (1) the existence of these cells as reproductive spores is a wide-spread fact, and occurring in remote groups of organisms, has perhaps but little value in classification; and (2) the mode in which myxies reproduce through swarm spores is entirely different from that pursued by any Alga or Fungus. It is, as we have already shown, neither by parthenogenesis of the ordinary kind, nor by conjugation, but by the fusion of a great number of swarm spores, whether from the same or different sporangia, into a single mass of plasmodium.

But if we turn towards the animal kingdom, we shall find that its claim to include the myxies in the swarm spore stage is very strong.

A mass of naked protoplasm, furnished with a nucleus and vacuoles, capable of pushing forward pseudopodia, and moving by these means, capable of including and digesting food, and also of encystment—this is a description which will fit indifferently the swarm-spore of a myxie and the well-known Amæba, and we are thus brought to see that close relationship, to which we have already referred, between the swarm spores and the large group of protozoa which naturalists generally place in the animal kingdom, and all of which may be said to consist of undifferentiated and naked protoplasm.

Their Relations in the Plasmodium Stage.—The motor power of the plasmodium seems to recall animal life, but we recollect that there are kindred organisms, like the Diatoms, which are generally regarded as vegetable, and retain a power of movement through life.

As regards food, it is a familiar fact that, generally speaking, plants feed on inorganic and animals on organic substances. So far as observations have hitherto gone, the food of myxies consists of bacteria, or minute particles of wood or fungi (and, in the case of *Badhamia utricularis*, of living fungi). No evidence seems to exist to show that they have any power of deriving nutriment from inorganic substances. The mode in which the myxies eject the undigested matter recalls animal rather than vegetable life. In the methods of digestion, therefore, they seem to lean distinctly towards an animal character.

The movement of the granules of protoplasm in the plasmodium is a phenomenon at least analogous to that found in plants, and even in plants with highly developed cells, but it is not unknown amongst the lower forms which are considered to be animals, for it appears to have been observed in some protista, and especially in the tentacular-like pseudopodia.

In the plasmodium condition, the relationship of the myxies seems on the whole rather with animals than plants.

Their Relations in the Sporangium Stage.—On the other hand, when we reach the sporangium stage, the absence of motion, the erect form, the stalk, the foot, the spores, all recall some of the Fungi; the elaters remind us of the Jungermanniæ.

The methods of opening the sporangia, sometimes by an indefinite rupture, sometimes by a distinct operculum, recall the distinction between the methods of opening which prevail in the mosses. On the whole, the facies of the sporangium stage is vegetable.

One other observation which relates to all the stages of development must be made. The two most characteristic of vegetable compounds are probably cellulose and chlorophyll: though neither is found in all plants, nor is absent from some animals. Of chlorophyll we have no trace in the myxies, and of cellulose very little. Nowhere do we find it as the wall of a true and living cell as we do in the most characteristic form of vegetable growth.

Their Relations Reconsidered.—On the whole it seems impossible to assign these minute organisms with any certainty to the one realm or the other. If, with Hæckel, we were, for purposes of classification, to speak of a new kingdom—a buffer state between the animal and vegetable realms, the *Regnum protisticum*—we should no doubt place the myxies there. But, if we retain the two ancient kingdoms only, then it almost seems as if the myxies were a vagrant tribe that wander sometimes on the one side, and sometimes on the other side of the border line—like nomads wandering across the frontier of two settled and adjoining States, to neither of which they belong. They would seem to begin life as animals and end it as vegetables—a life-history not without some sad analogies in human experience.

The absence of a satisfactory position for the myxies in the great network of organized beings leads one to think of them as a group which probably from very remote antiquity has stood aside from the great currents of evolution, whether in the animal or the vegetable world.

Distribution.—The species at present known of myxies are not very numerous. Mr. Lister figures less than two hundred in his monograph; De Bary speaks of them as numbering nearly three hundred. No doubt many species remain to be discovered.

Of the distribution of the myxies in time, nothing is known. The protoplasm is too delicate to leave its memorial in the rocks, and its lime particles are so small and so indistinguishable that it is no wonder that they have never been traced.

In space, the group, and many individual members of it, are cosmopolitan. A large number of the species are, says Mr. Lister, "found with identically the same characters in Europe, India, the Cape of Good Hope, Australia, and North and South America." What is implied in the identity of a species in Australia and England? Does it mean that the species have passed the great intervening oceans? or does it mean that the species were defined before the separation of the continents, and have continued in both seats unchanged ever since?

Suggestions for Study.—In the hope that some of our readers may be induced by what we have written to take up the study of these little organisms, we will say a few words as to how to begin the study of them. They may be found often in great abundance, and more or less in all times of the year, except in extreme cold or prolonged drought, on moist dead wood and dead leaves (hazel, holly, and beech leaves are very good); a wood yard near a country house, rotting stumps of trees, the dead stalks of last year's nettles, the wooden pillars and parts of gates and rails, the straw heaps in a farmyard—all these are likely places for the chase. Sometimes, too, as we have said, they leave the dead substances, which are their chief habitat, and climb over growing plants, as nettles, periwinkles, or moss. The eye wants some training to see them quickly, and there is no doubt but that young eyes are better than old ones. We know a case in which a young lady detected a Trichia growing on the roadside from her pony's back.

If it be desired to keep specimens for use, they should be preserved in dry boxes (the common lucifer match boxes, lined with white paper, make very good receptacles), into which they can be securely fixed by glue or pins attached to the wood or leaves on which they rest. For more minute observations recourse must, of course, be had to the pocket lens and the microscope. There are few more beautiful objects than some of the sporangia under a low power, or than the capillitium and spores of some kinds under a higher power: the *Trichia* with lemon-coloured hairs and spores are especially lovely to look upon. The spores should be examined under water to prevent shrinkage, and a little spirit is often useful in the examination of the capillitium, as it helps to expel the air.

The beginner will very likely at first sight mistake some of the small fungi for myxies, but a very little experience will enable him to distinguish the sporangium walls, the hairs, and the spores of a myxie from anything which he will meet with in the structure of a fungus.

A visit to the botanical department of the British Museum at South Kensington, and an examination of the microscopic slides and drawings prepared by Mr. Arthur Lister and his daughter, Miss Gulielma Lister, and presented by them to the British Museum, will be of great utility to the student.

To Mr. and Miss Lister all students of myxies are under the deepest obligations, and we are especially so by reason of their constant help, and not least for their kindness in reading this essay in manuscript. Mr. Lister has published two books which are indispensable to the English student. The "Guide to the British Mycetozoa exhibited in the Department of Botany, British Museum," is a little pamphlet, price threepence, written by Mr. Lister for the Trustees of the British Museum, and published by them. It can be obtained at the South Kensington Museum; but booksellers are often stupid about getting it, as we believe that they get no profit on it, and therefore if ordered through a bookseller particular instructions should be given to get it from the South Kensington Museum. This little book is very admirable, and by itself will enable a student to identify most or all of his specimens. Mr. Lister's other book, "A Monograph of the Mycetozoa," which is not confined to British species, was also published by the Trustees of the British Museum, but is sold by Longmans and other booksellers. The price of this book, which is beautifully illustrated, is sixteen shillings. Mr. Massee has also published a "Monograph of the Myxogastres," 1892, illustrated with coloured plates. De Bary's "Comparative Morphology and Fungi, Mycetozoa, and Bacteria," of which an English translation has been published by the Clarendon Press, should be consulted by the student who desires further knowledge. The text-books on general botany and on general cryptogamic botany, such as Sach's Text Book, Kerner's "Natural History of Plants," Bennett and Murray's "Cryptogamic Botany," and Dr. Scott's "Structural Botany, Part II.," may all usefully be consulted.

For the student who desires to go further into the literature of the subject, the following bibliography may prove useful:—

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