

XXXIII. *Observations on the Gonidia and Confervoid Filaments of Mosses, and on the relation of their Gonidia to those of Lichens and of certain freshwater Algæ.* By J. BRAXTON HICKS, *M.D. Lond., F.R.S. and L.S.*

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FOR a considerable time it has been known that the Thallophytes throw off certain single cells, called *gonidia*, which are capable of reproducing the species from which they spring. It has also been known that, to a limited extent, they possess the power of segmenting before they produce a new thallus. The observations of a few Continental naturalists* pointed out that they could not be distinguished optically from the then-called *Protococcus*-forms (*Chlorococcus*).

These observations, however, had attracted but little general attention to the matter. Indeed their tendency was such that, fully carried out, they necessitated a reconsideration of all the Palmellaceæ or pseudo-unicellular Algæ (Braun) and of the true unicellular Algæ (Braun). The contemplation of such a revision might well be considered sufficient to alarm even the most persevering systematist; for it involves the very arduous task of watching the growths classed under these heads throughout a long period, and under every possible change of external conditions, with this additional difficulty, that, in case the observations produced no decisive result, they could not be admitted as absolute evidence that these forms were really unalterable, because the conditions to which they were thus exposed, perhaps, might not include all the combinations of influences to which they were liable in their natural state. Besides this, there is the fact already pointed out in the course of my observations on the gonidia of Lichens†, which increases the difficulty of proving the separate existence of these and allied growths, namely, their continuing in the same form of existence for an indefinite period, segmenting continually, till external conditions are favourable for inducing a change in the mode of growth, in which, again, they may continue for an equally indefinite period, and so on in every phase through which they are capable of passing. I believe the task just indicated has not yet been continuously undertaken; and at present any attempt at fixing the true position of these organisms would be completely vain and disappointing till more extensive researches in all directions shall furnish sufficient materials on which to argue.

The observations on the development of the gonidia of the Lichens, which I have brought forward in the 'Journal of Microscopical Science,' 1860 (July and October) and 1861 (January), also on the growth and diamorphosis of *Lyngbya muralis*, and on the statospores‡ of *Volvox* in 1861, show that from these plants large quantities and

* *E.g.* Meyen, Itzigsohn, Kützing.

† Quart. Journ. Mic. Sc. 1860-61.

‡ See the remarks on this point by Pringsheim, in relation to this subject, on the "chronisporos" of *Hydrodictyon*. Translated in Quart. Journ. Mic. Sc. April 1862.

masses of green cells are produced having all the characters of the Palmellaceæ (*Chlorococcus*, *Hæmatococcus*, *Gælocapsa*, *Sorospora*, *Palmoglæa*, &c.), and [in the case of *Collema*] of *Nostoc*, and probably the Nostochaceæ, perfectly undistinguishable from the so-called true forms; and therefore it would be impossible to assert that any given mass of these growths was not the segmenting gonidia of these Thallophytes.

Hence, in the papers just mentioned, I have dwelt strongly upon the uncertainty attending the ranking of these as independent organisms, and the great necessity there is for re-examining carefully the entire subject afresh and with the advantage of the clue furnished by the observations above alluded to.

It is with the view of assisting in the solution of this difficult inquiry that I have brought forward the following observations—not with the presumption of being able by them to clear up the question finally, but to add information to that already acquired, upon which to make inferences regarding the separate entity of these forms—and also of introducing some other facts interesting to the vegetable physiologist.

The term *gonidium* has been applied to the single cell thrown off by the thallus-producing plants, and is probably the simplest homologue of the gemma of the higher Cryptogamia. The gemmæ of the higher kinds, consisting of several cells, are capable of growing out at once into the peculiar species from which they spring, by a process purely vegetative and agamic*. The gonidia of the Thallophytes have also the same power under certain circumstances (*e.g.* the sori of Lichens); and, besides this, they have been known to have the power of simple subdivision prior to their forming the perfect plant. That they have a far more varied and extensive property of multiplication than was originally supposed, I have shown in the papers quoted. That the production of *gonidia* is not confined to the Thallophytes, but may be abundantly traced in the Mosses, will be one of the endeavours of this communication to point out.

But, whereas in the Thallophytes they can be produced upon almost any part of the plant, except upon that especially set apart for gamic reproduction (if such be the true nature of the apothecia and spermatogones of Lichens, or of the receptacle of the Hymenomycetes, &c.), we shall find, on the other hand, that in Mosses a particular portion is set apart for their production,—though it must not be understood that the other portions of the plant cannot produce them; for, as I shall be able to point out hereafter, under peculiar circumstances almost every part is so capable.

These observations were made upon a variety of our own common native Mosses, *Bryum*, *Neckera*, *Polytrichum*, *Hypnum*, *Tortula*, &c. They all showed, equally well, under the same circumstances, the phenomena to be mentioned, as far as I was able to judge.

If we examine any Moss, more particularly in the early spring, about its base, just at the junction of the true roots with the ascending axis, we shall almost invariably find, where the axes of different plants do not grow together too closely, green filaments, of indefinite length, springing out and branching, the branches frequently interlacing

* The exact value of the distinction between the simple gonidium, tubercle, gemmule, propagule, does not appear clearly marked: transitions continually occur between each and all of them. The first certainly tends more particularly to multiplication by the production of separate cells; the latter kinds to the extension of filaments leading more directly to the formation of the leafy axis.

with those of neighbouring plants. These have been known as the “confervoid filaments,” or “confervoid radicles” (Pl. LVII. fig. 1).

Formerly they were not recognized as belonging to the Mosses, and were at one time very decidedly claimed by algologists*, under the name of “*Protonema*.” We owe to Kützing the discovery that *Protonema* is not an Alga, but the product of Mosses†, although, before him, it was not unknown that Mosses did produce confervoid filaments from their spore‡. Subsequently Schimper, in his excellent work on the Mosses§, confirmed the correctness of this observation of Kützing, and more fully traced the development and growth of the confervoid filaments from the spore, and the “propagule,” and the origin of the leafy axis from them. As far as my observations have proceeded in this direction, they coincide with those of Schimper, and therefore I must refer those interested in the subject to his work.

Now Kützing, in his ‘*Phycologia Generalis*,’ retains the group *Protonemeæ*, and of them he says, “They are Confervæ nearly allied to *Cladophora*. They are particularly distinguished by growing out of water, by pushing their roots into the earth, as the Mosses do, and by never developing their fruit between the branches of the thread, but either on the end of the same or on one side.” He gives two genera, *Protonema* and *Gongrosira*. Their characters he describes as follows:—

1. *Protonema*.

Trichomata radicantia, parenchymatica, ramosa, cœlogonimica. Gonidia in lineas longitudinales disposita; spermatia pedunculata, lateralialia.

2. *Gongrosira*.

Trichomata radicantia, parenchymatica, ramosa, apice demum torulosa. Articuli ultimi demum in spermatia terminalialia transeuntes.

That *Gongrosira* is also derived from the same origin seems clear to me; certainly *G. clavata* (Kützing), called by Dillwyn *Conferva multicapsularis*, and recognized as such by Kützing himself, is of moss-origin. So also is *G. sclerococcus* (‘*Phycologia Generalis*,’ tab. xvii. fig. 8), so far as can be judged from the figure given.

Besides these *Protonemeæ*, there is another allied family given by Kützing—*Chantresieæ*. In this is included the genus *Chroolepus*, the characters of which are thus given:—

“Trichomata cartilaginea, colorata, polygonimica, ramosa. Spermatia nunc lateralialia, nunc terminalialia.”

That some of the forms figured under this name belong to the confervoid filaments of a Moss I think highly probable.

The plate of *Chroolepus* (tab. vii. fig. 2) certainly resembles a condition which the moss-growth assumes.

* See Eng. Bot. “*Protonema*,” and Dillwyn’s Synopsis of British Confervæ.

† Kützing, *Phycologia Generalis*; and Linnæa, Band viii. (1833).

‡ Hedwig, *Fundamenta Muscorum*, vol. ii. pp. 50, 51. Drummond, *Trans. Linnean Soc.* vol. xiii. p. 1. Fr. L. Nees d’Esenbeck, *Nov. Act. Acad. C. L.-C.* vol. xiii. Cassebeer, *Entwicklung der Laubmoose*. Meyen, *Pflanzenphysiologie*, t. iii. p. 403. Gottsche on *Haplomitrium Hookeri*, *Nov. Act. Acad. Cæs. L.-C. N. C.* vol. xx. p. 1.

§ *Recherches sur les Mousses*, 1848.

The observations of Dr. Caspary*, which show that *Chroolepus* produces zoospores, are not inimical to this view, as will be pointed out in the course of the following remarks. In addition I may also add that I have often observed the peculiar form of the end-cells giving off these zoospores, as figured by him in the older confervoid filaments of Mosses.

The gonidia mentioned by Kützing (in the characters of *Protonema*) as being thrown off from the filament were first noticed by him†, who also showed that they sprouted out again into a filament, but that whilst free they were globular and then looked like *Protococcus*-cells.

Beyond this point in their history, and the knowledge of their "peculiar fruit" (*tubercles*, Schimper) and the propagules of Schimper, I am not aware that any one has preceded me in the observations about to follow. Before proceeding further, it will be useful to describe more particularly the "confervoid filaments."

They consist of a single series of cells, of a length varying according to outward conditions, each cell possessing the property of forming branches like themselves. They are, in the first instance, produced by the germination of a spore, as has been pointed out by the observers above quoted; and although, as Schimper‡ has beautifully shown, the ascending axis arises from them, yet the axis and the leaves in their turn give rise to the filaments, as Kützing§ and Schimper also have pointed out, and which can be readily verified.

When the filament springs from either axis or leaf, or from a single unsegmented gonidium, the first change in the cell (for in either case only one cell is involved) is a bulging out of a portion of its wall, which, after growing a certain length, is shut off from the original cell by a septum at the point of origin || (Pl. LVII. fig. 2). After this cell has grown a certain length, a binary subdivision of its contents takes place, upon the plan common to that form of parietal cell-formation ¶.

* Quart. Journ. Mic. Sc. vol. viii. p. 159.

† Linnæa, Band viii. p. 360.

‡ *Op. cit. suprâ.*

§ Phycologia Generalis, *Protonema*.

|| This corresponds with Nägeli's description of cell-formation in the Confervæ (Ray Soc. 1845, p. 260):—"The cell-formation occurs in a similar manner when a cell grows out sideways from the stem to produce a branch. The septum is then produced between the newly outgrown and the original portions of the cell. The cell-contents also remain unaltered here while the septum is becoming apparent." Again (Ray Soc. 1849, p. 141), "A cell grows out into a branch, and divides by parietal cell-formation into two cells, in such a way that one corresponds to the original cavity of the cell, the other to the expanded part. Here are to be enumerated the formation of branches in Algæ, Fungi, Floridæ, &c. It probably exists in all plants, but may be recognized best in organs composed of rows of cells."

¶ "The mode in which the process of division of cells takes place has been represented in different ways. While Unger explains the division of the cell-contents by the production of a dissepiment (partition), Nägeli, comprehending more correctly the relations of dependence between the formation of membrane and the contents, states, *vice versâ*, that the formation of the septum proceeds from the contents, previously divided into two halves; and Hoffmeister, in addition, directs attention here more particularly to the primordial utricle, bounding and cutting off the two parts from each other, even before the origin of the cellulose dissepiment. According to this representation, the septum is formed by the two individualized portions of contents into which the mother cell divides, and which secrete cellulose upon their whole surface after they become separately constituted, touching by their flat adjacent surfaces, whence, of course, the cellulose layers formed on the surfaces in contact become united and thus form what appears a single septum, which, however, from the nature of its origin, is composed of two plates. Referring to the *ab origine* existing contact of the daughter cells with the whole internal surface of the wall of the mother cell in the formation of

By the continuation of this process, chiefly in the terminal cell, and by the growth of the already formed cells, and by the formation of branches from branches continuously, the length of the filaments, and the area they occupy, are extended indefinitely (Pl. LVII. figs. 3, 4, 5). The branches are often commenced at an early period of the existence of the cell from whence they arise (Pl. LVII. fig. 2).

The contents of the cells vary much in appearance, according to their age. At first, in the growing end and in the half-formed cell of the branches, there is a tendency to general homogeneousness, although scarcely ever complete. In either case, very shortly after the cell is formed, the contents consist of a transparent, colourless layer (primordial utricle) lining the cell-wall, together with granules of uniform green colour (chlorophyll-granules), in greater or less quantity. In the actively growing cell, the centre contains a transparent fluid (sap-fluid); but in those which have solid, unyielding cell-walls, the endoplast fills up the interior, and the granules crowd each other, sometimes very closely.

A *nucleus* can frequently be observed in the mature cell, though not always. In the contents of the bulging commencement of a branch, no nucleus is to be observed; nor does the nucleus of the old cell undergo any change in consequence. The nucleus of the new cell must therefore be formed subsequently to the cell, which is certainly not produced by it. This, with many other facts, and with some which will hereafter be given, seem to point out that the nucleus does not necessarily play so important a part in cell-formation as some have supposed. I notice this only incidentally, as the discussion fully carried out would be foreign to the purpose of this communication. As I have remarked above, the length of each cell of the filament varies extremely, according to the external conditions. Under much moisture and heat, it is very much increased, so that it may be twenty or thirty times longer than wide; and sometimes the more terminal cells are elongated into delicate hairs, bearing a striking resemblance to the so-called cilia of the *Draparnaldiæ* (Pl. LVII. fig. 6) (which in some other respects they much imitate), their green protoplasmic contents being drawn out somewhat in the manner observable in that genus.

The general tendency of the growth of these filaments is towards an arborescent form when growing free and not crowded; and for a certain time they continue unaltered from the simple plan just described: sometimes they are scarcely branched at all (Pl. LVII. fig. 7); sometimes the secondary branches are arranged on the plan of a cyme (Pl. LVII. fig. 5).

In these forms the confervoid radicles continue to grow for an indefinite time, external circumstances remaining the same; and in course of time very large surfaces can be covered by them, unless usurped by other plants. They are perfectly capable of independent existence, whether they have arisen from a spore, leaf, stem, or root, when separated from their source; and hence the erroneous impression of their Algal origin. This is the less to be wondered at, if we notice the growth of one when placed in water. Under these circumstances the activity of its development and linear growth is wonder-

cells by division of the whole contents, Nägeli calls the formation of cells by division 'parietal cell-formation.'"
—*Braun's 'Rejuvenescence in Nature,' Ray Soc. 1853, p. 234.*

fully increased, if not exposed to too much light; so that in a week it can multiply itself 200 or 300 times, while the original type has been nearly preserved, the slight alteration being in the elongations of the cells, and a decrease of their breadth.

Now, although, for the most part, these *confervoid filaments* generally preserve their peculiar appearance, and are in this manner very readily distinguished from the *true root-filaments*, whose endoplast is colourless and the cell-walls more or less stained with a brown colour, yet there is a great tendency for each, even after full formation, to pass into the other. This can be frequently seen in their natural state, and can be shown by experiment (Pl. LVII. fig. 8). The greater tendency, however, is for the radicles to pass into the confervoid filament than the contrary. The colourless endoplast of the true radicles becomes green and granular; and ultimately they exhibit all the characters of true confervoid filaments. On the other hand, I placed in the sun a glass full of the filaments which had grown, and were then growing, in water. After a week the cell-walls of the older portions had become stained brown, and they had assumed the appearance of those radicles whose contents had assumed the green colour.

Some of the filaments which I had grown in water branched in a manner very similar to *Draparnaldia tenuis* (*Stygeoclonium tenue*, Kützinger); indeed, had it not been for its known origin, I should have instantly regarded it as such. I have shown one less marked at Pl. LVII. fig. 9 (the only one of which I preserved a drawing). In a glass of water, where I had placed Moss, on one occasion I found a very fine specimen of *D. tenuis*. This is a very unusual place to find this plant; and though I could not absolutely trace it to a Moss, yet, coupled with the fact that similar growths can be so originated, and also that the radicles produce elongated cilia-like cells, it seems to be a point worthy of further research, whether or not that genus, or at any rate the above species, may or may not have its origin from Moss in some one of its phases. Nor should this, in our present state of knowledge, be considered a wild speculation; for we know nothing of the agamic growth of *Draparnaldia*: we have nothing to militate against its being one mode of vegetative growth of a form considered altogether distinct; and this is not more extravagant than the known fact that these confervoid filaments can produce and spring from Mosses. I again remark, we know so little of the whole possible life-history of these simpler plants, that our want of knowledge of a precedent cannot be quoted against it.

Frequently in the larger filaments, and towards the extremity of those whose growth is not very active, may be seen here and there a considerable separation between the two adjacent cells. If this be carefully examined, it will be noticed that this space is filled by a transparent, colourless cell, which at first sight might be considered to have no contents; but upon careful examination, and the use of reagents, it will be found that there is colourless homogeneous endoplast, so closely applied to the inner side of the cell-wall as otherwise to escape detection (Pl. LVII. fig. 10). When the cells of this filament separate from one another, these transparent cells also become detached, and assume the shape of flattened spheres, or they may become quite globular. Whether they possess any further history I am unable to tell. It seems rather to be some abnormal condition of cell-formation at the line of the separation of the two portions—a portion detaching itself at the time of division, and forming around it a layer of

cellulose. It bears a considerable resemblance to the heterocysts of *Nostoc* (Collema-gonidium) and the so-called Nostochaceæ, considered by Braun * as the first appearance of vegetative permanent cells,—although he considers these to be formed by a cell dividing into two unequal halves, one of which remains permanent, and the other continues to segment.

It has already been remarked that these filaments will soon cover a large space of the ground in their neighbourhood with their branches, if they are permitted to grow unrestrained; but after a time, particularly in damp, shady situations, the numerous branches begin to crowd upon each other so as to form a compact mass of filaments (Pl. LVIII. fig. 16); sometimes these intimately interlace, but more often they run upwards, parallel to one another (Pl. LVIII. fig. 16, Pl. LVII. fig. 7). Very commonly these branches are of nearly equal length, so that the surface on which they grow appears clothed with velvet. Sometimes, when they press closely upon one another laterally, they become hexagonal, and the cells of the lower portion, deprived of their due quantity of light, become nearly, and occasionally entirely, colourless.

The foregoing description applies to confervoid filaments grown under circumstances favouring active vegetation, namely, under warmth and moisture, such as in the shade of walls, banks, and sides of ditches. The same can also be very readily produced artificially, by keeping them under a glass shade in a warm room, without direct sunlight.

But drought and cold produce very marked changes in their outward form and appearances, which I shall endeavour to describe.

Under drought, more particularly during summer, the growth of the cells is much checked, and at the same time the cell-wall becomes much thicker. The cell-contents still growing, the chlorophyll-utricles crowd the interior, and press upon each other (Pl. LVII. fig. 11). Sometimes the cell-wall is itself dyed with chlorophyll, and somewhat undefined from the contents, like the segmenting gonidia of *Collema*—a condition not very uncommon in the segmenting cell generally. This tendency to the blending of the contents with the cell-wall I have endeavoured to show at Pl. LVII. fig. 11 *b*. It is very curious to observe the effects produced by alternations of weather upon these filaments, illustrations of which may be procured artificially. Some of the cells are long, with few granules; some are short, and the contents closely packed. Some have begun to branch, and become suddenly arrested in the process, the bulging part becoming covered with a dense cell-wall, precluding further growth in that direction. Some of these branches, encouraged by warmth and moisture, have rapidly grown out into narrow elongated cells, so as to look something like roots (Pl. LVII. fig. 11 *b*). As any part of the cell is capable of bulging, and as any one of the cells can do so independently of the other, and as the rate of growth of one cell is not limited by that of its neighbours, it can easily be imagined how variable and tortuous may be the forms which these confervoid filaments assume under the varying influences of our climate. Perhaps it may be best observed in those filaments which inhabit the bark of trees or dry walls, where the effect of the alternations of the seasons is more marked.

A very common effect which drought produces or increases is the development of a

* Rejuvenescence in Nature, Ray Soc. 1853, p. 146.

red or reddish-brown colour in the cellulose of the cell-wall. It occurs most frequently in those found on bark of trees and walls, and is more noticeable in summer and autumn, although it is to be met with at all seasons in the older cells (Pl. LVII. figs. 7, 11). When a new growth springs up, the young cell-walls possess no colour, showing that it is the production of age. On one occasion, I saw this colour produced in all the cells of a large quantity of confervoid filaments which had grown in water in the shade. I had placed the glass out of doors in the sun, and was surprised to find that all the older cell-walls had become dyed of a reddish-brown hue, although previously colourless: the contents within remained green. There is another change I have observed, apparently connected with drought, and probably also with a diminution of vital activity, namely, the contents become brown or reddish brown. Pl. LVII. fig. 12*b* shows the filament green, while at *a* it is changed to brown. That they were from the same source was readily proved, by finding the green and brown cells on one filament in varying degrees of change. These brown cells separated very readily from one another, as is the case in all the older cells of the filaments. The filament possessed somewhat the appearance of the filamentous diatoms (*Melosira*, e. g.); and this was more striking upon the separation of the cells; for both the ends of each were marked with radiating lines, which, seen in profile, proved to be ridges (Pl. LVII. fig. 12*c*). At the same time the cell-wall was very rigid, thin, transparent, and comparatively indestructible. It seems to me that this condition is to be considered as a “*resting*” form, equivalent to that state well known in the Algæ. Their subsequent history I was not able to trace.

Having thus endeavoured to point out the more actively growing condition of the confervoid filaments, I shall attempt to show the various means by which they assist in the reproduction of the parent Moss*.

The first I shall mention is one variety of those modes in which in all cases the ascending axis is formed out of the cell of the filament. It is also one of the most direct methods by which the filament attains that end. For other modes I must refer the reader to Schimper's work above quoted.

From any cell of the filament, except from those which are concerned in the processes to be related hereafter, a branch is produced, the end cell of which divides into two cells in the ordinary way above described, the terminal one increasing considerably in size. From this, many (three or four) branches spring, in the mode of branching before mentioned, in a row or verticel; the cells of these branches are delicate and tapering, and have the property of curving in towards the centre. There is also a similar row of smaller branches springing from the same cell within the former row, surrounding as it were an imaginary axis. From this springs, by gradual increment in the number of the cells, the stem of the Moss. The first attempt at differentiation on the part of the confervoid filament is thus shown to be in the cell producing the rows of curving-in

* In the following remarks I have assumed that all these various phenomena tend, sooner or later, to the formation of confervoid filaments, and through them to the other parts of the Moss. I have not possession of definite proof of this; but, from our knowledge of kindred conditions, we may, I think, fairly assume such to be the direction of their growth.

branches. This I have drawn on Pl. LVII. fig. 12. The precise point from which the roots (true) are given off I have not observed. In Pl. LVII. fig. 13, the filament from which this ascending axis sprang is tinged with brown. This is not a necessary point; I have seen it arise from cells of the most distinctly marked Confervoid type. This mode of development is frequently to be met with, and seems to hold an analogous position to the buds on the creeping stems of Phanerogamous plants.

The next plan to be described, by which these filaments assist in reproduction, is that which has been described by Kützing as the "*peculiar fruit*" of the Protonemeæ. They are, however, by no means confined to the filaments, but can be found on any part of the plant except the spore-frond (sporangium and peduncle). They are found at the end of a branch of a filament whose cells, instead of elongating, become broader, the whole assuming the form of a club, containing 5 to 8 cells. The cell-walls become thickened, and the green granular contents closely approximated. After some time the cell-walls assume a reddish-brown colour, which becomes darker by age. Segmentation sometimes takes place in a direction parallel with the axis of the filament, or even irregularly (Pl. LVII. fig. 4 *a*). When the cell-wall has assumed a full brown colour, the green colour of the contents becomes fainter, and at last they are frequently transformed into oil-granules, after the manner of the formation of the oily contents of the hypnospores of *Volvox* and other Algæ. When these gemmæ have become quite brown, they easily separate from the filament and become free. They occur at all times of the year, but are most observable during drought. When they are excited to grow, they begin to shoot out into a confervoid filament, generally from the extremities, although sometimes each cell may push out a branch laterally. At Pl. LVII. figs. 4 *a*, 5, 15 *a*, Pl. LVIII. fig. 23 *b*, are shown these "gemmæ." No doubt these are "*resting gemmæ*," one of the means by which the life of the plant is preserved during severe trials of drought and cold*.

They have been called gemmæ, and considered the homologues of the gemmæ (bulbils, &c.) of the higher plants; but although they are subservient to the reproduction of the parent, yet the ascending axis does not immediately spring out of them, but, as has been already remarked, they sprout out into confervoid filaments first, from any one of the component cells, which then pass on to the formation of the ascending axis, as above noticed. They differ, therefore, from the bulbils in not possessing a true "*stirps*" within themselves. It seems that we should rather consider each as a resting *compound gonidium*,—the reason for which will be more apparent as we proceed to the consideration of the single-celled gonidium itself.

But this is not the only method by which the confervoid filaments are reproduced: any one of the cells, detached from the other, is capable of continuing the growth of the filament, in the same manner as each is capable of doing it whilst forming part of the filament, by branching and division, as I have before noticed. And there is a great tendency for these cells to separate from each other, more particularly in the older filaments (see Pl. LVII. figs. 4 *b*, 10, 11, 12, 14, 15); but whether old or young, they may bulge out

* Some of these points have been already shown by Schimper, but they are here repeated in order that a clearer idea may be formed of the single gonidium.

on any side and form a branch, which, segmenting, becomes a true filament (Pl. LVII. fig. 4 *c*). Not unfrequently these cells retain their linear form, especially after the cell-wall has become dense by age, though sometimes whilst the linear growth is very active. In the latter case, the contents of these actively growing cells occasionally become more or less homogeneous, with a distinct central nucleus (Pl. LVII. fig. 15 *c*), and much resemble a single cell of *Palmoglæa*. As a rule, when the separated cell retains its linear form, and is in active growth, it does not in general branch laterally for some time, but continues in the linear direction by binary division for a considerable period. But frequently, under certain conditions, the *terminal cells*, instead of possessing an elongated form, *become more or less globular*, which shape is not confined to the last one, although it may be more marked in it, but is frequently seen in the four or five (or even more) nearest the end of the branch (Pl. LVII. figs. 10 *b*, 13, 15). Of these the terminal one possesses the greatest tendency to become free, although all of them do so very readily. These free cells, then, appear quite globular, with green contents, which are sometimes granular, though more frequently more or less homogeneous, with or without a central nucleus, as is observed in the gonidium of the Lichens (Pl. LVII. fig. 10 *c*). Where there is this tendency to the globular form of the cells near the extremity of the filaments, there is also a disposition in the cell-contents to become more deeply green. This is partly owing to the deeper tint the contents assume, and partly to the closer crowding of the chlorophyll-granules of which they are composed.

These terminal globular cells have, under certain conditions, a tendency to become quiescent; the cell-wall then becomes thicker, and, as in the cells mentioned before, it frequently assumes a reddish-brown colour, whereby the whole becomes very dark—indeed, so as to become almost a black ball (Pl. LVII. fig. 15 *b*, Pl. LVIII. fig. 16). These cells also segment in a less regular manner than do those of the same filament below it; there is an imperfect tendency to branch. The cells thus formed at the side tend to the globular form (Pl. LVIII. fig. 16 *b, c*). The cells, thus altered in appearance, generally detach themselves in groups of two or three cells to each, and can be carried about by the elements. They, however, occasionally do not become globular, but more or less oval, springing from the end of one cell in groups of three or four, as shown at Pl. LVII. fig. 15 *b*, each cell of which, becoming free, appears like the cell of a *Palmoglæa*, especially as in some the contents become homogeneous, with a central nucleus. As this mode is observable on the branch of the same filament which possesses the other forms at the same time, this peculiar appearance is thus traced to its true origin, which would otherwise scarcely be guessed at. The cells are more active than the globular forms; and some, as soon as they separate, begin to segment linearly, and to form a filament. These conditions were looked upon as Confervæ by the older algologists, under the name of *C. multicapsularis* (Pl. LVIII. fig. 16; see Dillwyn's 'Confervæ') and *C. umbrosa* (Pl. LVII. fig. 15 *b*). I have already pointed out Kützing's arrangement of these and other forms.

These free dark cells with crowded contents, when influenced by warmth and moisture, form branches in the manner already described, thus giving rise to new filaments. They, however, may become mother-cells, as will appear below. In Pl. LVIII. fig. 16 *a*

will be seen a number of filaments crowding each other and running parallel, the terminal cells of which, having assumed the dark colour and globular form, produce a dark velvety covering to the surface upon which they grow—and thus presenting an appearance easily mistaken for *Confervæ*.

I have hitherto in this communication shown the multiplication of the cells upon the linear-binary form of growth; we now, however, come to another stage, where the segmentation proceeds upon the quaternary or its multiples; and this leads us into still more interesting ground.

The first time I observed this was in some filaments which I placed in water; and these, after growing some time, produced cells at various points, chiefly at their ends, which had not only segmented once upon the quaternary plan, but their subdivisions had also repeated the process. This I have shown on Pl. LVIII. fig. 17. In some the process had extended still further, and in some less regularly, so as to produce irregular masses of green cells, in varying degrees of the same form of segmentation (Pl. LVIII. fig. 17 *b*). However, in some the contents had divided into six or more portions round a common centre (Pl. LVIII. fig. 17 *c*), and the parent-cell wall, bursting, set free a group of cells ready again to divide.

Guided by these facts, I pursued my investigations in the same direction, and found that the globular cells, which I have already described, separating from the ends of the filaments, frequently underwent quaternary subdivision, and that in them the process went forward to the infinite multiplication of these green cells, the result of which repeated and rapid segmentation was to produce cells of exceeding minuteness. This, as I have formerly shown in a similar condition in the gonidia of Lichens, is dependent on the preponderance which the process of subdivision holds over individual cell-growth. When the former process is in abeyance, then the latter regains the ascendancy; and these little divisions, so small as scarcely to show any distinction between cell-wall and contents, gradually increase in size so as at last to equal the original parent cell*.

At first the contents of the cells were somewhat granular, but after a generation or two they became homogeneous and, in every respect, could not be distinguished from the subdivisions of the Lichen-gonidium.

And in another respect they much resembled these latter, namely, in the great tendency for the process to keep on unvaryingly in the form in which it had begun. This can readily be observed by any one who will take the trouble. Large areas may thus be covered by the growth of these cells, which may continue for a long period of time, certainly over a year, and probably, as far as I can make out, for many years.

It may always be noticed on the face of any wall where Mosses grow, that underneath

* In both the Lichen- and Moss-gonidium, this property of repeated and incessant subdivision is commenced so early in the cell, that one subdivision is hardly fairly perceptible before the next can be recognized; indeed, in some of the cells, three and four generations are included in one parent. Upon this point Braun says, in 'Rejuvenescence in Nature' (Ray Soc. 1853, p. 239):—"There are cells which never become old, but in their earliest stage, by dividing, give up their existence again, or rather continue it in a new generation, till age finally is attained in a last generation, which never undergoes division."

each patch, a large stream of these *Chlorococcus*-like bodies may be seen, running downwards. I have not separately drawn these cells, because they are so like those on Pl. LVIII. fig. 18 *c*, to which I refer the reader.

Sometimes on trees I have observed that, instead of producing the globular free cells just described, as occurs in most situations, the whole cells of the filament, which is generally tapering towards the extremity, undergo this quaternary form of segmentation *in situ*. It will be first noticed that the cell-walls become thicker, the contents less granular, while the whole filament increases in diameter, and that then the contents are segmenting (Pl. LVIII. fig. 18 *a*). After a time the parent-cell walls dissolve away, and the subdivisions become free (Pl. LVIII. fig. 18 *b*). From this point the description applied to those cells which were free before division corresponds so exactly as not to need repetition (Pl. LVIII. fig. 18 *c*). By this means, as by the other, large portions of bark of trees are covered with the *Chlorococcus*-like bodies, which multiply also indefinitely.

But in some filaments there is a still more unsuspected change, namely, in the production of cells of *Glæocapsa*. The segmentation proceeds within the filament, as in the instance just quoted; but the divisions become invested in a gelatinous envelope, while the parent-cell wall breaks up. These *Glæocapsa*-like bodies then become free, and continue the segmenting process as in *Glæocapsa*. This I have shown on Pl. LVIII. fig. 19 *a*. It is a condition by no means rare in the winter months: considerable masses of these bodies are to be found so produced.

I have frequently seen *Glæocapsa polydermatica* (Kützing), &c., formed, as well as other so-called species. After frequent segmentation, the cells are imbedded in an indefinite mass of gelatinous substance.

But there is a variety of this "*Glæocapsa*-formation" frequently met with (Pl. LVIII. fig. 20 *d d*).

The cells of a filament in one or in every part at once begin the process of quaternary segmentation, as before noticed, at first regularly, but shortly after irregularly; besides this, a certain amount of free-cell formation goes on within the divisions (mother cells); so that it is difficult to say which kind of cell-formation predominates (Pl. LVIII. fig. 20 *a a*). In this manner large irregular masses of segmentary cells are produced, like some of those resulting from segmentation of the so-called *Palmellaceæ* (Pl. LVIII. fig. 20 *b b*). The cells set free from them are either *Chlorococcus*-like cells of variable size (Pl. LVIII. fig. 20 *c c*), or they are like *Glæocapsa*, undergoing segmentation in their variable manner (Pl. LVIII. fig. 20 *d d*).

These changes can be readily observed in the colder months. They frequently, by distortions in all directions, produce a mass whose origin might be very doubtful to determine, were it not generally possible to find some small part retaining the original filamentous condition (Pl. LVIII. fig. 20 *a a*).

Up to this point of the observations I have made, with the exception of that just noticed, the efforts made by the confervoid filaments towards multiplication have been carried out upon the plan of the "parietal cell-formation" of Nägeli, and that principally upon the quaternary mode.

The next series of remarks will show the results of "*free-cell formation*" (Nägeli), or "*free cytogenesis*" (Pringsheim), as it occurs in these filaments.

As far as my observations extend, there are *two varieties* of this mode of cell-formation in this portion of the Mosses.

1. The *first* is by the gathering together of the whole contents into one or more oval masses, which become covered by a cell-wall thrown around each portion; and by the segmentation of these while still within the parent cell (Pl. LVIII. fig. 21 *a, b, c*). In both instances these masses are released by the destruction of the parent-cell wall. That they again divide when set free, probably many times, is all that I have been as yet able to discover, beyond the amœboid change to be alluded to below. This I have observed best in those cells which have lived in water—a position probably favouring this mode. That these portions of contents can segment, and continue to do so, seems to me to militate entirely against the opinion that the whole process is not a healthy one.

There is another point in connexion with these new cells, namely, that their contents become of a red or reddish-brown colour, in manner similar to the change so frequently observed among Algæ that I need not particularize it here.

But the most remarkable feature in their history is that upon which I have already dwelt in a paper on vegetable amœboid bodies (Mic. Journ., April 1862), and therefore need not do more than call attention to the point, namely, that these cells gradually lose their colour, with the exception of a few reddish granules. When this change is complete, they *possess the power of moving about* as do *Amœbæ* (Pl. LVIII. fig. 22 *a, b*). After they have continued to do so a certain time, they reassume the ovoid form, and are clothed with very delicate cilia, in a constant state of vibration (Pl. LVIII. fig. 22 *c*). For further remarks on this curious change, and its connexion with similar occurrences in the Algæ, I must refer to the paper above quoted.

2. The *second* mode of free-cell formation is as follows:—

The cells in the stem and leaves of the Mosses contain, as is well known, a varying number of granules of a homogeneous green colour, which are called by Nägeli and others "*chlorophyll-utricles*." They are generally connected with each other by means of delicate colourless threads of endoplast. These utricles or granules are also found in the confervoid filaments, in variable quantity, sometimes, as in rapid growth, widely separated, sometimes, as in slow growth, closely pressed together.

In either case these chlorophyll-masses have the power of throwing around themselves a cell-wall, of growing, of forming in their centre a nucleus, and of segmenting, and also of *forming an independent cell* capable of undergoing further changes presently to be pointed out.

Now Nägeli has already pointed out that they possess an outer membrane, and has shown that they multiply by subdivision*. The fact, however, of their having a new membrane has been denied by Caspary†, Mohl and Gris, and by the author of the article on Chlorophyll, in the 'Micrographic Dictionary,' who, on the other hand, admits of the

* Ray Society, 1849, pp. 176–178.

† Die Hydrillæ, Pringsheim's Jahrb. d. Wiss. Botanik, i. p. 399.

possibility of their segmenting. It is hoped that the following observations may tend to throw some light upon the question, and to reconcile the conflicting evidence of these great observers, upon which I shall more particularly dwell in reviewing the points of interest in this paper.

During the years 1859-60 I grew Moss under glass. The various branches threw out numberless confervoid filaments, some of which approached the radicular rather than the confervoid type. However, it was in both that I observed that each of the bodies which corresponded to the "chlorophyll-utricles" of other parts possessed the power of enlarging. This is drawn in Pl. LVIII. fig. 23 *a*. In Pl. LVIII. fig. 23 *b* are shown two portions of filaments, with the chlorophyll-granules just beginning to show consistence on their exterior. This was best noticed in those which were escaping from a broken cell. At *c* is shown a number of these cells in various degrees of growth; and it was easy, by comparing the contents of the various cells, to see that the smaller possessed the same origin as the larger.

As they increased, they showed a more distinct outline; and it was clear that, whatever doubts might attach itself to the existence of a membrane on the exterior of the chlorophyll-utricles of the leaves and ordinary confervoid filaments, these contents were enclosed by a delicate envelope: and as they further enlarged, a nucleus appeared in the centre. After a time, the parent cell broke up, and these once chlorophyll-utricles, but now distinct cells, became free.

In the undisturbed condition in which they existed, and being held together by the gum-like character of the residue of the parent-cell wall, they of course did not spread far; and as the filaments had attached themselves to the sides of the glass, I had an excellent opportunity of watching their subsequent progress.

After increasing gradually in an oval form, they arrived to about the $\frac{1}{1700}$ inch in size, when they began to segment into two, or three, or four divisions, or even into more (Pl. LVIII. fig. 22 *d*), a nucleus appearing in each division.

When the resulting cells were two or three, they were almost always oval, the line of separation taking place obliquely in the oval parent cell (Pl. LVIII. fig. 23 *d*). When, however, the secondary cells were more than that, then they formed around a common axis. At this period the cell-wall of the parent cell (once chlorophyll-utricle) was very marked.

After they had remained some months in a state of nearly complete quiescence, I placed some of these segmenting cells into water on a slide, and, covering them with ordinary thin glass, I put them in the sun for about an hour. To my great surprise, *I found the whole water alive with zoospores*. There were thousands in the square inch, in a most active state. Further examination showed that the segments had been released by the bursting of the parent-cell wall, and had now become these zoospores. After a time they came to rest, and altogether lost their activity. I preserved the slide for some time, but I could not determine anything very definite as to their after-life, beyond that they came to rest, lost their cilia, and again subdivided.

These zoospores were of light-green colour; they differed slightly in size, and were principally oval; some, however (and these were the larger), were round. They possessed

two cilia, and their contents were granular (Pl. LVIII. fig. 23 *e*). The smaller measured about $\frac{1}{1800}$ by $\frac{1}{3500}$ th of an inch.

Thus far I have dealt with the confervoid filaments and their gonidia. I shall now point out two other methods by which independent cells are set free from Mosses, possessing the power of segmentation, and doubtless of reproducing the parent Moss, although I have not been able to trace them back again to the parent.

It has been mentioned above, that in the thallogenous plants the power of producing gonidia is diffused through almost any part of the thallus, but that in the Mosses it is more localized. Yet it is not entirely confined to the confervoid filaments.

I have frequently noticed that *Glæocapsa*-like cells are produced from the contents of the cells of the older leaves, which, situated at the base of the stem, towards autumn and during winter and spring have become brown. These leaves are not wholly dead. It is their cell-walls only which, having become brown, give them the appearance of dead tissue; but the contents as yet retain their vitality and green colour within. Their condition is precisely similar to that of the cells of the filaments described above, whose walls have become dyed of a brown colour. After a time the old cell-wall dissolves away, and then it becomes evident that the contents have assumed the form of, or rather have become a *Glæocapsa*, which certainly undergoes segmentation freely. I have shown a portion of some of these leaves in this state in Pl. LVIII. fig. 24; a portion of the margin has lost its dark cell-wall, and has already produced *Glæocapsa* (Pl. LVIII. fig. 24 *a*). I have seen considerable masses of *Glæocapsa* produced in this manner.

Another very curious mode of forming free cells, capable of segmentation, is the following.

The axis springs up in the usual way, and proceeds to form leaves. The cells, however, which should in the ordinary way unite to form their lamina, in this case do not cohere, but either *run parallel to or branch away* somewhat from each other (Pl. LVIII. fig. 19). The terminal cell of each of these pseudo-leaves possesses the power of separating from the others (as the terminal cell of the filaments did, see Pl. LVII. fig. 10). In the instance from which I give this description, it might be noticed that the freed cell was more or less of a pointed oval form, one side being, however, much straighter than the other (Pl. LVIII. fig. 19 *c*), and having somewhat the appearance of the frustule of *Isthmia nervosa*. Each of these cells might be noticed to have already begun to divide by binary division before their separation.

Large numbers of these cells were shed, and disseminated readily. Many for the time remained in contact with the structure from which they sprang, and gave the whole the appearance of little yellow dots on the ground whence they arose. I cannot tell to what Moss it belonged, but there were numerous examples of it. From the same stem confervoid filaments arose, and some (*a*) were giving rise to *Glæocapsa*, as before mentioned.

In Pl. LVIII. fig. 25, I have shown a condition of the axis of one of the *Jungermannia* from Jamaica, precisely like that of the Moss shown at Pl. LVIII. fig. 19. I observed it in plenty in a hot-house, where the plant grew in abundance. The whole had very much the appearance of an Alga, and was a very beautiful object, from the transparency

of the cells. Every terminal cell seemed ready to separate, or had already done so. Each was divided by a septum into two portions; after separation, the cells began to increase, and the contents became darker, more homogeneous, and ultimately they possessed the appearance of a *Chlorococcus*, and underwent subdivision.

Retrospect.—In reviewing the points of interest contained in the foregoing communication, I shall take them in the order in which they have been presented. And the first which seems to stand most prominent is,

1. The peculiar tendency of the confervoid filaments to grow for any indefinite period and extent in the same form and state, both in and out of water; so that it is not to be wondered at that they should have been considered independent vegetations. This opinion appears still more excusable when it is considered that they can reproduce themselves by any one of their cells, which sometimes, becoming free and globular, presents the appearance of a spore. How much more would it have been justified had the knowledge of their segmentation, &c., been then possessed? It gives another instance of the importance of the study of the entire life-history of all forms. We are much indebted to Kützinger (whose studies have had generally an opposite tendency) for first pointing out the true nature and origin of these so-called Algæ.

At the same time, may I not ask, does it not make us question the origin of many of the Confervoids, the tracing of whose whole history we have never achieved, of whose sexual life we have no knowledge? Of how many do we know only the vegetative growth, with its formation of active (zoospores) gonidia and passive gonidia! Let us not conclude these to be finally placed, but let us follow them through by every possible way, in order to detect all their phases of existence.

The remark of Braun applies to this subject, as well as to those which follow:—"The greatest care is requisite in their determination as independent organisms; nor should this be decided unless every stage of their evolution, from beginning to end, is known"*. I can only add, *When* are we to know when we have found both or either?

2. The second thought which seems worthy of detention arises from the circumstance that, out of these confervoid filaments, two or three genera with numerous species of Algæ have been founded. *Protonema*, *Gongrosira*, and certainly some forms of *Chroolepus* are not Algæ, but the varying forms of these Moss-productions. We might well feel our faith in specific and even generic distinctions in general staggered by these and similar facts, but more particularly in respect to the Confervoideæ. We are bound to suspend our implicit trust in the certainty of their position, at least as to many whose history is as yet undetermined. It might be brought forward as an apology, that these forms were really distinct, each kind belonging to separate Mosses. In answer, I might say that a few observations would readily show that this excuse could not be sustained; for I have reason to believe that nearly all the varieties can be produced from each one of the Mosses, if placed under varying conditions.

The different forms of the confervoid filament, as I have already shown, depend on external circumstances, rather than on the species to which they belong, although it is possible that some exceptions may be found to this rule. The value of the distinctive

* Braun, on Unicellular Algæ, Mic. Journ., vol. v. p. 91.

marks between many Confervoids is very questionable, and they have doubtless led to much misconception and incorrect assumption. These plants being formed of very simple parts, their characteristics are necessarily ambiguous, and hence the difficulty of fixing their true position; and this is especially the case in those kinds which are composed of a single cell, whether belonging to those which have been designated by Braun as "true unicellular Algæ," or "pseudo-unicellular," or to those which are multicellular, but which spring at some portion of their history from a single vegetative cell (spore, gonidium, &c.).

3. The third subject to be dwelt upon has already received some attention at the commencement of this paper,—namely, that the function and development of the cells separated from the filaments are evidently analogous to those of the gonidia of Lichens and also of many Algæ, and therefore the term gonidia* may be rightly applied to them. It is the office of the filaments to produce these gonidia; or perhaps it should rather be considered that each filament, in its most marked condition, is a series of gonidia developed in a linear form, each division of which is capable of becoming a gonidium: and this mode of viewing these filaments points out the analogous condition observable in the moniliform filament of gonidia in *Collema*, each cell of which, although generally segmenting linearly on the binary plan, can at any time assume the other actively segmenting states, as has been pointed out by me in the papers above alluded to.

The position in which these filaments stand towards the rest of the plant is peculiar. Looking at them as a basis upon which the axis producing the organs of the true fructification is supported, they have at first been considered as the homologue of the prothallium of Ferns; but they really represent only a portion of that organ. They correspond, indeed, only to the few confervoid cells first generated from the spore; while the heart-shaped Marchantia-expansion of the prothallium of the Fern is to be considered as corresponding to the stem, leaves, antheridia, and archegonia in the Mosses. They differ also in the respect of producing gonidia, at least so far as is known at present, although it is quite possible (judging from analogy) to suppose that gonidia may be found to be produced from this position of the prothallium of Ferns, under certain conditions. Compared with Fungi, they seem to hold an analogous condition to the mycelium, more particularly apparent in the simpler forms of the *Hyphomycetes*; for it is questionable whether the so-called fruit of these Fungi is not rather analogous to the gonidium than to the growth which results from impregnation. It is at present uncertain whether any antheroids exist in the Fungi, and, if they do, whether the spores take any part in true fecundation.

It is very necessary to bear in mind that the confervoid filaments play a very important part, if not the most important, in the disseminating of Mosses—much more so than has been generally supposed. Considered quite independently of their powers of producing gonidia, they tend to spread the order in every direction, and cover very much larger surfaces than the species from whence they are derived could do by gametic reproduction, whereby, simultaneously as it were, large spaces, even many feet in length, are

* The distinction between "gonidium" and "spore," as marked out by Braun in 'Rejuvenescence in Nature,' is borne out here and in the Lichens much better than in the Algæ.

covered with Moss of equal-sized growth. It is also to be remembered that, amongst the Cryptogamia, it is in the Mosses that they assume the most important position. They are known at present in only three divisions, viz. in Ferns, Liverworts, and Mosses. In the two former they are confined to a very small number of short-lived cells.

But it is when they are considered in combination with their gonidia and their indefinite powers of subdivision (only comparable to the Lichens in this respect) that we can appreciate the influence they possess in multiplying the Mosses, accounting, doubtless, for their well-known abundance and wide diffusion; and this brings me to another consideration in relation to the reproduction of Mosses by their means.

I have shown above, that the cells thrown off from the filaments, as also those that remain attached, multiply by subdivision on the binary or quaternary plan principally (parietal cell-formation), and also that both within these cells when separated, as well as in those still attached, cells were formed (free-cell formation) which again continued to subdivide. By these processes and their continuation innumerable myriads of cells are produced, which possess all the appearances assumed by the results of the same efforts in the Lichen-gonidium. At first, I remarked, the contents of the cells were granular, but soon became homogeneous and without perceptible nucleus. Thus forms of segmenting cells hitherto classed as *Chlorococcus* (*Protococcus*) and *Glæocapsa* (*Hæmatococcus*) are produced undistinguishable from those so-called Algæ; so that, considering the exceeding diffusibility of the Mosses and Lichens alone, it seems to me to be almost impracticable to declare that any of these forms, as well as those I have mentioned in my paper on the gonidia of Lichens (above quoted), have an independent existence as Algæ.

On the contrary, it seems to me impossible to discriminate between the cells of the segmenting gonidia of Algæ*, of Lichens, and of Mosses; and hence I believe we shall be obliged to conclude that all the cells classed as Palmellaceæ—*Chlorococcus*, *Glæocapsa*, *Sorospora*, and some others†, with their so-called species—are but varieties of one mode of simple vegetative cell-growth, common to most of the Cryptogamia. What is the value of the differences between each kind it seems difficult to decide, but it may possibly be less than hitherto supposed.

Without digressing far into a subject not here intended to be discussed, I shall content myself with pointing out the effect such an opinion produces in unsettling our belief in the reality of the separate existence and position of the Protophytes generally, more particularly those classed by Braun as pseudo-unicellular Algæ‡. Whether it affects Braun's true unicellular Algæ requires further investigation; but it is worthy of notice that it is in the former that the forms above named are arranged.

4. The chlorophyll-utricles next arrest our attention. I have already quoted Nägeli's remark upon their segmentation, in which opinion Henfrey, in Linn. Trans. vol. xxi. pt. 2. p. 121, coincides. But in regard to their cell-wall, difference of opinion exists. The observations I have here recorded, it appears to me, tend to explain the two opinions, and especially confirm the opinion expressed by the writer of the article on Chlorophyll,

* See Pringsheim, Mic. Journ. 1862, April, p. 105.

† Probably also *Tetraspora* and *Hormospora*.

‡ Mic. Journ. 1857, p. 13.

in the 'Micrographic Dictionary,' namely, that chlorophyll-granules are probably small portions of contents coloured by chlorophyll. If we consider them to be such, and that they are capable of losing colour, or of changing it to brown or red, &c., then it is easy to conceive, and what indeed we should expect, that each granule could proceed to form a cell within the parent cell in accordance with what we know of free-cell formation; and thus the various opinions expressed upon this point are capable of being reconciled. Whether this condition extend to the chlorophyll-granules of *Nitella*, *Chara*, &c., I am not in possession of any facts to show.

5. But perhaps the most interesting fact I have met with in the course of my observations on the filaments is that of the *formation of zoospores* from these enlarged and segmenting chlorophyll-utricles. I am not aware of their having been noticed in the Cryptogamia above the Algæ, though they have been seen in the Fungi.

The evidence upon which it is based seems to me at least as conclusive as it is possible to obtain under the circumstances, unless the zoospores were seen to emerge directly from within the cell of the filament. It is possible that future observation may be able to confirm my observation in this direction; but without that, it seems that we may fairly conclude that zoospores can spring from these cells; and this is perhaps not quite so surprising a fact as it would at first sight appear, when we reflect that the formation of zoospores is purely a vegetative process and, for anything we know, may be more extensive throughout the vegetable kingdom.

I have already remarked*, with respect to the diamorphosis of *Lyngbya*, that the distinction between *Ulva* and *Prasiola* was now confined to the supposed fact that the former produced zoospores, while the latter did not. This, I objected, could not be held a sufficiently distinctive sign, on account of the truly vegetative origin of the zoospores, which are merely a variety of gonidial formation.

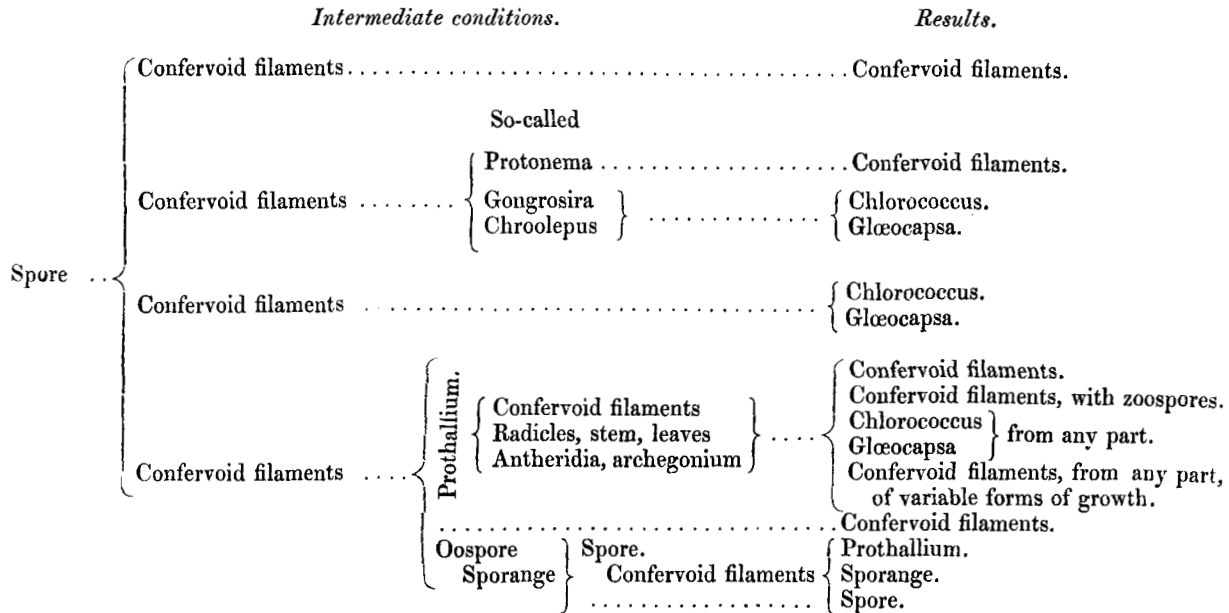
Zoospores seem capable of arising at various epochs in the life of a plant, and of various sizes. An interesting account, as they occur in *Hydrodictyon*, is given by Pringsheim in Mic. Journ., April 1862.

It is a very interesting feature, however, to find, that the confervoid filaments of Mosses, which in so many ways present the confervoid type, should also in this show one of the most marked and frequent phenomena of the Algæ.

6. The last point to which I shall allude is the near connexion with the Algæ which the Mosses hold in their capability of producing gonidia from any portion of their stem or leaves. The facts I have brought forward here show a very curious link existing between the Thallogens and the higher Cryptogamia, and prove that the formation of gonidia by no means ends with the Algæ.

* Mic. Journ. *suprà cit.*

PHASES IN THE LIFE OF A MOSS.



EXPLANATION OF THE PLATES.

PLATE LVII.

- Fig. 1. *a.* Moss-plant, with confervoid filaments.
b. Confervoid filaments, one assuming the radicular type.
- Fig. 2. Growing extremity of confervoid filament, showing the different stages towards the formation of branches.
- Fig. 3. Branching filament in active growth.
- Fig. 4. Branching filament (enlarged) growing under stimulus of heat and moisture, producing—
a. The “peculiar fruit” (compound gonidium) or gemma.
b, b, b. Terminal cells of a linear form, given off plentifully; some of the cells tapering almost to cilia.
c. A detached cell, giving off a branch.
- Fig. 5. Branching filament, with gemmæ, showing another variety of growth.
- Fig. 6. Tapering end of filaments, the result of very rapid growth.
- Fig. 7. Branching filaments of nearly equal length, giving a velvety appearance to the surface on which they grow. The commencement of the red tinge visible in the cell-walls.
- Fig. 8. Condition intermediate between confervoid filaments and radicles.
- Fig. 9. Peculiar mode of growth of filament in water, approaching *Draparnaldia tenuis* (*Stigeoclonium tenue*, Kützing).

- Fig. 10. Occasional state of a growing filament.
- a.* With a small colourless cyst or cell between two ordinary cells.
 - b.* End of a filament of beaded appearance, shedding the terminal globular cells, *c.*
- Fig. 11. Various appearances of portions of filaments: *a*, showing the reddish-brown colour of old cell-wall; *b*, ditto, growing; *c*, growing with rapidity; *d d*, portion of broken-up filaments.
- Fig. 12. *a.* Filament with cell-contents changed to brown.
- b.* Single cell of same.
 - c.* Single cell of same, showing indication of binary division: each end has ridges.
 - d.* The ends of cells, in profile and in full.
 - e.* Filament of same before change, tapering at the end.
- Fig. 13. Mode by which the ascending axis is formed from confervoid filaments.
- Fig. 14. Three branches of filaments, which have been crowded with others, so as to cause absence of colour in the lower cells. The terminal cells are separating to form gonidia.
- Fig. 15. Ends of filaments.
- a.* Producing "gemmae" (compound gonidia).
 - b.* Producing single-celled gonidia. One branch is producing four cells at its extremity.
 - c.* Cells becoming separate, of linear form, with nucleus.

PLATE LVIII.

- Fig. 16. Portion of a mass of filaments growing like velvet, consisting of multitudes of filaments crowding closely each other, forming a variety of resting gonidium.
- a.* Section of the mass.
 - b.* Single filament.
 - c.* Detached cells, with dark contents and reddish cell-wall.
- Fig. 17. Filaments showing the cells of filaments segmenting *in situ*.
- a.* On the quaternary plan.
 - b.* Ditto, and on its multiples.
 - c.* Round a common centre.
 - d.* Contents of some of the cells changed to reddish brown.
- Fig. 18. Segmentation, *in situ*, of the contents of cells of a filament.
- a.* Commencement of subdivision;
 - b.* Shedding cells of various sizes.
 - c.* Free cells (gonidia) segmenting, without much decrease in size.
 - d.* Ditto, ditto, after lapse of time, diminishing in size as segmentation proceeds.
- Fig. 19. Ascending axis, giving off gonidia in two ways:—
- a.* As *Glæocapsa* from a short confervoid filament;
 - b.* As segmenting cells from the ends of the pseudo-leaves.
 - c.* A detached cell (enlarged), with granular contents. Short diameter about $\frac{1}{800}$ inch.
- Fig. 20. Confervoid filament changed into irregular segmenting masses, partly by parietal, partly by free cell-formation.
- a a.* First stage.
 - b b.* Masses of segmenting cells separated.
 - c c, d d.* Results of breaking-up of the former.
 - c c.* Into Chlorococcus-like cells.
 - d d.* Into Glæocapsa-like cells.

Fig. 21. Free-cell formation in confervoid filaments.

Fig. 22. Amœboid changes occasionally found in some of the same.

Fig. 23. *a.* Chlorophyll-utricles growing, and forming nuclei.

b. Incipient stage.

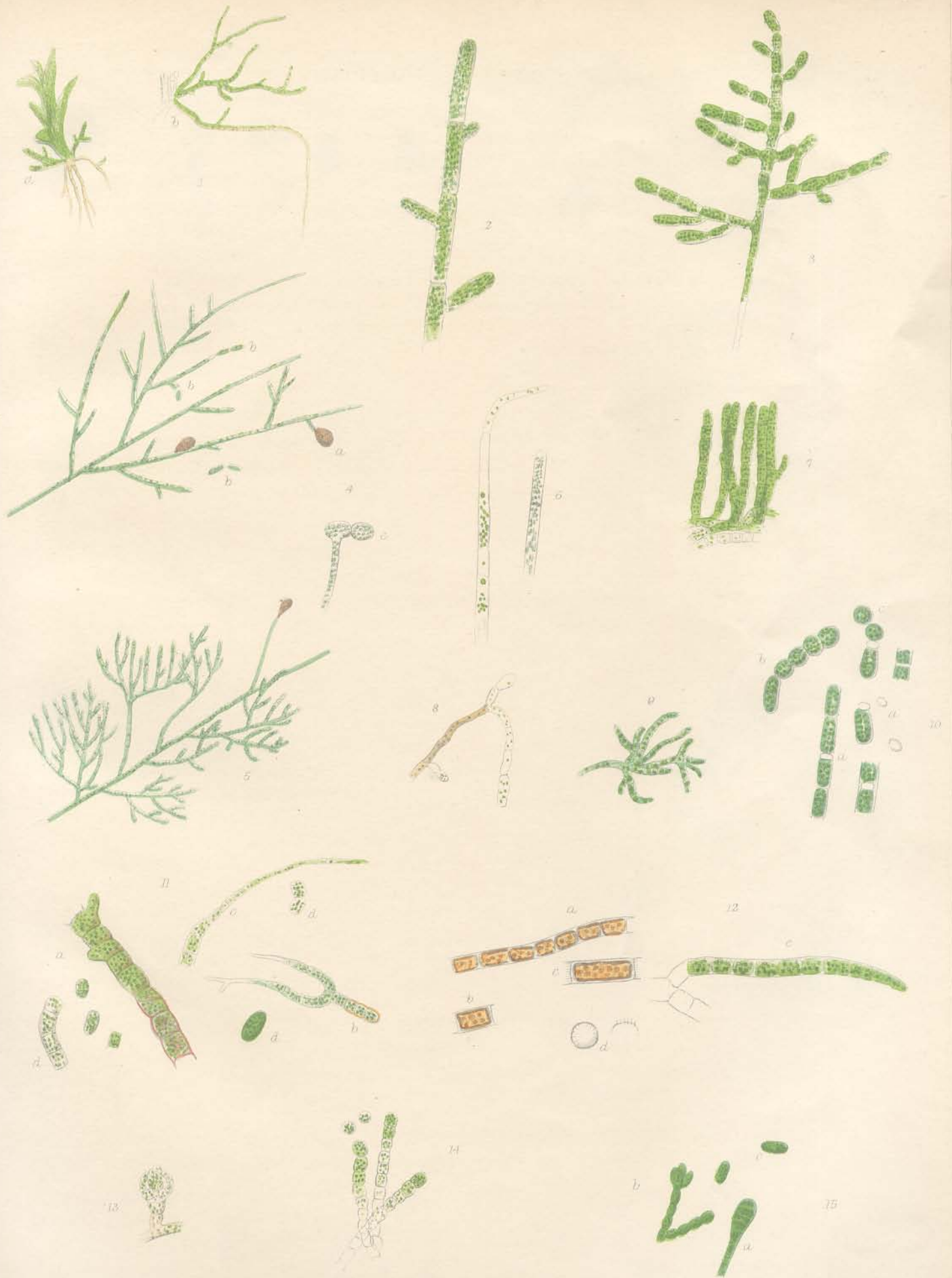
c. Same as *a*, dispersed from parent cell.

d. Same, having segmented.

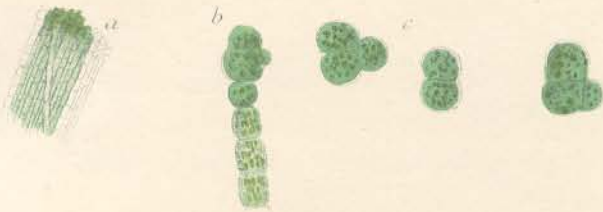
e. Zoospores produced from the segments.

Fig. 24. Portion of edge of old leaf, contents of cells changing into *Glæocapsa* (*a*).

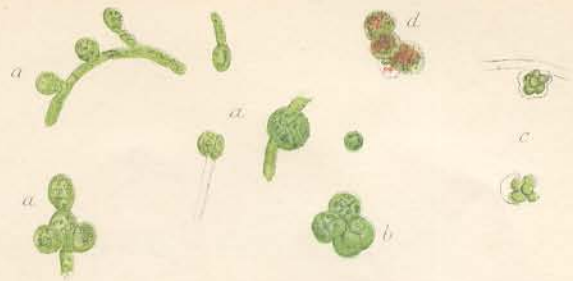
Fig. 25. Portion of stem and leaves of a *Jungermannia*, in a similar state to that of the Moss, fig. 19, the terminal cells of which are separating and becoming free, and segmenting (gonidia).



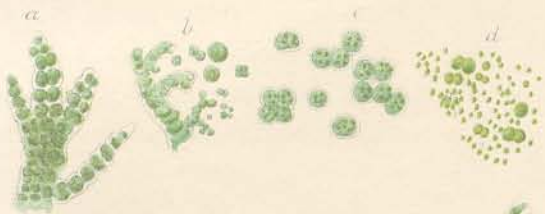
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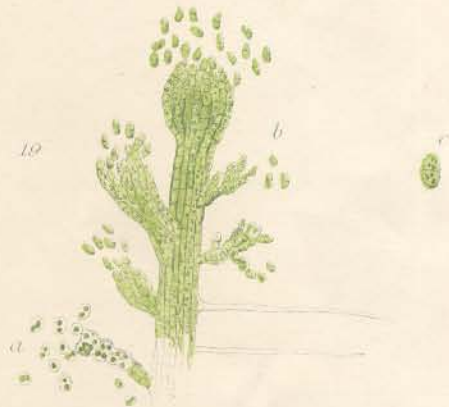
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