XIX.—*On the Formation of the so-called "Siphons," and on the Development of the Tetraspores in Polysiphonia.* By EDWARD PERCEVAL WRIGHT, M.A., M.D., F.L.S., F.R.C.S.I.; Professor of Botany in the University of Dublin. [With Plate XIV.]

[Read April 8, 1878.]

THE result of my observations on the development and growth of the so-called endochrome bags in *Griffithsia setacea* made me curious to know by what means such a wonderful series of such closely-related structures as occur characteristically in the so-called siphons of Polysiphonia could arise. It appeared to me that there was more than at first sight might appear in a statement of Professor Agardh, that the ultimate ramuli in the various species of this genus were, at first, monosiphonous. How, then, did the polysiphonous condition arise?

The fronds are described by Harvey in *Polysiphonia urceolata* (Lightf. mscr.) as "filamentous . . . . articulations marked with two broad tubes, siphons four, surrounding a minute cavity." In *P. fibrata* (Dillw.) "the articulations are marked with two wide, coloured tubes, separated by narrow pellucid spaces, siphons four, containing coloured bags, and surrounding a minute central cavity." The descriptions of these species are purposely selected as being those not only of common British species, but of species which I have the more particularly examined, and as having a minimum number of siphons: these were the much more easily observed. Among the species with a more numerous array of siphons, *P. nigra* (Hudson) = *P. atro-rubescens* (Dillw.) is also common, and has been the species chiefly examined by me for the development of the tetraspores. In this species "the articulations are variable, the lower twice or thrice as long as broad, the upper

gradually shorter, marked with several spirally curved tubes; siphons about twelve," while in *P. fastigiata* (Roth) "the articulations are shorter than their diameter, with hyaline dissepiments, many striate and marked with a dark central spot, being a bag of coloured endochrome which fills the central tube or cavity of the frond; radiating cells from sixteen to eighteen."

Some years after the publication of the "Phycologia Britannica,"* Professor Harvey published the "Nereis Boreali Americana." In Part 2 of which important work, while describing the structures to be met with in this genus, he writes: "The species simplest in structure have the internodes or articulations of the stem and branches composed of four large cells containing endochrome or colouring matter, placed crosswise round a small central cavity"; these are called the four primary cells, and then the smaller cells formed external to these are called secondary cells.

In that most painstaking work, so perfectly indispensable to every working algologist, the "Species Genera et Ordines Floridearum"† of Professor J. G. Agardh, the structures to be met with in Polysiphonia are described with a great deal of care and correctness, and with an appreciation of modern research which will often enable the attentive reader to see where fresh research is still necessary.

In Agardh's detailed diagnosis of the genus we read:‡ "In omnibus frons revera est articulata"; but in some the fronds are covered over by the cortical layer of cells, which does not here concern us; and as to the siphons "Cellulæ nempe 4 aut plures circa centralem, ipsis diametro nunc latiorem nunc augustiorem, longitudine iisdem æqualem, in orbem dispositæ articulos singulos in omnibus speciebus constituunt." I cannot feel sure that this implies that the four or more cellules are grouped around a central cellule of the same nature in each articulation. If this is implied, then this "central

* The *Phycologia Britannica* bears the date on its title-pages of 1846–51. Part 2 of the *Nereis Boreali Americana* was accepted for publication in July, 1852, by the Smithsonian Institution, and the last page bears the date March, 1853.

† Work quoted. Vol. 2, Part 2, p. 902, *et seq.*

‡ The object of this memoir being to record facts as I have seen them, rather than to criticise the records of others, my sole object in quoting from Professors Harvey's and Agardh's works is to indicate how far my facts may serve as a supplement to theirs.

cellule" seems overlooked in the next paragraph: "Cellulæ istæ pericentrales, quas siphones vocant, sunt endochromate colorante repletæ, parietibus hyalinis crassis polystromaticis invicem et a cellulis articulorum proximorum separatæ. Parietes, quibus articuli proximi separantur, genicula vocant—sunt in omnibus, quarum siphones nudi, quasi linea hyalina articulos separantes." But it is specially referred to in another paragraph where it (the "central cavity" of Harvey) is called a tube. "Tubus centralis, cujus articuli eandem cum siphonibus pericentralibus longitudinem servant, his immediatim in plurimis speciebus cingitur," and "Ubi rami frondis exeunt, exit quoque a tubo centrali ramus, inter pericentrales caulis excurrens, et ramo tubum centralem tribuens." The origin of additional siphons is thus described: "Ubi siphones nudi manent, frons hoc modo externe articulata cernitur: in multis autem inter siphones et in angulo exteriore oriuntur quasi spatia intercellularia, endochromate sensim repleta, cellulas novas (h.e. seriem siphonum exteriorem) constituentia. . . . Siphones rami cum siphonibus caulis alternant . . . Articulus ramorum supremus sæpe indivisus cernitur et monosiphonius, unico nucleo instructus: transversali divisione hujus inferiores articuli sensim formari videntur. In articulo penultimo aut antepenultimo nuclei plerumque subdividuntur et siphones oriuntur."

The points I wish to call special attention to are as follows:—

1. The articulation of the frond—is it a res vera?
2. The central cavity or tubus centralis. What is it?
3. The siphons, and their evolution in connexion with that of the central cavity.
4. The growth of the cell wall of the frond; and
5. The evolution of the tetraspores.

The first four subjects are so intimately connected one with the other, that it is difficult to decide which to commence with. It need hardly be said that from the point of view of their investigation there could be no graduated sequence. All the points in relation to each seemed to proceed on the same road and together.

The species of this genus examined, and the details of the structure of which are here described and figured, were *Polysiphonia urceolata*, *P. fibrata*, and *P. atro-rubescens*—the two latter chiefly for the development of their tetra-

sporic capsules. The method of investigation was practically the same as that referred to in the previous memoir on *Griffithsia setacea*. For the most part, fresh gatherings of fronds were made each week, and these were kept in closed bottles and examined night by night. All those portions revealing any (to me) new point of structure were at once mounted, and while in a perfectly fresh condition sent to my friend, Tuffen West, F.L.S., to be drawn. The beauty of his drawings will speak for itself; to their accuracy I bear a willing record.

The Frond and its Articulations.

The frond is a filamentous one: according to Agardh it is made up of "a series of cells, the opposing walls of which form a series of joints (genicula), and inside of which, in many species, there will be found, arranged in a crucial manner around a central tube, four cellules or siphons; in the ultimate cell but a single siphon is to be found, by the transverse division of which the lower cells are formed, and out of which, in the penultimate and antepenultimate cells, the four siphons can be seen to take their origin. When the frond branches, the siphons in the branches alternate with those on the main stem."

The frond may fairly be called a filamentous one; and were it not that it would give a new meaning to an old term, I would call it also a monosiphonous one, for to me it appears that the whole frond is, in its early condition, formed of a single external cell wall, the continuity of which might well be compared to a single pipe (sipho). When this frond branches, as in *P. urceolata* it does over and over again, these branches are also continuations outwards of this common cell wall, as also occurs in Griffithsia. In process of time, as the internal cells (siphons of authors) become matured organs, then it is true that partly by the thickening of the inner wall of the common investing cell wall, by the addition to it of secondary deposits, and partly by the thickening of the two opposing surfaces of the walls of the internal cells, there come to be established *quasi* joint-like structures, more especially in the very oldest portions of the frond, which may be for convenience sake described as "genicula" or "joints," and the portions between any two of which may also be described as "articulations" or

"internodes"; but even outside of these genicula there is a continuous cell wall which is often not only conspicuous at a time when these *quasi*-genicula are best marked, but also even then will have on its inner surface several continuous secondary layers of cell membrane. It would therefore seem as if the frond in Polysiphonia could not be called truly articulate or jointed; and I would venture to suggest that, unless there be a true invagination in which the outer cell wall will take its part, or a division be caused in the frond by some actual inward and transverse growth, so as to leave the two opposing cell walls separate from each other, there is no true articulus or geniculum. In the siphons and central tube, what I take as true joints between these cellular structures will be found. This subject may by some be regarded as, perhaps, a little too much a dispute as to terms; its interest to me is its close connexion with cell growth, with which, to the best of my judgment, the cell wall has more to do than is by many conceded.

The Tubus centralis.

The second point to be determined is, what is the tubus centralis, that central cavity of Harvey around which the siphons arrange themselves. If a young growing frond of *P. urceolata* or *P. fibrata* be examined after it has lain for a short time steeping in glycerine and water, it will be evident that this central tube is really only a central cell, of exactly the same nature as the other four cells surrounding it (called siphons). This central cell, the evolution of which can be best treated of in connexion with that of the four surrounding cells, is invariably of much smaller diameter than these; it forms quite a narrow tube, which when complete is pinched in, sausage-like as it were, at both ends; but it is also constantly filled with the same pink-coloured protoplasm as the surrounding cells. On the application of re-agents it does not, or scarcely at all, contract in its long diameter; or, if compelled to do so, it draws itself away from its attachments to the cells of the same nature with itself that are both above and below it, just at a point where, as we shall see in process of time, a true articulation will be formed. In addition, however, to being attached to a cell like itself, situated both above and below it, it is noteworthy that this central tube-like cell is also attached to each of the cells (siphons) that surround it by a thread of protoplasm

that takes its origin from one portion of the circumference of this central cell, and is inserted into the central inner surface of each of the surrounding cells (siphons)—four in the case of either of the species at present being described; but exactly the same state of things is found taking place in *P. atro-rubescens*, where the siphons are from nine to twelve in number; so that this tubus centralis has at least six points of attachment, one to each of the central cells above and below it, and one to each of the four cells (siphons) surrounding it. This, of course, is true only in a four-siphoned form; nor is it true of the ultimate central tube in the filament, and sometimes not of the penul- and antepenultimate ones, as in the next section will be more distinctly seen. For the present it will suffice as an answer to our question to say that in a living state there is no central cavity in the frond of Polysiphonia, but that there is a central cell many times longer than broad, putting one in mind of a prosenchymatous cell, with four or more rays proceeding from about its central portion, and its two poles somewhat drawn out. In its early condition, the tips of the rays and of the two ends are quite distinctly open, and the protoplasmic contents freely communicate with the tube-like cells above and below, and the siphon cells around it; but as it becomes mature, and as a cell wall is definitely formed around it, these pore-openings are closed up, and these plugs will present sometimes even the "stopper"-like form described by Archer; so that here, as in Griffithsia, it seems to me that these plugs or stoppers are, as it were, only the result of the cell finally closing itself up. In very old portions of the frond, where this closing up has long since taken place, these tube-like cells lose their pink-coloured protoplasm, and often appear to be rather densely filled up with secondary deposits, thus giving a rigidity, accompanied with a flexibility, to the frond.

The Evolution of the Internal Cells.

This is by far the most interesting portion of the life history of the frond. Except in detail it does not, however, differ from the form of evolution which is met with in Griffithsia. At the growing tip of a frond, and within its investing cell wall, a mass of more or less dense mucilaginous pink-coloured protoplasm will be seen. The growing tip of the frond is somewhat, in optical section, the shape of a flattened cone, and it is nearly

filled with the pink protoplasm. After a short period of growth, a thin flattened disc-shaped piece is detached from the lower portion of this protoplasmic mass: this detachment conveys quite the idea of the disc being let down from the mass above, after the fashion of the laths of a Venetian blind. Three, four, or five such like discs will be let fall, as it were, one after the other, and with care in the manipulation of the light, especially with the help of reagents, obscure indications of other discs about to be separated off will be observed; but if now the lowermost of the discs be examined, when by the use of glycerine the laths of the Venetian blind have been separated to their very utmost, the comparison becomes more exact and the likeness truer; for each disc is found to be suspended by (*P. urceolata*) five delicate protoplasmic cords, the full significance of which will soon appear. Confining one's observation to the lowermost disk, and supposing it in a living frond, the next process of development is that it divides into five masses. The formation of the disc itself was by a transverse division (as has been mentioned by Agardh), but the division into five masses is a longitudinal one. This division does not take place until by a process of growth the disc has greatly increased in both diameters; but the amount of growth that will take place ere this second form of division takes place varies much. By this longitudinal division the now broad disc-shaped mass becomes divided into, and apparently simultaneously, a central (comparatively small) cell, and four other cells, surrounding the small central one in a crucial manner: the apices of these five will be continued up into the five threads already referred to as suspending the mass. The central of these threads will remain in its place, but the four surrounding ones will push out towards the inner circumference of the cell wall of the frond. When these four cells divide off from the central cells, they also each remain attached to it by a thread of protoplasm, which starts from the inner side (that which has just become detached) of each cell at about its central portion, and unites with a corresponding thread starting from about the same region in the central cell. At this period the difference in size between these five cells is not very great, but in process of growth a marked difference is very soon apparent. The central cell (tubus centralis, Agardh) grows only in length, or at least very little in breadth; the four surrounding cells grow

both in length, width, and depth, the proportions of these to each other being, as it were, specific differences, but also in the very same species varying much in the same frond. The evolution of the original disc-shaped piece of protoplasm being complete, and it being, say, the second disc in the frond that we are examining, it will finally consist of five parts, each of which is a cell. Each peripheral cell having three points of attachment, and the central one just double that number, it may be convenient for the systematic Phycologists to designate this latter the "central cavity," and the former "the siphons." This must be left to their judgment.

The formation of such a central tube and such a mass of siphons goes on step by step adding to the length of the frond; but in process of time the frond will branch: and, leaving to the next section the discussion of the question in what manner this branching actually takes place, here it is important to note that the central cell of a branch nearest to the main axis, from which the branch starts, is in direct communication with the central cell of the main axis nearest to it; so that in such a case this central cell of the main axis subtending a branch will have seven points of attachment, and that the new (seventh) point will be drawn out from its upper peripheral margin. The surrounding cells (siphons) do not alternate with those of the main axis (at least in any of the species which I have examined), and in the species under consideration the two lower cells (siphons) are in direct line, and each is connected with the corresponding cell (siphons) of the main axis, so that these cells of the main axis have an additional point of attachment.

It may also be well to remember that in Polysiphonia these inner cells never seem to break from out of the cover of the common cell wall of the frond, as is sometimes the case in Griffithsia, and yet they are to all intents and purposes the same form of cell in all that relates to their origin and growth. The outer cell wall in Polysiphonia would seem to go on growing; in Griffithsia it would seem, in connexion with the development of the species, to have its onward growth arrested: the inner cells grow out, and these bear the antheridia and tetraspore cells.

The points of junction between these inner cells in Polysiphonia constitute only in part the pore system of Nägeli. When the inner cells become

fully adult, these tubes of communication seem to separate from each other, and then to get plugged up with adhesive stoppers, of which the upper and lower ones are often those best marked; but the presence of such can be without much difficulty seen in all the others, so that the description of Nägeli* must be here emended. In writing of the Rhodomeleæ (the family in which he places this genus), under the description of Laurencia, he says: "All its cells—those of the stem as well as those of the branches—possess pores, and, as in Polysiphonia, one finds between every two cells one pore in the middle of its partition wall. Where the axis ramifies, each leaf cell has three pores. Where the axis is simple each joint cell has two pores, and each partition cell one. The stem cells bear dissimilar pores—some being large and some small—the latter are often indistinct"; but we have seen that the central cell at the junction of a branch, may have seven connexions (in a so-called four-siphon species), and for each of these a so-called pore may be found.

The Growth of the Cell Wall.

Throughout my investigations into the growth and development of the cells in the Algæ, I have found it very difficult to explain the phenomena witnessed, according to the ordinary views held on this subject. While watching the progress of some of these phenomena, it seemed indeed easy to explain and account for them; when one's eyes were withdrawn from the object; when one attempted to reconcile what one saw with what one read, then the difficulty began, for it seemed to me as if the cell wall once formed might have some share in the originating as well as in the carrying on of growth.

Growth means increase of bulk: it is independent of increase of structure; but this latter is a product of growth, and dependent thereon. A cell is formed—how, we need not delay to consider; it consists of a sphere of protoplasm; it has, say, its smooth-surfaced cell wall; it increases to, say, twice its first dimensions. This increase is easily accounted for: the cell takes in water, the chlorophyll granules take up carbon; so the protoplasm of the cell is added to, and from it new molecules are laid down between the

* C. Nägeli: *Die Neuern Algensysteme*, p. 225.

already existing ones in the cell wall (intus-susception of Nägeli), and thereby its surface is increased, and the phenomenon of such cell growth is explained by Nägeli's law of universal growth (allseitiges Wachsthum); but if this cell were to go on growing as if it belonged to a species of Bryopsis or of Vaucheria, until it reached quite gigantic proportions, and if, as does take place, the cell walls would seem to increase chiefly in one, and that an onward, direction, and if, as it pushes along, it leaves the chlorophyll-bearing portions of the protoplasm stowed away considerably in the rear of the growing portion, will the explanation as to this special growth be equally satisfactory?

Examine the spore of a Red Alga: as it escapes from the carpogonium it consists of a mass of pink granular matter. Practically it forms a homogeneous mass, surrounded by a cell wall. As it grows, a marked difference will be seen in one portion of the cell wall: this becomes thinner, and draws itself away from the spherical inner mass. This point of growth then becomes better defined. There is now a perfectly evident difference in the layer of protoplasm beneath it: when this is contrasted with the bulk of the protoplasm of the cell, we now see what is called apical growth; but the problem, as I take it, is—is this caused by a growth out of the existing mass of protoplasm—this, pushing some of its increase, as it were, forward, thinning and then adding to the cell wall in the direction of this push forward—or has this growth been a something inherent in a portion or portions of the cell wall itself, which by a power of taking in the atoms that compose it has set up, as it were, a manufactory at this spot, with the results as seen?

Nägeli's views on this form of growth are briefly as follows*:—The origin and growth of the cell membrane are products of the cell contents. These merely differ relatively. The original production of membrane gradually changes into growth of membrane; a line of demarcation is quite arbitrary. Immediately below the growing point new contents and new membrane are formed: here there lies a layer or disc of homogeneous mucilage; below, this passes into granular mucilage. To this follows a mass of granular mucilage in which starch, chlorophyll, or other colouring matters

* Ray Society's Volume, 1845, pp. 150, *et seq.*

originate: still lower down, the solid contents are deposited upon the walls. In the disc of homogeneous mucilage, lying on the *punctum vegetationis*, new homogeneous mucilage is unceasingly produced, so that it remains the same, although its lower edge is being continually converted into granules, and then a portion unceasingly given over into the zone of granular coloured mucilage. The apical growth is then connected with a production of contents, which takes place at the apex of the cellular branch. Not merely is there a continual production of contents, but also there is a continual production of new membrane; and this growth commences with the new formation of homogeneous mucilage which produces new membrane, and is continued by the persistence or new formation of membrane-forming mucilage. In secondary cells a little portion of mucilage is the rudiment from which a new branch is produced. These secondary cells originate in a parent cell. The production thus of a cell does not take place through unilateral nutrition, but by a new formation; this is seen especially from the fact that the wall of the parent cell is sometimes already tolerably thick, and even lamellated before the branch is formed, and because the growing out then assumes an aspect much more as if the membrane of the parent cell were pushed outward and broken through, than as if it were expanded and formed a branch through nutrition.

But I am strongly impressed with the view that this *punctum* is not so much a disc of homogeneous mucilage, separate from the cell wall, and separate from the rest of the protoplasm, as that it is rather a point localised in the cell wall (not by any means necessarily in its apical direction), which commences first to show itself as a point of vegetation by its growing outwards, and which speedily forms and incessantly keeps up a formation of protoplasm, a portion of which is the small disc of Nägeli; and I take it that the branch formation is exactly of the same nature—that no matter how laminated the old cell wall may be, any portion of this can act as a vegetating point and carry on the growth.

A striking instance of the power of growth in such a *punctum* as I allude to will be often found in the winter-growing cells of Bryopsis. Under the influence of some local irritation, which must not be enough to injure the cell wall of the specimen under examination, the denser portion of the

protoplasm will often be found to draw itself from the upper part of these cells. As it does so, the very conspicuous chlorophyll granules will be seen to be drawn together until they become pretty tightly packed. There is an apparent rounding off of the upper portion as it gets drawn down in the tube of the cell wall, and under a low power of the microscope this convex surface seems pretty sharply defined; but turn on a high quarter of an inch or an eighth of an inch objective, and a very remarkable phenomenon will present itself—for there will then be seen a mass of pseudopods not easily to be forgotten and difficult to describe under any other name; they stream away from below the apex of the cell wall, converging downwards until they are lost in the centre of the convex margin of the withdrawing mass of protoplasm. Here they are broad, while towards the apex of the cell they disappear through their very tenuity. Coursing down along these pseudopods, very minute granules can be, on careful focussing, detected; these are ultimately lost in the denser protoplasmic mass which engulphs them. This streaming goes on for a while, until all the protoplasm of a certain density is drawn into the lower mass; this then finally rounds itself off and forms an independent cell wall in front, which of course will be below the former growing point of the cell. There is apparently no plastic protoplasm remaining above this—no small disc even of homogeneous mucilage to be seen; all the viscid protoplasm seems to have gone to the rear, and it would appear as if the upper portion should now become sphacelated—perhaps disappear—and a new apical growth proceed from below it; but this is not so; there is life in the front still; it goes on growing as before, and in process of time it will be found to leave in its rear dense chlorophyll-bearing protoplasm, and so on through the several layers until the *punctum* itself is, as before, reached. From often witnessing this phenomenon, it has appeared to me that these several layers did not quite appear in the order indicated by Nägeli, but that the one nearest to the *punctum* was the most highly granular layer; the next in order the more watery; the next the more mucilaginous (this the layer that forms the pseudopods), and then would come the thick chlorophyll- and starch-carrying layer.

As to the branch formation, I have in another memoir* explained

* *Ante*, p. 499.

what takes place in Griffithsia. In Polysiphonia, although the branching is more like dichotomy, and occurs in connexion with the apical growth, still there is the same phenomenon of the projecting outwards of the cell wall at the place where a branch will arise; and this projecting outwards originates apparently with the cell wall itself, and is not caused by the instigation, as it were, of a disc of protoplasm, and certainly not at all by the growth outwards of an inner cell. One very well-marked instance, out of many such, is figured on Plate XIV., fig. 3 d.

The Evolution of the Tetraspores.

As to the development of the tetraspores in Polysiphonia, I have carefully watched it in both *P. urceolata* and in *P. atro-rubescens*. I have not found much written on the subject. Agardh* says:—"Primam sphærosporarum originem in divisione transverse obliqua unius siphonis (peripherici) videre credidi." In *P. urceolata* the tetraspores are described as forming a line in the middle of the ramuli, which then become fusiform. In *P. atro-rubescens* the tetraspores are small, always found on plants whose ramuli are mostly multifid or tufted. The point of origin of the tetrasporic cells seems to be always between the central cell and its surrounding cells. This origin is therefore better seen in a frond with a small number of internal cells. At the base of the central cell a small portion of protoplasm is detached, which then soon divides transversely into two, the lowermost of which forms a very minute parallelogram, and the other speedily assumes an oval form; this latter remains attached to the former, and this point of attachment forms in a little time a stalk, upon which the globular or oval cell bearing the tetraspores is borne. The basal cell scarcely increases in size, but the upper one very rapidly enlarges; for some time it appears to have a very feebly differentiated cell wall, but as its protoplasm increases in density and in colour (in *P. urceolata* it assumes an intensely deep pink), the cell wall is more definitely laid down, and assumes an oval outline: just previously to this, a division of its contents into four parts takes place, and sometimes these divisions gave me the idea that they were on the way to

* Agardh, loc. cit., p. 905.

form four short inner cells (siphons), without, however, a central cell. Once, however, that the four-fold division has taken place, it is pretty evident that it is soon a complete one, and that there is no thread of attachment between them; this cell development therefore cannot be compared to that which gives rise to the inner cells, as above described, and where such an attachment is invariably found to exist. The four portions soon arrange themselves as in Griffithsia: one remains next to the stalked portion of the cell, two mount up over this, and the fourth takes a corresponding position, only above, that the first one does below them. The tetrasporic cell now greatly enlarges: in doing so it forces out and greatly distorts the inner cells with which it comes into contact. In a species like *P. urceolata* this distortion is symmetrical, as seen in one view—that one where it presses out equally the two of the inner cells on either side of it. From that point of view where it presses out the inner cell in front of it, the distortion is not so symmetrical; but in a species like *P. atro-rubens* the distortion is very great, and the ramulus bearing the tetrasporic cells is often quite irregularly knobbed; for these cells make their appearance in an irregular manner to the right and left of the central cell, pushing before them as they grow outwards, and distorting in doing so, the inner cells—seven to eight in this species; and it is this which gives to the ramulus a tufted appearance.

EXPLANATION OF PLATE.

PLATE XIV.

*Polysiphonia urceolata.**

Fig. 1. Terminal portion of a frond of *Polysiphonia urceolata,* as seen after treatment with glycerine. × 150.

Fig. 2. Terminal portion of one of the twigs of the former specimen, much enlarged, to show the apical disc of protoplasm, and the gradual separation and division of the layer of protoplasm until the normal number of "siphons" and the "central tube" are formed. × 400.

Fig. 3. *a.* Terminal cell giving origin to a side cell, back view. *b.* The process a little more advanced, front view. *c.* In this case the appearance is like a growth by dichotomy, but is really only a modification of the form seen at *a*, in which the development of the side cell has overtaken the leader cell. *d.* In this specimen is well seen the distinct outward and upward growth of the outer cell wall *before* the specialisation of a disc of the pink protoplasm, which will occupy the central portion. × 400.

Fig. 4. A portion of the frond showing the siphons and their attachment to each other, also the central tube, and the points of attachment between this latter and the surrounding siphons. This drawing is from a fully grown portion of the adult frond. × 150.

Fig. 5. A portion of the same, more highly magnified, showing obscure striation in the outer cell wall, also the central tube, and three siphons, by focussing down, the fourth siphon is lost to view. × 400.

Fig. 6. A portion of a frond, showing the connexion between the central tube and the surrounding siphons of a side branch and the corresponding portions of the main stem.

Fig. 7. Cross sections (slightly diagrammatic) of the frond. *a.* Section just under the growing tip. *b.* A little older portion. *c.* When the "siphons" and central cell are nearly of the same calibre. *d.* Section through a nearly adult frond.

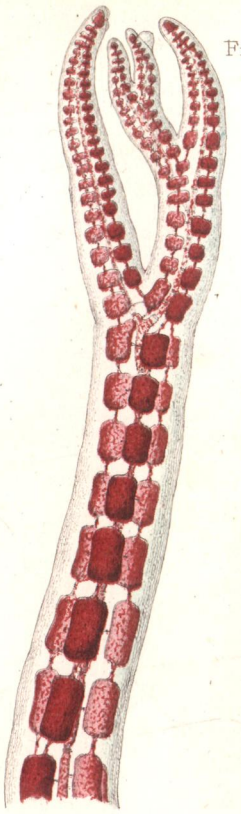
* All the figures, except 7 and 9, are drawn from specimens which have been for some time soaked in weak glycerine.

Polysiphonia atro-rubescens.

Fig. 8. A greatly magnified portion of a tetraspore-bearing frond of *P. atro-rubescens*. In the lower portion the thickening of the original and common investing cell wall is apparent; and there are traces of stoppers to be seen at some of the entrances to the "pores"; while on the upper portion the tetraspore cells are scarcely apparent; yet towards the lower and more adult portion of the frond the tetraspores are fully formed. The tetraspore-bearing twigs of this species are often very much distorted. × 250.

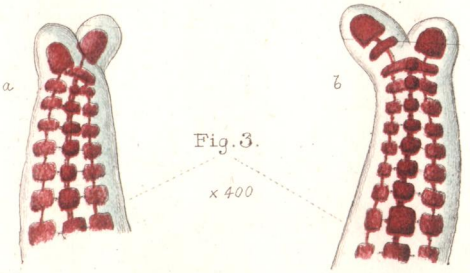
Fig. 9. Development of tetraspores. *a*. Stalked cell. *b*. Division into four masses of its protoplasm. *c*. Only three spores seen. *d*. The same, but further grown.

Fig. 1.



x 150

Fig. 3.



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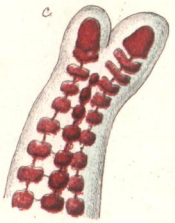

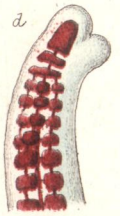

Fig. 2.

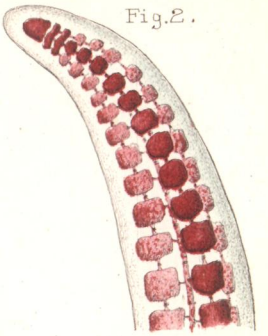

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Fig. 5.

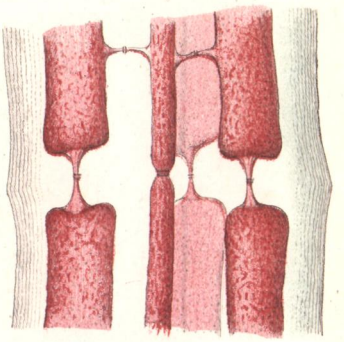

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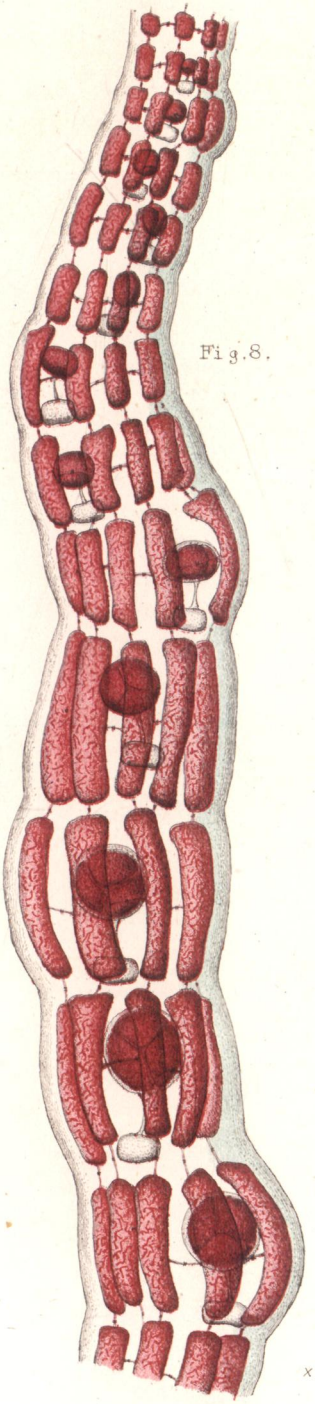
Fig. 8.



x 250

Fig. 7

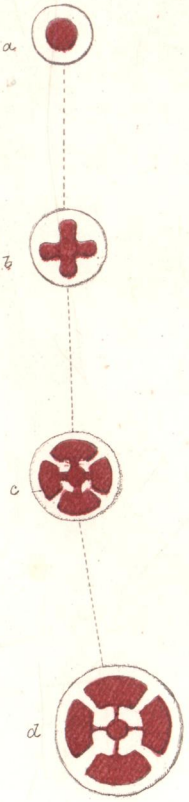


Fig. 9.

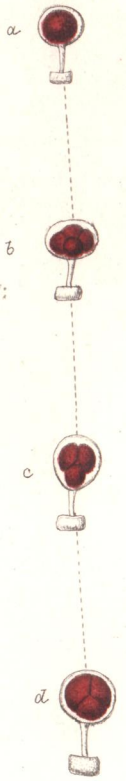


Fig. 4.

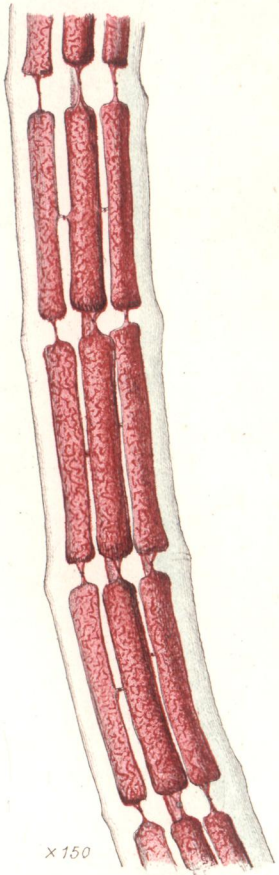


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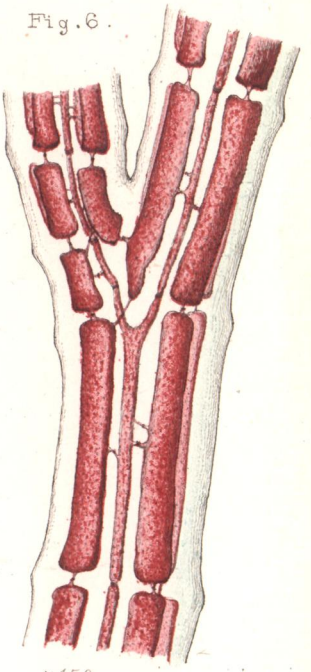
Fig. 6.



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