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Sexual Reproduction of Thallophytes (Supplement).

Every microscopist is familiar with the members of the Proto-coccoid group of algæ, but it is astonishing how very vague our knowledge of the life history of the greater part of them still remains. Speaking in general terms, it exhibits three distinct stages:—1, a non-motile vegetative phase, in which ordinary cell-division may take place; 2, a motile condition, in which the protoplasm of the quiescent cells divides into a small number of portions—macrozoospores (which germinate asexually), or by a continuation of the process into a large number of portions—microzoospores (which conjugate, but otherwise in most cases appear incapable of germination); 3, a resting stage, in which the green colour of the chlorophyll gives place to a red hue. The non-motile conditions have been placed by systematic algologists in the genera of *Protococcaceæ* and *Palmellaceæ*, and have been mostly limited by insecure diagnostic characters such as the degree of diffluence of the mother-cell-wall, or the manner in which the daughter-cells remain for a time aggregated. On the other hand, the motile phases have to be sought in *Volvocineæ* amongst the species of the genus *Chlamydomonas*.

It will be convenient to sum up briefly what appears to be the present state of our knowledge as to three of the most common types.

Chlamydococcus.—Cohn's study of *Ch. (Protococcus) pluvisialis*¹ still remains the most complete account of the life history of any member of the group. As I have already stated (p. 303), Velten has described what he believed to be the conjugation of the macrozoospores. Rostafinski has, however, obtained further confirmation² of his own statement that what Velten saw were merely zoospores destroyed by a parasitic monad. One of Velten's figures (fig. 9) Ros-

¹ Ray Soc. 'Bot. and Phys. Mem.,' 1853, p. 517.

² 'Mém. Soc. Sc. Nat. de Cherbourg,' 1875, p. 144.

tafinski considers a monstrosity arising from the adhesion of two macrozoospores, a circumstance which he believes often to happen. It must be very difficult to discriminate such an adventitious adhesion of a pair of zoospores from the actual process of conjugation. In this case, however, since macro- and not micro-zoospores were in question, an adhesion and not a conjugation is probably the right explanation. Rostafinski now regards *Chlamydococcus* as altogether asexual. The microzoospores which are produced during the night have the singular property of collecting on the side of the vessel in which they are placed which is least illuminated. Cultivated in one of Van Tieghem's cells, they passed into the resting stage, assumed a red colour, gradually acquired the size of the normal resting cells, and finally gave rise, by division into four, to zoospores. Rostafinski has also found that *Chlamydococcus pluvialis* is able to exist on snow and in ice, and considers that it and *Ch. nivalis* are identical. He therefore substitutes Agardh's generic name *Hæmatococcus* (1828) for A. Braun's (1851). He further identifies with *Hæmatococcus Volcox lacustris*, which Girod-Chantrans described (in 1797) as giving a fine red colour to water near Besançon, and proposes, on the principles which are adopted by many foreign botanists, to rename the plant *Hæmatococcus lacustris* (Girod).

Protococcus.—The genus which Agardh founded (1824) under this name has furnished material for *Protococcus*, Kütz., in which the cells are isolated; *Pleurococcus*, Menegh., where they are quaternate; and *Cystococcus*, Näg., which has them irregularly aggregated. Rabenhorst suggests that *Protococcus viridis*, the solitary species of the genus, may be a state of *Pleurococcus vulgaris*. *Protococcus*, in its restricted sense, is supposed not to exhibit any increase of its quiescent stage by cell-division. But this may be due to unfavorable external conditions. *Pleurococcus vulgaris*, on the other hand, is stated not to develop zoospores.¹ The two modes of reproduction are therefore in this case mutually exclusive. *Cystococcus humicola* supplies many lichens, such as *Parmelia parietina*, with their gonidia; under these circumstances they still retain the power of producing zoospores.²

¹ 'Micrographic Dictionary,' under *Chlorococcum*. *Ch. vulgare*, Grev., is a synonym of *Pleurococcus vulgaris*. The editors of the last edition of the 'Micrographic Dictionary,' forgetting this, have given a full description and figure of the species under *Chlorococcum*, and have added a further description and figure (both from Rabenhorst) under *Pleurococcus*.

² Famintzin and Baranetzky, 'Ann. des Sc. Nat.,' 5e sér., vol. viii (1867), p. 137; Woronin, vol. xvi (1872), p. 324.

Chlamydomonas.—The species of this genus are probably all motile stages of forms which are placed in other genera. *Ch. Pulvisculus*, the least known, could be traced, according to Kützing, into *Stigeoclonium stellare*; but he probably confused with it the zoospores of that alga. With more probability Cienkowski has described the development of the macrozoospores into a species of *Glæocystis*, which only differs from *Pleurococcus* in the thicker walls of the cells, and is hardly generically distinct. It is true that his figure shows a more rounded contour than the ovoid zoospores of *Chlamydomonas* usually possess. But as he has traced the same course of development in two other species of the genus, it is exceedingly probable that *Glæocystis* or *Pleurococcus* is the normal quiescent stage which they all attain. The authors of the 'Micrographic Dictionary' describe under the head of *Protococcus viridis* a Pleurococcoid alga which would probably be placed by Rabenhorst under *Glæocystis*, and of this they also state that a *Chlamydomonas* is the motile stage. Reinhardt has observed the conjugation of *Chlamydomonas Pulvisculus*,¹ and Gorjankin states that he has seen this take place between a macro- and a micro-zoospore,² an observation which, if confirmed, may be compared with what takes place in *Pandorina*. Rostafinski has also observed the conjugation of the microzoospores of *Ch. multifilis*, Fres. The zygozoospore, after about six weeks, developed by cell-division into a Pleurococcoid alga.³ It appears, therefore, probable that this stage is reproduced in all cases under particular suitable conditions by both macrozoospores and zygozoospores.

Pandorineæ.—In considering the position which the *Volvocinaceæ* hold in Sachs's classification, I found myself confronted by the same difficulties which had also struck Cohn (see *supra*, p. 312). The group, in point of fact, includes two distinct types of reproduction; and it seemed to me justifiable—taking into consideration the importance, on the whole, of the points which Sachs's classification brings out—to run the risk of doing some violence to what at first sight appears to be a natural assemblage of genera in order to bring it into conformity with that classification. I accordingly proposed (p. 310) to limit *Volvocineæ* to *Volvox* and *Eudorina*. The remaining genera which are usually also placed amongst the *Volvocineæ* I proposed to separate under the name of *Pandorineæ*. Within the last few weeks I have received,

¹ 'Bot. Jahresbericht,' 1873, p. 22.

² Quoted by Rostafinski, 'Mém. Soc. Cherb.,' l. c., p. 146.

³ 'Bot. Zeit.,' 1871, p. 787.

through the kindness of Dr. J. Rostafinski, a copy of the paper from which I have already quoted, and in which I find he has proposed to rearrange the *Volvocineæ* in the same way as I have done, and to constitute a new family, to which he had also given, apparently simultaneously, the name of *Pandorineæ*.

According to Rostafinski,¹ Hieronymus, since the autumn of 1872, has observed at Halle the conjugation of the microzoospores of *Gonium*.

Hydrodictyæ.—Rostafinski makes the interesting announcement that (as I suggested was likely to be the case²) the microzoospores of *Hydrodictyon* have been observed to conjugate by Suppanetz in Prof. De Bary's laboratory. The conjugation takes place while the zoospores are still within the mother-cell, or immediately after their emission. Not only two, but three and even six, zoospores take part in the formation of the isospore. That the zoospores of the same mother-cell should conjugate seems at first sight remarkable, but when it is remembered that from 30,000 to 100,000 are produced from each cell the whole mass of protoplasm must be so enormous relative to each individual zoospore that there is room for the amount of differentiation, which is at the bottom of the sexual process, to exist between the zoospores from different parts of the cell. The formation of the zygozoospore from more than two zoospores is also interesting as confirming Sachs's view that the formation of the plasmodium of the *Myxomycetes* is to be regarded as a sexual process, and it is not superfluous to remark that numerous antherozoids effect the fertilization of the oosphere of the higher algæ, such as *Volvox*, *Vaucheria*, and *Fucus*.

Ulvaceæ.—Janczewski and Rostafinski have failed³ to confirm Areschoug's observations on conjugation in *Enteromorpha compressa*. They observed the microzoospores attach themselves in pairs by their beaks, but after a time these separated. They also met with pairs partially united together, and these they consider to be monstrous conditions by which Areschoug has been misled. On the other hand, they satisfied themselves that the microzoospores are incapable of germination, and were consequently unable to attribute to them any function. Thuret found the zoospores of *Enteromorpha clathrata* "tous réunis deux à deux par le rostre,"⁴ and this has been regarded as a monstrous condition. In *Cladophora glomerata* Cohn observed the fusion of two to five zoospores into a

¹ Loc. cit., p. 146.

² *Supra*, p. 304.

³ 'Mém. Soc. Sc. Nat. de Cherbourg,' 1874, p. 372.

⁴ 'Ann. des Sci. Nat.,' 3e série, xiv, p. 244.

rotating mass.¹ In *Hydrodictyon* he also figured a double spore. In all these genera in which these monstrous unions have been observed normal conjugation is now believed to take place. It is very difficult to suppose that the two things have nothing to do with one another.

Hydrogastreæ.—Rostafinski has made a most interesting discovery respecting *Hydrogastrum*. This curious little alga has hitherto been placed amongst the *Siphophyceæ*.² It turns out, however, not to belong to the *Oosporeæ*, but to the *Zygosporeæ*. The resting spores which have been described by Cienkowski under the name of *Protococcus botryoides*, when placed in water, give origin to zoospores which immediately conjugate. This takes place, Rostafinski assures me, with sufficient precision to enable it to be employed as a class demonstration. Inasmuch as Sorokin has observed conjugation in the Chytridineous genus *Tetrachytrium*,³ it may be suggested that the real affinity of *Hydrogastrum* is with the *Chytridiæ*. There will then be a relation between *Hydrogastreæ* and *Chytridiæ* amongst *Zygosporeæ*, similar to that between *Siphophyceæ* and *Siphomycetes* among *Oosporeæ*.

Rostafinski proposes that Sach's ZYGOSPOREÆ should be divided into *Isosporeæ* and *Conjugatæ*, the former group to contain all forms in which the conjugation of zoospores occurs. What Areschoug terms a zygozoospore he proposes to call an isospore. There can be no doubt that this is a pleasanter terminology to use.

Volvocineæ.—The observations of Carter upon *Eudorina* have been confirmed by Gorjankin.⁴

Siphophyceæ.—In *Bryopsis* Janczewski and Rostafinski consider⁵ that the bodies which Pringsheim supposed to be the antherozoids (*supra*, pp. 313, 314) are really parasitic Chytridineous organisms. It is an open question so far whether *Bryopsis* may not, like *Hydrogastrum*, turn out to belong to the *Zygosporeæ*. The zoospores also exhibit the propensity to "agglomerate," and, judging from other instances, this suggests the probability that they conjugate also.

Phæosporeæ.—Janczewski and Rostafinski⁶ studied zoospores of various species at Cherbourg during 1872, with

¹ I have copied one instance from him (*supra*, p. 305). Perhaps I should have put a ? after 'Conjugation.'

² E. Parfitt has given a strangely erroneous account of its life-history in 'Grevillea,' vol. i, pp. 103-105.

³ *Supra*, p. 307.

⁴ *Loc. cit.*, p. 375.

⁵ *Supra*, p. 310; Rostafinski, l. c., p. 145.

⁶ *Loc. cit.*, p. 371.

especial reference to the possible occurrence of conjugation amongst them. They failed entirely to detect anything of the kind, the zoospores coming to rest and germinating within twenty-four hours. They conclude, therefore, that the problem of the sexuality of *Phæosporeæ* will be solved, not by the further study of the zoospores of these algæ, but by the detection of female organs which have hitherto eluded observation.

I must conclude with an historical reclamation. I am indebted to Dr. Carpenter for pointing out to me that in 1848 Thwaites¹ indicated that sexuality existed in its most generalised form in conjugation, a view of which I attributed the first conception to De Bary (*supra*, p. 299) ten years later.

I may also add that, as early as 1854² Cohn pointed out the morphological parallelism which exists amongst Thallophytes in which chlorophyll is present and those in which it is absent.

W. T. THISELTON DYER.

¹ 'Ann. Nat. Hist.,' 2nd series, vol. i, p. 163.

² 'Nov. Act. Acad. Nat. Cur.,' vol. xxiv, p. 141.